WCIS - 2012

Seventh World Conference on Intelligent Systems for Industrial Automation

Edited by N. Yusupbekov, R. Aliev, K. Bonfig

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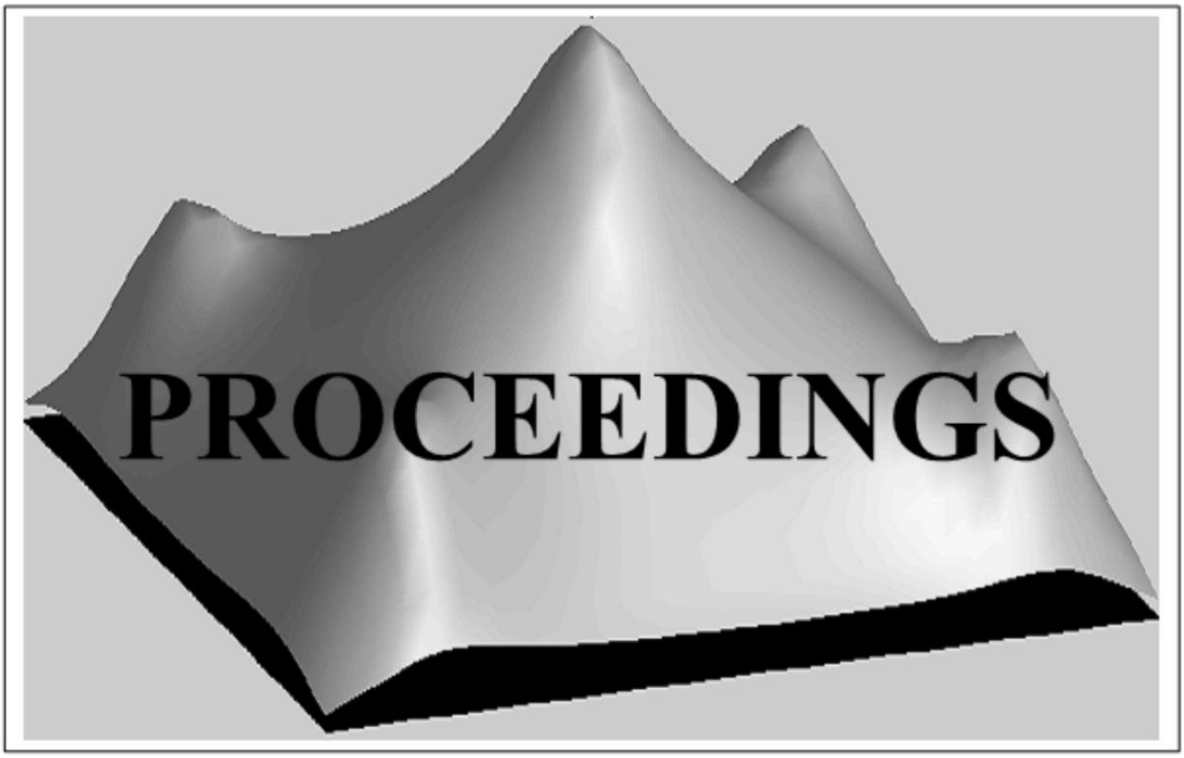

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Editors: N. Yusupbekov (Uzbekistan), R. Aliev (Azerbaijan), K. Bonfig (Germany)

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WELCOME

We are very glad to welcome the participants of the WCIS'2012 in Tashkent, in city with rich history.

This is the seventh time that we are gathering here, in Tashkent, to hold this conference. The First World Conference on Intelligent Systems for Industrial Automation was held in Tashkent in 2000.

Since that time the Conference on Intelligent Systems for Industrial Automation aims at bringing together researchers from academic and industrial institutions to discuss new developments in the field of intelligent systems, Soft Computing technology, and especially, intelligent systems for industrial automation.

The sessions will focus on the development and application of Fuzzy Logic, Neural Networks, Evolutionary Computation, Neurocomputing, Chaos Theory and hybrid systems for industrial automation purposes. Applications in other related areas are also considered. We are proud to have the honour of presenting this conference in Tashkent. As a result, we hope to be able to further promote research in the above mentioned fields. Futhemore, this conference is to give students the opportunity to become familiar with these subject matters.

We would like to thank everyone who participated in the preparation and presentation of this conference.

We hope to be able to welcome many of WCIS'2012 participants in the year 2014 for the Eighth WCIS'2014 Conference.

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Department of Manufactures Process Automation
Tashkent State Technical University
University str. 2, 100095 Tashkent, Uzbekistan
Phone: (+99871) 227 17 16
e-mail: WCIS-2012@mail.ru

THE CONCEPT OF A Z-NUMBER

Lotfi A. Zadeh

Department of EECS, University of California, Berkeley, CA 94720-1776;
Phone: 510-642-4959; Fax: 510-642-1712;
e-mail: zadeh@eecs.berkeley.edu

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Abstract

Decisions are based on information. To be useful, information must be reliable. Basically, the concept of a Z-number relates to the issue of reliability of information. A Z-number, Z, has two components, Z=(A,B). The first component, A, is a restriction (generalized constraint) on the values which a real-valued uncertain variable, X, is allowed to take. The second component, B, is a measure of reliability (certainty) of the first component. Typically, A and B are described in a natural language. Example: (about 45 minutes, very sure). An important issue relates to computation with Z-numbers. Examples: What is the sum of (about 45 minutes, very sure) and (about 30 minutes, sure)? What is the square root of (approximately 100, likely)? Computation with Z-numbers falls within the province of Computing with Words (CW or CWW).

To view the concept of a Z-number in a general perspective it is helpful to construct a conceptual framework in which there are levels of generality of uncertain computation, with each level representing a class of restrictions. The lowest level, referred to as the ground level, is the space of real numbers, R. The next level, level 1, is the space of intervals. Level 2 is the space of fuzzy numbers (possibility distributions on R) and the space of random numbers (probability distributions on R). The top level, level 3, is the space of Z-numbers.

A Z-valuation is an ordered triple of the form (X,A,B) which is equivalent to the assignment of a Z-number (A,B) to X, written as X is (A,B) A collection of Z-valuations is referred to as Z-information. What is important to observe is that much of uncertain information in everyday experience is representable as Z-information. Example: Usually, Robert leaves office at about 5 pm. Usually, it takes Robert about an hour to get home from work. When does Robert get home? This information and the question may be represented as: (time of departure, about 5 pm, usually) and (time of travel, about l hour, usually); (time of arrival, ?A, ?B).

Computation with Z-numbers is complicated by the fact that what is known are not the underlying probability density functions but fuzzy restrictions on such functions. To deal with computation with fuzzy restrictions what is needed is the extension principle of fuzzy logic. Basically, the extension principle is a formalism for evaluating the value of a function when what are known are not the values of arguments but restrictions on the values of arguments.

Computation with Z-numbers is an important generalization of computation with real numbers. In particular, the generality of Z-numbers opens the door to construction of better models of reality, especially in fields such as decision analysis, planning, risk assessment, economics and biomedicine.

ABOUT THE CURRENT STATE AND PROSPECTS OF THE CHEMICAL AND PETROCHEMICAL INDUSTRY DEVELOPMENT OF THE REPUBLIC OF UZBEKISTAN

G.I. Ibragimov

Republic of Uzbekistan

Key words: *petrochemical industry, chemical industry, reconstruction of productions*.

With the goal of control system improvement and economic efficiency increase of the chemical industry enterprises and organizations, deepening the incorporating processes of the branch enterprises, wide attraction of foreign investments for development, modernization and modernization of chemical production by the resolution of the Cabinet Ministry of the Republic of Uzbekistan from March 13, 2001 of No. 124 «About measures for improvement of structure of management by the chemical industry» the Uzkimyosanoat State joint stock company in the form of state joint-stock company (SAC "Uzkimyosanoat") is formed.

In accordance with general practice the enterprises and the company organizations use preferences and the privileges provided by governmental decisions on implementation of projects of localization, modernization, and also their product exporting.

The main strategic directions of the chemical industry development are:

- reconstruction and modernization of operating productions of mineral fertilizers;
- construction of new capacities, expansion of production of export - focused production;
- organization of production of import-substituting production;

According to the accepted governmental decisions in recent years in branch new productions were constructed and placed in operation:

- caustic soda, chlorine, hydrochloric acid, disinfectants on JSC Navoiazot (2001);
- cotton cellulose at the Fergana chemical plant of furan connections (2001);
- chlorate - a magnesium defoliant and sodium chlorate on JSC Ferganaazot (2002);
- nitric acid and ammoniac saltpeter on JSC Fargonaazot (2003);
- soda limed at Kungradsky soda plant (2006).

In 2010 building of the 1st turn of Dekhkanabad plant of potash fertilizers in capacity of 200 thousand tons per year on the basis of the Tyubegatan field of potash salts was completed. Commissioning of object allowed to exclude import of potash fertilizers to the republic, to create production and social infrastructure in the region, to provide employment more than 1300 people and the balanced loading of the railway of "Tashguzar-Baysun-Kumkurgan".

Now on volume and types of made mineral nitric and phosphoric fertilizers SAC "Uzkimesanoat" takes a leading place in Central Asia, being the largest producer of ammonia, a carbamide, ammoniac saltpeter, ammonium sulfate, ammophos and nitrophos. With start-up of Dekhkanabadsky plant of potash fertilizers there was a possibility of creation of new NPK fertilizer on the basis of local resources.

The enterprises SAC "Uzkimesanoat" provides with the production for leading branches of economy of the republic: agriculture (mineral fertilizers, chemical means of protection of plants, defoliants, a film for a cotton), gold mining branch (cyanic sodium, thiourea, polyacrylimides), light industry (acetate threads, fiber Nitron), the industry of building materials (soda calcined), etc.

For the last five years in branch the steady tendency of volume growth of commodity production (9-10 %), extensions of its nomenclature remains.

In 2008-2009 reconstruction of productions of ammonia at the JSC Maksam-Chirchik enterprise with increase in production from 243 thousand tons to 420 thousand tons per year and on JSC Ferganaazot - from 300 thousand tons to 400 thousand tons per year is carried out.

On the basis of the local not enriched raw materials production of new nitrocalciumphosphatic fertilizer on JSC Samarkandkimyo with annual project capacity of 250 thousand tons with application of domestic technology of phosphoritic raw materials processing is created.

In 2010 on JSC Navoiazot the project on introduction of ammoniac saltpeter granulation process with an additive of phosphoritic raw materials that will allow to receive stabilized ammoniac-phosphorus fertilizer (AFU) in volume of 180,0 thousand ton in a year was completed. Market researches showed a demand for this product both on internal, and on external markets.

In 2011 building of new production of porous saltpeter on JSC Maksam-Chirchik for manufacturing of a special purpose products with its subsequent realization for export is completed.

Special value is gained by the production localization program during which realization the list of the localizable goods from year to year increases. For example, if in 2005 on branch there was orderly a production of 10 types of product, in 2011 the number of the localizable goods reached 33, within this program the localizable production was made for 269,8 billion sums.

According to the Program of measures for acceleration of construction and development of production of new types of chemical production (the resolution of the President of the Republic of Uzbekistan from March 11, 2009 of No. PP-1071) at the enterprises SAC "Uzkimyosanoat" accustoms production of 11 new types of chemical production.

It is phosphatised ammoniac saltpeter, carbamide - ammoniac saltpeter, methanol (brands A), dimethilic ether, sodium nitrate, threesodiumphosphate, fodder phosphate, carbooxidemethilcellulose, catalysts for production of ammonia.

Implementation of innovative projects within the above-stated program in the chemical industry is carried out in three main directions.

The first direction considers world tendencies on ensuring explosion safety of ammoniac saltpeter by using of special additives. Experts of SAC "Uzkimesanoat" together with scientists of Institute of the general and inorganic chemistry defined as such additive a phosphate contained waste from Kyzyl kum phosphoritic complex.

The second direction of innovative development of chemical branch includes production of products on the basis of profound processing of natural gas.

The third direction of innovative development of branch provides extension of the of chemical products nomenclature produced by domestic producers for satisfaction of domestic market requirements and deliveries to export.

The Kungrad soda plant makes about 100 thousand tons of calcified soda which is widely applied in glass production, the fat and oil industry, industrial water preparation, production of detergents. Import of soda to the republic is completely stopped, its export to Kazakhstan, Kyrgyzstan, Russia is begun.

Construction of the railway of Guzar-Boysun-Kumkurgan in many respects promoted development of the region of the Dekhkanabadsky area including development of the Tyubegatansky field of potash salts.

With a view of ensuring further development of branch the Concept of chemical industry development of the of the Republic of Uzbekistan for 2011-2020 which provides the measures directed on creation of productions of highly liquid chemical product for domestic market and export, optimization of production volume and the range of mineral fertilizers, updating of fixed assets of branch by construction of new, modern capacities on the basis of power - and resource-saving technologies, a stage-by-stage conclusion of out-of-date capacities is developed.

Taking into account study of new project offers directed on expansion of the assortment and a product range diversification, increase of an export potential of branch, the Program of measures for implementation of the major projects on modernization, technical and technological re-equipment of production for 2011-2015, approved by the Resolution of the President of the Republic of Uzbekistan from 15.12.2010 of No. PP-1442 is accepted. 30 projects of modernization and new construction by total cost of 2,86 billion dollars are included in the Program.

Within the Program study of projects on complex creation on production of polyvinylchloride (PVC) and caustic soda, a complex on production of ammonia and a carbamide on JSC Navoiazot, the organization of production of conveyor tapes and agricultural tires to base of JSC Rezinotekhnika, expansion of capacities of Dekhkanabadsky plant of potash fertilizers and Kungradsky soda plant is conducted.

As a result of these measures realization, by 2015 products growth to 2 250,2 billion sums, including new production – for 550,0 billion sums is predicted. Growth rate of production relatively to 2011 will make 147,4 %. The nomenclature of made production will increase from 160 names in 2011 to 185 names in 2015. The volume of non fertilizer production will increase from 26 % to 37 %. Power consumption of production on 1 million sums of products decreases in the following volumes:

– natural gas from 2,49 thousand m^3 to 1,51 thousand m^3, or for 39,4 %;
– the electric power from 3,5 thousand kW to 2,03 thousand kW, or for 42 %;
– heat power from 4,2 Gcal to 2,4 Gcal, or for 43 %.

In export structure the share of mineral fertilizers will decrease from 83 % (in 2011) to 72 %, and export of non fertilizer production will increase from 17 % to 28 %. About 3 000 new workplaces will be created.

Subsoil of Uzbekistan possesses high potential of oil and gas contents. About 60 % of the territory of the republic are potential on oil and gas which are located on 5 oil-and-gas regions – Ustyurtsky, Bukharo-Hivinsky, Gissarsky, Surkhan-Darya, Fergana.

The oil and gas sector of the republic is presented by the National Holding Company "Uzbekneftegaz" (NHK "Uzbekneftegaz").

The first years of Independence the state objective on achievement was the fuel and energy independence. Rates of production of liquid hydrocarbons considerably increased that allowed not only to provide internal requirements, but also to declare itself in the export markets. The accelerated development of branch demanded also structural transformations.

On August 22, 1997 in the Karavulbazar region of Bukhara area the modern oil refinery, with annual volume of processing of 2,5 million tons of gas condensate was placed in operation. Works on its design and construction were conducted in partnership with the TECHNIP company (France). Opening of the enterprise equipped with last generation technology, began a new stage of oil-processing industry development of the Republic of Uzbekistan.

In CIS area it became the first plant constructed on the basis of modern technologies, high-quality types of fuel providing production without application of harmful octane rising additives.

Today it is share up to 50 percent of all non-polluting gasoline made in the republic, the 35th percent of aviation fuel, the 30th percent of diesel fuel.

Since 2009 the Bukhara oil refinery started a mass production of a new type of aviation fuel for gas-turbine engines of brand Jet A-1 recognized as regular international fuel, widely used for filling of aviation vessels of the Boeing and Airbus.

Considering features of local raw materials processing with the high content of sulfurous connections, together with the Japanese companies "Mitsui" and "Toyo Engineering" reconstruction of the Fergana oil refinery was carried out.

In year 2000 reconstruction finalized with start-up of a complex of installation of hydrotreating of diesel fuel and reequipping of the catalytic reforming unit which allowed for plant turning to new modern level of oil refining. Capacities of the Fergana oil refinery allow to overwork annually to 8,7 million tons of hydrocarbonic raw materials, letting out about 60 types of production – light oil products, fuels, petroleum oils, bitumens, gas carbons, greasings, paraffin, gatch, consumer goods.

In 2001 the Shurtan Gas-chemical Complex is put into operation in Kashkadariya region. Construction of a technological part was conducted by a consortium as a part of «ABB Lummus Global» (Germany), «ABB Soimi» (Italy), «Mitsui&Co.Ltd», «Nissho Iwai Corp.» and «Toyo Engineering Corp» (Japan). Capacities of plant allows making 125 thousand tons of the polyethylene, more than 100 thousand tons of the liquefied gas and gas condensate, about 1,5 thousand tons of the granulated sulfur.

On the basis of the cleared methane of Shurtansky GHK implementation of the plant construction project on production of synthetic liquid fuel on the GTL technology together with the Malaysian company PETRONAS and Southern African – SASOL is begun. Design capacity assumes processing of 3,5 billion cubic meters of natural gas in diesel fuel, the aviation fuel, the liquefied gas, naphtha - total amount about 1,57 million tons per year.

Besides, in common in the Consortium of the South Korean companies led by KOGAS there is a work on implementation of the project «Construction of Ustyurt GHK on the basis of a field Surgil with field arrangement». Its planned that the annual project capacity is calculated on processing of 4,5 billion cubic meter of natural gas with production to 400 thousand tons of polyethylene, 100 thousand tons of polypropylene. Now there are works on external infrastructure objects building: external water - and power supply, the inhabited settlement, railway and automobile ways access to projected Ustyurt GHK.

With purpose of extension of the nomenclature of made brands of polyethylene, release of accompanying production and commodity natural gas by profound processing of natural gas with extraction of valuable components, further increase in raw and production base of petrochemical branch the project «Construction of a gas-chemical complex on the basis of UDP «Mubarek GPZ» is realized. The project provides production of polyethylene of high and low density in volume of 492,0 thousand tons per year, gas condensate – 66,0 thousand tons per year and pyropetrol – 53,0 thousand tons per year.

Subsoil of our republic, along with oil and gas, is rich with combustible slates. Preliminary stocks make about 47 billion tons of combustible slates. For example, stocks of combustible slates only Sangruntau's fields are made by 347 million tons.

With the aim of diversification of raw materials source of hydrocarbons and the organization of industrial development of technologies of receiving slate oil (pitch) the project «The organization of complex processing of combustible slates on a source of raw materials of a field of Sangruntau (Navoiysky area)» is carried out. As initial raw materials for slate processing the field of Sangruntau in volume of 8 million tons per year is accepted. Annual capacity of the enterprise of 470 thousand tons per year of slate oil (pitch) and 24 thousand tons tiofen. Process of processing of slates is accompanied by formation of combustible gases and superfluous heat that is used for the electricity generation, consumed for own needs. The construction of mine of slates production in volume of 8 million tons per year, slate reprocessing plant (8 installations of UTT-3000), thermal power plant (96 MWt), the inhabited settlement on 1700 inhabitants with infrastructure, automobile (15 km) and railway (101 km) are planned in the project.

FOUNDATIONS OF DECISION THEORY WITH IMPERFECT INFORMATION

R.A. Aliev

Joint MBA Program (USA, Azerbaijan) 20 Azadlig Ave., AZ1010 Baku, Azerbaijan,
Phone: +99412 493 45 38, Fax: +99412 598 45 09, E-mail: raliev@asoa.edu.az

***Key words**: NL-described information, imperfect information, fuzzy sets theory.*

Decision making is one of the key parts of human activity. It is especially important for human-centric systems, in particular, economic, political, military and other systems. There exist a large spectrum of theories of decision making starting from von Neumann-Morgenstern Expected Utility up to multiple priors-based theories and Prospect theory. The most famous and main representatives of this spectrum are von Neumann-Morgenstern Expected Utility, Savage's subjective Expected Utility, Maximin Expected utility, Choquet Expected Utility, Prospect theory. These theories yielded good results. However, they are created to deal with precise, perfectly known decision-relevant information which is intrinsic for thought experiments and laboratory examples. In contrast, every day decision making and decision making in complex human-centric systems are characterized by imperfect decision-relevant information. Imperfect information, as Prof. Lotfi Zadeh states, is information which in one or more respects is imprecise, uncertain, incomplete, unreliable, vague or partially true. One main source of imperfect information is uncertainty of future, particularly, impossibility to exactly predict values of the variables of interest, actual trends, partially known present objective conditions etc. Even when it is sufficiently clear how events are developing, unforeseen contingencies may always essentially shift their trend. As a result, the prevailing amount of relevant information is carried not at a level of measurements but at a level of subjective perceptions which are intrinsically imprecise and are often described in a natural language (NL). The other source of imperfect information is behavior of a decision maker (DM) influenced by mental, psychological and other aspects like feelings, emotions, views etc. The latter are not to be described by numbers, information about them is imprecise, partially true and partially reliable, approximate, and, in general, is also described in NL. Due to imperfectness of information and complexity of decision problems, preferences of a DM in the real world are vague. Main drawback of the existing decision theories is namely incapability to deal with imperfect information and modeling vague preferences. More concretely, these methods are developed to deal with precise (numerical) probabilities or a crisp set of probability distributions, ideal description of states of nature, precise outcomes and perfect, that is, binary logic-based formulation of preferences. In the present decision theories a small transition to dealing with imprecise, non-numerical information takes place. Mainly, this transition is only related to information on probabilities and is represented by the use of non-additive measures, sets of probability distributions, second–order probabilities. Actually, a paradigm of non-numerical probabilities in decision making has a long history and arose also in Keynes's analysis of uncertainty. Transition to imprecise probabilities is a form of generalization as a coercive measure to provide the decision theories ability of modeling experimentally observed evidence of humans' decision making. However, this generalization is, in our opinion, not sufficient. There is a need for further generalization – a move to decision theories with perception-based imperfect information described in NL on all the elements of a decision problem. This is often the only information with which people reason in real-world decision problems. Being not developed for dealing with such information, the existing methods are not adequate for applying to real world decision problems. Nowadays there are no economic models that provide sufficiently feasible descriptions of reality and new generation of decision theories is needed. Development of new theories is now possible due to an increased computational power of information processing systems which allows for computations with imperfect information, particularly, imprecise and partially true information, which are much more complex than computations over numbers and probabilities.

Humans have outstanding ability to make proper decisions under imperfect information. Thus, a new generation of decision theories should to some extent model this outstanding capability of humans. This means that the languages of new decision models for human-centric systems should be not languages based on binary logic and probability theory, but human-centric computational schemes able to operate on NL-described information. Enlargement of a role of NLs in decision analysis is a generalization which helps constructing models which are more flexible to deal with imperfect information and, as a result, allow yielding more realistic (not more exact!) results and conclusions. This opens doors to modeling phenomena of decision making which are impossible to analyze by using the existing approaches. For example, experimental evidence show that parametrical modeling of a DM's behavior, on which such a famous behavioral decision theories as Cumulative Prospect theory is based, often cannot describe human choices. From the other side, as we can observe in real life, NL is often used as an intuitive description of a rather complicated behavior.

Operating over NL-described information requires formal representation of meaning of words. The only theory developed for mathematical description of linguistic information is the fuzzy set theory. In this paper we suggest the developed decision theory with imperfect decision-relevant information on environment and a DM's behavior. This theory is based on the synthesis of the fuzzy sets theory as a mathematical tool for description and reasoning with perception-based information and the probability theory. The main difference of this theory from the existing theories is that it is based on a general statement of a decision problem taking into account imperfect information on all its elements used to describe environment and a behavior of a DM. The theory allows to model vague preferences naturally arising in real decision activity.

THE INTERVAL APPROACH AT DESIGNING OF CONTROL SYSTEMS OF TECHNOLOGICAL PROCESSES

N.R. Yusupbekov[1], H.Z. Igamberdiev[1], M.B. Bazarov[2]

[1] Tashkent State Technical University, Uzbekistan
[2] Navoi State Mining Institute, Uzbekistan

Keywords*: adaptive regulating, adaptive stabilization, technological process, adaptive algorithm.*

The given work is logic prolongation of works [1, 2, 3] and is devoted control system engineering by various technological processes on the basis of developed, authors of the given work, interval algorithms and the software.

In the given work the developed control systems of technological processes of oxidation of ammonia in nitric acid manufacture, evaporation amophosely pulps in manufacture of the granulated fertilizers, deriving of formalin, manufacture of a liquid methanol-raw, cutting of a dry plait from a filament of "Nitron" are is short described, allowing to stabilize technological conditions of course of processes and to raise efficiency of their functioning.

1. Adaptive regulating of technological process of oxidation of ammonia in the conditions of parametrical uncertainty

Automatic control systems technological processes of manufacture of nitric acid provide, first of all, regulating of loading of units, relations of expenses of ammonia and air, pressure, water, acid and overheated pair in different installations of units, air temperatures, overheated gas of exhaust gases, a velocity of rotation of machine units, etc.

In real situations the entering and other parameters defining a course of technological process, because of errors of measurements, and also because of other random factors, happen are precisely unknown. But always it is possible with sufficient degree of reliability to set intervals in which they lie. For example $x_a \in [\underline{x_a}, \overline{x_a}]$ $x_в \in [\underline{x_в}, \overline{x_в}]$ $a_{ij} \in [\underline{a_{ij}}, \overline{a_{ij}}], T_i \in [\underline{T_i}, \overline{T_i}]$ etc. At these suppositions, rated schemes, defining mathematical models of technological process, have a specific appearance.

In the conditions of Joint Stock Company "Navoiazot" on the basis of handling of an initial material areas in which connection between entering components - ammonia expenses x_a and air $x_в$ with an exit of process T (temperature of grids of catalysts) can be described the simplified mathematical model of a controlled process have been defined and selected:

$$\frac{dT}{dt} = \sum_{k=1}^{3} \theta_k(U)\left(a_{11}^k T + a_{12}^k + a_{13}^k U\right), \tag{1}$$

where $\theta_k(U)$ - characteristic function;

$$U = \frac{x_a}{x_b}, \quad a_{11}^k = 0.17;\ a_{12}^k = 195;\ a_{13}^k = 7.5\,.$$

Representing a temperature transmitter as an inertial link of first order, mathematical model of plant of regulating we will note in an aspect:

$$\frac{dT}{dt} = \sum_{k=1}^{3} \theta_k(U)\left(a_{11}^k T + a_{13}^k U\right), \quad \frac{dT_1}{dt} = a_{21}T + a_{22}T, \tag{2}$$

where T_1- temperature on an exit of a transmitter of temperature; $a_{21} = -0.0042$, $a_{22} = 0.004$.

Adaptive regulating of technological process of oxidation of ammonia is carried out on the basis of correction of temperature of grids of a contact means taking into account the data of the foreteller of temperature.

On the basis of experimental researches it was possible to deduce empirical relations between temperatures of grids, initially a contact means and a percentage relation of oxygen and ammonia in forced in a contact means ammoniac - an air mixture. For calculation of special summary tables of adjusting values of proportional, integral and differential components used adaptive pro rata-integral differential - regulator the adaptive-interval synthesis algorithms of control systems developed above have been used by technological plants.

2. **System of adaptive stabilization of an operating mode of process of evaporation of a pulp in manufacture granulated amophos**

At control of considered technological process essential value is gained by a problem of interval adaptive stabilization of operating modes of plant. This problem is one of the control main tasks technological processes in the conditions of the uncertainty caused by partial knowledge of values of parameters of plant of control and performances of exterior revolting actions.

The basic data-ins of process are the pulp expense on steam, natural gas, air, temperature and a pulp denseness on an input in a means, and days off - a denseness and pulp temperature, temperature of top internal gases on an exit.

On the basis of the developed interval adaptive algorithms [4] syntheses of operating actions by means of an evaluation of optimum tunings of adaptive governors the general structure of system of a direct adaptive control with corresponding algorithmic security is offered.

The operating sequence is calculated by means of expression $u^*(t) \in \mathbf{U}^*(t)$,

where $\mathbf{U}^*(t) = -\mathbf{G}_0^{-1}\left[\sum_{i\geq 0}\mathbf{F}_i\mathbf{y}(t-i) + \sum_{i\geq 1}\mathbf{G}_i u(t-i) + \sum_{i\geq 0}\mathbf{D}_i\mathbf{y}^d(t-i) + \gamma + \sum_{i=0}\mathbf{S}_i\vartheta(t-i)\right]$, γ - the vector characterizing established values of output variables of plant.

For the analysis of system effectiveness of an adaptive control evaporation process amophosely pulps on the basis of the system of a direct adaptive control synthesized above structure and the developed algorithmic security [4] spends control system modeling. Series of experiences on removal of experimental curves of dispersal of process of evaporation on the channel *"the heat-carrier expense - a denseness steamed pulps" have been under production conditions* spent. Interval statistical handling of the received curves of dispersal in various conditions of functioning of plant shows that dynamic characteristics of process of evaporation of a pulp can be approximated a transfer function of the second order with delay. Thus transfer function parameters varied depending on a condition of functioning of evaporating installation in following limits:

$$\mathbf{T}_1 = [3.9\,\text{min}, 4.5\ \text{min}],\ \mathbf{T}_2 = [3.4\,\text{min}, 3.8\ \text{min}],\ \mathbf{K} = [1.9\cdot 10^{\ 3}, 2.1\cdot 10^{\ 3}],\ \tau = [2.8\,\text{min}, 3.2\ \text{min}]$$

Thus, dynamic characteristics of evaporating installation as control plant have explicitly no stationary character.

The control system was modeled by means of the module of the programs, realized algorithms of an aspect

$$\Phi_t = \mathbf{y}_t - \mathbf{y}_{t-k}^d + l u_{t-k},\ \mathbf{x}_{t-k} = \left[\mathbf{y}_{t-k},\ldots; u_{t-k},\ldots; \mathbf{y}_{t-k}^d,\ldots; 1; \vartheta_{t-k},\ldots\right]^T,\ \theta_t = \theta_{t-1} + \mathbf{K}_t\left(\Phi_t - \mathbf{x}_{t-k}^T\theta_{t-1}\right),$$

$$\mathbf{u}_t = -\frac{1}{\mathbf{g}_0}\left[\sum_{i=0}\mathbf{f}_i\mathbf{y}_{t-i} + \sum_{i=1}\mathbf{g}_i u_{t-i-1} + \gamma + \sum_{i=0}\mathbf{c}_i\mathbf{y}_{t-i}^d + \sum_{i=0}\mathbf{d}_i\vartheta_{t-i}\right], \tag{3}$$

where $\theta_t = \left[\mathbf{f}_0, \mathbf{f}_1,\ldots; \mathbf{g}_0, \mathbf{g}_1,\ldots; \mathbf{c}_0, \mathbf{c}_1,\ldots; \gamma; \mathbf{d}_0, \mathbf{d}_1,\ldots\right]^T$.

Outcomes of modeling have shown that the offered algorithms of control satisfy to conditions of convergence both on co-ordinate, and on parametrical mismatches.

Practical realization of the offered control system gives the chance to reduce time of the forced idle time of evaporating means's for technological cleaning and preventive maintenance in the conditions of real manufacture, considerably to reduce denseness oscillations steamed pulps, and also to reduce the heat-carrier expense that finally allows to stabilize a temperature condition of process and to raise quality indicators of a ready yield in manufacture phosphorus containing complex fertilizers.

3. An interval adaptive control formalin structure.

In a basis of algorithm of shaping of operating actions transformations connecting degree methanol and a formaldehyde exit are supposed received experimentally regression models with the interval factors:

$$\mathbf{Y}_1 = \mathbf{a}_0 + \mathbf{a}_1\mathbf{X},\quad \mathbf{Y}_2 = \mathbf{b}_0 + \mathbf{b}_1\mathbf{X}. \tag{4}$$

where X - a relation oxygen/methanol; $\mathbf{Y_1}$ - transformation degree methanol; $\mathbf{Y}_2$ - a formaldehyde exit; $\mathbf{a}_0, \mathbf{a}_1, \mathbf{b}_0, \mathbf{b}_1$ - factors.

For quality management of ready formalin we offer the adaptive algorithm, allowing to stabilize quality of formalin by correction of temperature of a contact means depending on a relation formaldehyde/methanol in a ready yield, thus at the expense of reduction of a variance of the specified relation there is a possibility to reduce the specific expense methanol.

On a line of ready formalin after an absorption stage concentration of formaldehyde are measured $\mathbf{C}_ф$, methanol $\mathbf{C}_м$ and their current relation pays off $\mathbf{Y}(n) = (\mathbf{C}_ф / \mathbf{C}_м) \cap \mathbf{Y}(n-1)$. The received relation $\mathbf{Y}(n)$ is used for calculation of correcting factors $\mathbf{a_0}(n) = [\underline{a_0(n)}, \overline{a_0(n)}]$ and $\mathbf{a}_1(n) = [\underline{a_1(n)}, \overline{a_1(n)}]$ according to expressions:

$$\mathbf{a}_0(n) = [\underline{a_0(n-1)} + (\underline{Y(n)} - \overline{Y^{back}})/(2 + \overline{T^2(n-1)}),$$
$$\overline{a_0(n-1)} + (\overline{Y(n)} - \underline{Y^{back}})/(2 + \underline{T^2(n-1)})] \cap [\underline{a_0(n-1)}, \overline{a_0(n-1)}],$$
$$\mathbf{a}_1(n) = [\underline{a_1(n-1)} + (\underline{Y(n)} - \overline{Y^{back}}) \cdot \underline{T(n-1)}/(2 + \overline{T^2(n-1)}),$$
$$\overline{a_1(n-1)} + (\overline{Y(n)} - \underline{Y^{back}}) \cdot \overline{T(n-1)}/(2 + \underline{T^2(n-1)})] \cap [\underline{a_1(n-1)}, \overline{a_1(n-1)}]$$

Where n - number of a step of control; $T(n-1) \in [\underline{T(n-1)}, \overline{T(n-1)}]$ - value of temperature of the contact means, realized on a $(n-1)$ control step; $Y(n) \in [\underline{Y(n)}, \overline{Y(n)}]$ - value of a relation of concentration of formaldehyde and methanol in the formalin, realized on a $[n]$ control step; $Y^{back} \in [\underline{Y^{back}}, \overline{Y^{back}}]$ - a preset value of a relation of concentration of formaldehyde and methanol in formalin.

The corrected factors are used for an evaluation of new value of temperature of a contact means at a stage of synthesis of formaldehyde under the formula:

$$\mathbf{T}(n) = [(\underline{Y^{\text{back}}} - \overline{a_0(n)}) / \overline{a_1(n)}, (\overline{Y^{\text{back}}} - \underline{a_0(n)}) / \underline{a_1(n)}].$$

The calculated value of temperature $\mathbf{T}(n)$ is established in a contact means by means of a corresponding governor. Then again $\mathbf{C}_ф$ and methanol concentration of formaldehyde are measured $\mathbf{C}_м$ in formalin, their relation pays off $\mathbf{Y}(n)$, factors are corrected $\mathbf{a}_0(n)$ and $\mathbf{a}_1(n)$, new value of temperature of the contact means $\mathbf{T}(n)$, established pays off with a temperature governor in a contact means, and thus regulating is carried out until the current relation $\mathbf{Y}(n)$ does not become equal set $\mathbf{Y}^{\text{back}}$.

For check of the considered algorithm of control by formalin structure trial experiment industrially has been made. From the analysis of outcomes of experiment follows that application of the offered algorithm of control by formalin structure allows to reduce a variance of a relation of concentration of formaldehyde and methanol in formalin, thus technological process can be conducted near to the lower boundary of an admissible range of concentration methanol in formalin that leads to a drop of the specific expense methanol. Besides, the offered algorithm possesses adaptive properties, in particular, ability to compensate in managerial process a drop of activity of the catalyst. On the basis of the synthesized adaptive algorithm the system of automatic control is developed by process of deriving of formalin.

4. Synthesis of an interval governor for control of a temperature condition of manufacture liquid methanol - a raw.

The problem of calculation of a multi-channel governor of control by a synthesis column methanol in a column, considering existing temperature influence of shelves, uncertainty and a variation of some parameters of system was considered. For the purpose of control system creation by a temperature condition of a column experimental researches of plant of control in a normal condition of functioning in the supposition of small deviations on channels *«the expense of gas -*

gas temperature in a zone canalize» in the conditions of Joint Stock Company "Navoiazot" have been spent.

Modeling was spent for the values of parameters averaged on all arrays which start as the base. Values ***u*** varies within 10 %.

The linear model is searched in an aspect $y = Ku + b$.

In our case $N = 15$, dimension of matrixes $u, y - 3\times 15;\ K - 3\times 3;\ b$ - a vector a dimension column - 1×3.

We discover a matrix $\mathbf{K}$ and a vector $\mathbf{b}$ with interval elements

$$\mathbf{K} = \begin{bmatrix} [-1.52,-143] & [0.11,0.17] & [-0{,}1,-0.13] \\ [-1.53,-1.49] & [-0.74,-0.71] & [-0.11,-0.05] \\ [-1.42,-1.35] & [0.64,0.72] & [-0.45,-0.39] \end{bmatrix},\ \mathbf{b} = \begin{bmatrix} [615.34,621.67] \\ [655.98,662.43] \\ [658.23,667.71] \end{bmatrix}.$$

As a result of identification process on performance data the interval model of plant of control in a condition of maintenance of the set temperature conditions of shelves has been received linearly.

Let's note an interval matrix transfer function of plant and a governor in the form of polynomial expansion:

$$\mathbf{W}_p(s) = \mathbf{N}_p(s)\mathbf{D}_p^{-1}(s),\ \ \mathbf{N}_p(s) = [\mathbf{k}_{ij}];$$

$$\mathbf{D}_p^{-1}(s) = \{1+[0.07,0.2]s, 1+[0.07,0.2]s, 1+[0.07,0.2]s\}.$$

Thus, the transfer function of a column of synthesis of a methanol-raw in the form of polynomial matrix expansion has the following appearance:

$$W_p(s) = D_p^{-1}(s)N_p(s) = \begin{pmatrix} 1+[0.07;0.2]s & 0 & 0 \\ 0 & 1+[0.07;0.2]s & 0 \\ 0 & 0 & 1+[0.07;0.2]s \end{pmatrix}^{-1},$$

$$\begin{bmatrix} [-1.52,-143] & [0.11,0.17] & [-0{,}1,-0.13] \\ [-1.53,-1.49] & [-0.74,-0.71] & [-0.11,-0.05] \\ [-1.42,-1.35] & [0.64,0.72] & [-0.45,-0.39] \end{bmatrix}.$$

It is required to develop a multi-channel interval Pi-regulator of an aspect

$$\mathbf{W}_c(s) = \mathbf{N}_{cl}(s)\mathbf{D}_c^{-1}(s)\mathbf{N}_{cr}(s).$$

Governor matrixes have the following appearance

$$N_{cr}(s) = \begin{pmatrix} k_1 & 0 & 0 \\ 0 & k_2 & 0 \\ 0 & 0 & k_3 \end{pmatrix} \subset \mathbf{N}_{cr}(s) = \begin{pmatrix} \mathbf{k}_1 & 0 & 0 \\ 0 & \mathbf{k}_2 & 0 \\ 0 & 0 & \mathbf{k}_3 \end{pmatrix};$$

$$N_{cl}(s) = \begin{pmatrix} 1+n_1 s & 0 & 0 \\ 0 & 1+n_2 s & 0 \\ 0 & 0 & 1+n_3 s \end{pmatrix} \subset \mathbf{N}_{cl}(s) = \begin{pmatrix} 1+\mathbf{n}_1 s & 0 & 0 \\ 0 & 1+\mathbf{n}_2 s & 0 \\ 0 & 0 & 1+\mathbf{n}_3 s \end{pmatrix}$$

$$D_c^{-1}(s) = \frac{1}{s}\left[\ _{ij}\right]^{-1} \subset \mathbf{D}_c^{-1}(s) = \frac{1}{s}\left[\ _{ij}\right]^{-1}$$

Where

$$\left[\ _{ij}\right]^{-1} = \begin{pmatrix} [-0.9161,-0.8547] & [0.0244,0.7987] & [0.1131,0.1675] \\ [1.4744,2.0278] & [-1.5386,2.2845] & [0.0121,0.0701] \\ [-0.1819,-0.1032] & [2.2981,3.1231] & [-1.9237,-2.3903] \end{pmatrix},$$

$k_i \in \mathbf{k}_i$, $n_i \in \mathbf{n}_i$ - unknown parameters of a governor which are necessary for discovering.

The synthesis problem dared in the following statement:

$$\max_i \mathrm{Re}(\lambda_i) < -0.4\,,\ \arctan_i\left(\frac{\mathrm{Im}(\lambda_i)}{\mathrm{Re}(\lambda_i)}\right) \le 45^0\,,\ \max_i \mathrm{Re}(\lambda_i) - \min_j \mathrm{Re}(\lambda_j) \to 0\,.$$

The characteristic polynomial of the closed system has an order $n = 6$.

As a result of optimization it is had

$$\mathbf{k}_1 = [3.3211, 3.3764];\ \mathbf{k}_2 = [3.2992, 3.3676];\ \mathbf{k}_3 = [2.4563, 3.0978];$$

$$\mathbf{n}_1 = [1.38045, 1.4223];\ \mathbf{n}_2 = [0.9809, 1.312];\ \mathbf{n}_3 = [1.2816, 1.3212].$$

The control system has been realized on the basis of programmed microcontrollers Simatic S5 with use of software of this set of controllers. Outcomes of work have allowed simplifying algorithm of control of steam formation system, and also it is essential to lower expenditures on system operation.

5. An interval control system of technological process of cutting of a dry plait from a filament of "Nitron"

Here the problem of working out of an interval control system by technological process of cutting of a dry plait of a filament of "Nitron" on short segments of the set length in cutting to the car of type MRB-100 was considered.

Outcomes of preliminary researches allow to note the equations of considered plant in an aspect

$$\dot{x}(t) = A(t)x(t) + B(t)u(t)\,, \tag{5}$$

$$y(t) = Hx(t)\,, \tag{6}$$

Where $x(t) = (\Delta T_2(t), \Delta v_1(t), \Delta v_2(t))^T$, $u(t) = (\Delta u_{\partial в}(t), \Delta u_{TT}(t))^T$, $y(t) = (\Delta T_2(t), \Delta v_2(t))^T$ - small deviations of current vectors of a condition, inputs and controlled variables. Here: $T_2(t)$ - forces of a tension of a cloth on a free site, $v_1(t)$, $v_2(t)$ - linear velocities of a peal and an intermediate shaft, $u_{\partial b}(t)$ - pressure in an anchor chain of the electric motor rotating an intermediate shaft, $u_{TT}(t)$ - pressure in an anchor chain of the brake generator.

Matrixes $A(t)$, $B(t), H$ have the following structure

$$A(t) = \begin{pmatrix} a_{11}(t) & a_{12}(t) & a_{13}(t) \\ a_{21}(t) & a_{22}(t) & 0 \\ a_{31} & 0 & 0 \end{pmatrix},\quad B(t) = \begin{pmatrix} 0 & 0 \\ 0 & b_{22}(t) \\ b_{31} & 0 \end{pmatrix}, H = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}. \tag{7}$$

Their elements depend on parameters of a nominal condition and an instant.

Let's solve a problem of stabilization of quasi stationary system (5), (6) on a time interval $[0, T]$.

Quasi stationary parameters on an interval of time $[0, T]$ vary in following ranges:

$$\begin{aligned} &a_{11} \in [-3.61, -2.41], a_{21} \in [0.0036233, 0.0037491], \\ &a_{22} \in [0.063918, 0.068375],\ b_{22} \in [-0.01353, -0.01286] \end{aligned} \tag{8}$$

So, behavior of plant (5), (6) on the set time interval $[0, T]$ it is possible to describe linear system, matrixes of dynamics and which inputs look like:

$$A = \begin{pmatrix} \mathbf{a}_{11} & a_{12} & a_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & 0 \\ a_{31} & 0 & 0 \end{pmatrix},\ B = \begin{pmatrix} 0 & 0 \\ 0 & \mathbf{b}_{22} \\ b_{31} & 0 \end{pmatrix}.$$

Efficiency of use of the received regulators at any combinations of indefinite parameters from the set ranges is confirmed by modeling of transients in the closed system by means of PAP INTAN [4]. Adaptive-interval synthesis algorithms were applied to security astathism in a control system. It has allowed receiving **PI** - the governor guaranteeing a zero established static error on adjustable voltage.

Thus, in work: 1) the problem of automation of control is considered and solved by technological process of oxidation of the ammonia which is composite in the course of manufacture of nitric acid. Use of the offered synthesis algorithm of adaptive governors has allowed to eliminate the uncertainty of control depending from not stationary of temperature near to a working point of a reactionary zone of a contact means; 2) it is developed an adaptive suboptimal interval control system of process evaporation amophosely pulps in manufacture of the granulated fertilizers, allowing to stabilize a technological condition of course of process and to raise efficiency of functioning; 3) the system of automatic control is offered by process of deriving of formalin which allows to realize engineering the offered interval mode of quality management of ready formalin; 4) the control system of a temperature condition of process of manufacture liquid methanol - a raw is offered. The control system allows simplifying algorithm of control of system of steam formation and to lower expenditures on system operation; 5). The interval control system of technological process of cutting of a dry plait from a filament of "Nitron" on short segments of the set length in cutting to the car of type MRB-100 is developed. Transmission factors of the dynamic governor guaranteeing astatic regulating of a tension of a dry plait before the knife shaft at any admissible modifications of indefinite parameters are calculated.

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SUSTAINABLE ENERGY SYSTEMS: CYBER-PHYSICAL BASED MANAGEMENT OF MICRO-GRIDS BY A FUZZY SYSTEMS APPROACH

Mo Jamshidi, Yashar Sahraei Manjili

ACE Laboratory, Department of Electrical and Computer Engineering,
University of Texas at San Antonio, San Antonio, TX
moj@wacong.org

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Abstract. *A Fuzzy Logic-based framework is proposed for control of Battery Storage Unit in Micro-Grid Systems to achieve Efficient Energy Management. Typically, a Micro-Grid system operates synchronously with the main grid and also has the ability to operate independently from the main power grid in an islanded mode. Distributed renewable energy generators including solar, wind in association with batteries and main grid supply power to the consumer in the Micro-Grid network. The goal here is to control the amount of power delivered to/taken from the storage unit in order to improve a cost function, defined based on summation of payment required for purchasing power from main grid or profit obtained by selling power to the main grid and distribution power loss, through reasonable decision making using predetermined human reasoning-based fuzzy rules. Profiles of system variables such as Consumer's Load Demand, Electricity Price Rate, and Renewable Electricity Generation Rate are assumed arbitrarily for obtaining general results. Measures of payment/profit will be extracted to compute amounts of cost and balance for the network which represent benefits of using Fuzzy logic for Storage Unit control with and without considering storage unit capacity limits. Simulation results are presented and discussed.*

Keywords*: Micro-Grid Network, Intelligent Control, Power Flow Analysis, Fuzzy-Logic, Load Demand, Variable Electricity Price Rate.*

1. Introduction

Micro-Grid is a small-scale grid that is designed to provide power for local communities. A Micro-Grid is an aggregation of multiple distributed generators (DGs) such as renewable energy sources, conventional generators, in association with energy storage units which work together as a power supply network in order to provide both electric power and thermal energy for small communities which may vary from one common building to a smart house or even a set of complicated loads consisting of a mixture of different structures such as buildings, factories, etc [1]. Typically, a Micro-Grid operates synchronously in parallel with the main grid. However, there are cases in which a Micro-Grid operates in islanded mode, or in a disconnected state [2]. In this article we assume that when the Micro-grid is connected to the main grid and is working synchronously with it, the flow of electric power can be either from the main grid to the Micro-grid or vice-versa. If the flow of electric power is from the main grid towards Micro-grid it means that the Micro-grid is consuming the main grid's energy for each KiloWatt-Hour of which the consumer, here Micro-grid, must pay to the Grid. This borrowed power can be either sent to local load to be consumed or can be stored in battery for future use. But, in case the flow of power is from the Micro-Grid towards the main grid, this means that Micro-Grid is delivering power to the main grid. In other words, the excess power generated currently by the renewable electricity generators or stored previously in the batteries is being sold to the main grid, and the Micro-Grid, or in general the consumer, is making profit by selling energy to the main grid. Without loss of generality, we have assumed that the price rate for buying energy from the main grid is equal to the electricity price rate which is sold to the grid. The excess power can be sold to the grid whenever the storage unit or load don't need that power or whenever it is more beneficial to sell power to grid than to use it for supplying the load. However, in this article the main goal is to have the load completely supplied by the required power demand at all conditions. Authors have previously simulated the Micro-Grid assuming no maximum and minimum limit for the amount of energy stored in the battery unit [1]. In this article, storage unit's limits on maximum and minimum amount of stored energy are considered and the results are compared to the results of the previous work.

2. System Model

The model used for simulation of the Micro-grid network is a three-bus system. One of the busses in the distributed generation model is assumed to serve the renewable generators which include either solar farm, wind farm, or any other renewable generation units either in association with battery storage unit or without storage. Another bus is assumed to be there as the grid (utility) bus which will provide the complement part of the power demanded by the local load that renewable electricity generation system cannot afford. The third bus will be the specific load to which the demanded power is to be provided. This load can be anything from a common building or a smart house, to even a group of plants and factories or a mixture of all of them. Figure 1 shows an overall Micro-Grid schematic including Renewable Electricity Generators and Storage Unit, Utility, and Local Load.

There are three scenarios defined for simulation in this article; scenario 1 deals with a Micro-Grid which includes the renewable electricity generators without any battery storage unit. Therefore there will not be any approaches required for controlling the battery storage system in this scenario. The second scenario deals with the same Micro-Grid system as mentioned in scenario one but after the battery storage unit is connected to the same bus with the renewable generators. Also, the fuzzy approach is applied in this scenario for energy management through battery unit control. The point in this scenario is that the battery storage is assumed to be an ideal battery without any maximum or minimum limits on stored energy, i.e. infinite battery capacity. In the third scenario which is the last one, the Micro-Grid is assumed to have everything mentioned in scenario two plus the fact that maximum and minimum limits of stored energy are taken into account for storage unit and are assumed to be 85% and 15% of the nominal maximum storable energy respectively. These three scenarios will be described in more detail in section III.

Figure 1. ***A sustainable energy micro-grid.***

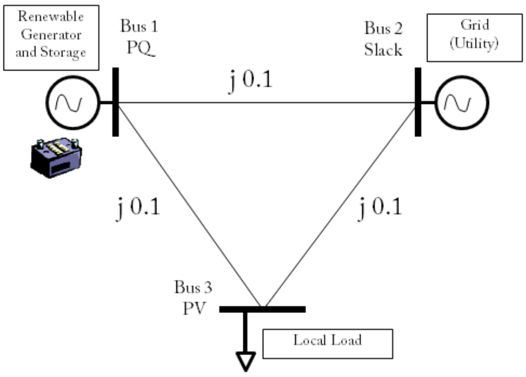


Figure 2. ***Three Bus Model for Micro-Grid.***

Characteristics of Buses in Scenario 1

The three buses in the model of Micro-Grid Network simulated in this article have the following characteristics in the first scenario:

- Bus 1 is of type PQ and is used as the renewable electricity generation unit's bus.
- Bus 2 is of type Slack (reference) and is used as the Utility (grid) bus.
- Bus 3 is of type PV and is used as the Local Load bus.

Characteristics of Buses in Scenario 2

The characteristics of the three buses in the Micro-Grid Network model simulated in this article are as follows in the second scenario:

- Bus 1 is a PQ bus and is used as the bus for renewable generation unit and infinite-capacity battery storage.
- Bus 2 will be the Slack (reference) bus and is used as the Utility (grid) bus.
- Bus 3 is of type PV and is used as the Local Load bus.

Characteristics of Buses in Scenario 3

Bus characteristics of the three buses in the Micro-Grid Network model simulated in this article are as follows in the third, i.e. last, scenario:

- Bus 1 is a PQ bus and is used as the bus for renewable generation unit and finite-capacity battery storage unit.
- Bus 2 will be the Slack (reference) bus and is used as the Utility (grid) bus.
- Bus 3 is of type PV and is used as the Local Load bus.

This must be noted that battery units are assumed to be ideal batteries, i.e. no dynamic transient of change in the amount of stored energy in batteries are assumed, i.e. the amount of stored energy in the batteries is assumed to be changing as a pure ramp by time in both ascending and descending direction.

3. Problem Statement

The important point which lies behind the idea of this article is that we have assumed the real-time pricing for electricity. The update duration of pricing is assumed to be 15 minutes, which means that the price per KiloWatt-Hour of electricity consumed by the customers of the load region is updated every 15 minutes. This means that the money consumers need to pay to the utility for the same amount of energy used during different time-intervals might be different. Therefore, a function is required to be defined which takes into account the difference between amount of power given to the utility by the Micro-Grid, and the amount of power taken from the utility by the Micro-Grid. The Equation 1 represents this cost function:

$$Cost = \sum_{t=1}^{T} (\Pr(t).S_U(t)) \qquad (1)$$

where the electricity price $\Pr(t)$ is determined by the CPS energy every 15 minutes for the next 15 minute period. $S_U(t)$ is the amount of power transferred to/from the Grid during each 15 minute period. If power is received from the Grid $S_U(t)$ will be positive, and if power is delivered to the grid in case of excess power generation by the renewable generation system $S_U(t)$ will appear in the equations with a negative sign.

Figure 2 represents the three-bus model used for simulation of the Micro-Grid in different scenarios along with the branch impedances and the types of buses. Simulation is done on the Micro-Grid system considering three scenarios. In the following the summary of these scenarios is given:

Scenario 1

Analysis of the Micro-Grid system profits and costs under real-time electricity pricing policy; in this scenario the simulation, analysis and study will be done on a Micro-Grid model which includes the renewable generation unit without any battery storage unit. Therefore there will not be any approaches required for controlling the battery storage system.

Scenario 2

Fuzzy Control of the Micro-Grid system under real-time electricity pricing policy; the cost function assumed in this scenario is the same as the cost function used in the scenario 1. The main difference here is that the storage unit exists in the network and will appear to be on the same bus with the renewable electricity generation unit. The storage unit in this scenario is assumed to be ideal with infinite capacity.

Scenario 3

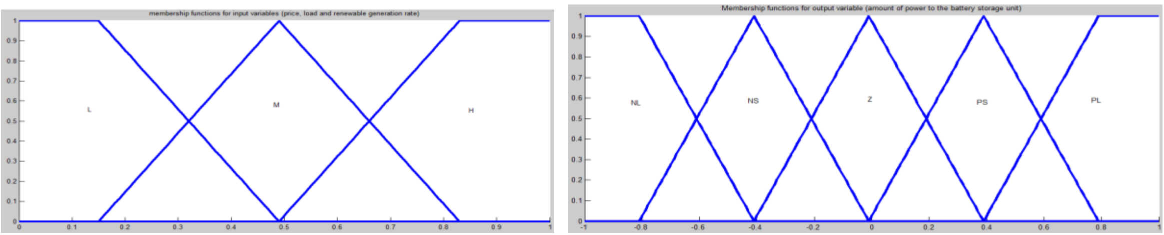
Fuzzy Control of the Micro-Grid system under real-time electricity pricing policy; the cost function assumed in this scenario is the same as the cost function described in the two scenarios 1 and 2. In this scenario also the storage unit exists in the network on the same bus with the renewable generation unit. The critical difference between this scenario and scenario 2 is that the storage unit in this scenario is assumed to be an ideal battery with finite capacity. Therefore, the maximum and minimum amounts of energy stored in the batteries are finite values and serve as boundaries which cannot be exceeded.

The power flow calculation and analysis in the Micro-Grid is the key to simulate the whole system. There are a number of well-known methods for calculation of power flow in the distributed generation network [3]. There are four different types of busses considered in a distributed generation network, the characteristics of which will be calculated in power flow algorithms. These four types include PQ, PV, Slack, and isolated [4, 5].

4. Fuzzy Control Approach

The control strategy implemented in this paper is to use Fuzzy Logic [6] for controlling the power flow to/from the battery storage unit in order to improve the value of the cost function introduced in section III. The three input variables to the fuzzy inference engine are Electricity Price, Renewable Generation Rate, and Load Demand. The Fuzzy inference engine serves as the controller which determines a measure of the amount of power that must be sent to/taken from the battery unit during the next time interval, i.e. 15 minute period, based on the current values of its three inputs.

The fuzzy membership functions for the three inputs price, load demand, and renewable generation rate, and also for the output variable which determines the amount of power transaction with the storage unit are shown in figure 3.



(a) (b)

*Figure 3. **Fuzzy Membership functions for input and output variables of the Fuzzy Controller;(a) inputs (b) output.***

The numerical values for these three input variables are normalized to the [0 1] interval, and then are Fuzzified using three fuzzy sets defined as Low (L), Medium (M), and High (H) as can be seen in figure 3a. The input variables after fuzzification will be fed to a fuzzy inference engine where the rule-base is applied to the input-output variables and the output will be determined by human reasoning. There is only one output variable from the fuzzy controller. This variable determines the amount of power to be stored in the battery, or to be drawn out from battery in each 15 minute interval. As represented in figure 3b, output variable fuzzy set is assumed to have five membership functions called Negative Large (NL), Negative Small (NS), Zero (Z), Positive Small (PS), and Positive Large (PL). The power drawn from the batteries can be used to complement the renewable electricity generation unit's power for providing the load's demand, can be sold to the Grid, or can be partially used for both reasons [7]. The role of fuzzy inference engine is critically important for obtaining satisfactory results. For example a rule can be as follows:

IF the *Price* is *Low*, AND the *Renewable Generation rate* is *High*, AND the *Load Demand* is *Medium*, THEN the amount of *Power to Battery* storage system should be *Positive-Large*.

The primary goal in these simulations is to provide the local load with all the power it demands at any circumstances. Meanwhile, this must be noted that whenever the price is high or low, the secondary goal will be to sell the most power to the main grid, and to purchase the most power possible from the main grid respectively. Under low-price electricity conditions, the action required by the rules might even require the Micro-Grid network to purchase power from grid and store it in the battery storage unit because the main point here is that the Price is low. This means by storing the energy in the batteries during low price times, the system will have enough stored energy in order to sell to the Grid during high-price periods. Even under cases of High local Load demand this will be a rational strategy. Therefore, having feasible rules predefined for the fuzzy system will help improve the cost function drastically. The proposed approach may even sometimes result in making the cost function value negative, which means that the system is making some profit instead of paying to the utility by the use of this control approach.

5. Simulation results & discussions

The simulation is done on the three bus system shown in figure 2. The Gauss-Seidel algorithm is implemented using Matlab for power flow calculation [8]. Some typical data are generated for electricity price rate, time-varying Load Demand and Renewable Generation Rate.

The power demand of the Load on bus 3 (Smart House) is supplied by two generators on buses 1 and 2. Bus 1 includes solar panel and/or storage unit and bus 2 is slack which is connected to utility as shown in figure 2.

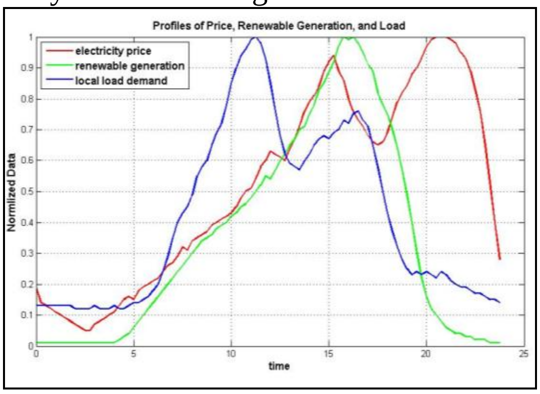


Figure 4. ***Profiles of Price, Renewable Generation, and the Load.***

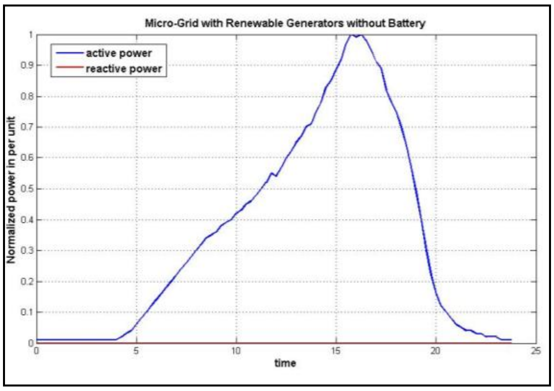


Figure 5. ***Power Flow of Bus 1 connected to Solar Panels; scenario 1.***

The numerical values of the data profile for the three input variables which are fed to the fuzzy controller are shown in figure 4 during a typical day. These variables include electricity price which is assumed to be variable as time passes, renewable electricity generation rate, and local load demand. The data is generated arbitrarily for simulation purposes only with regard to the fact that the peak electricity consumption duration of the whole region of interest for the main grid is around 8:30 pm where the electricity price gets to its maximum value.

The simulation results for scenario 1 are represented in figures 5 to 7.

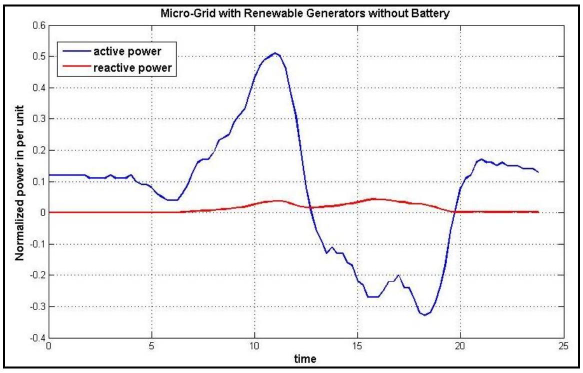


Figure 6. ***Power Flow of Bus 2 connected to Utility; scenario 1.***

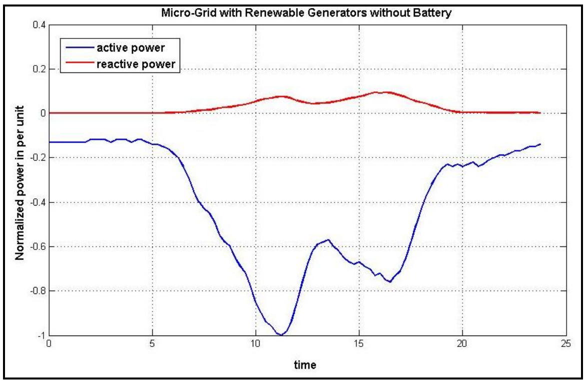


Figure 7. ***Power Flow of Bus 3 connected to Load; scenario 1.***

As it can be inferred from figure 5, the value of reactive power for bus 1 is constantly zero which corresponds to the assumption that the renewable generators do not provide reactive energy. Figure 6 shows that the active power is taken from the Utility during first half of the day time, and during most of the second half of the day the active power is being delivered to the grid. Load is evidently consuming active power regarding the blue curve represented in figure 7.

Simulation results for scenario 2 which associates ideal storage with infinite capacity to the renewable electricity generators on bus 2 are represented in figures 8 and 9.

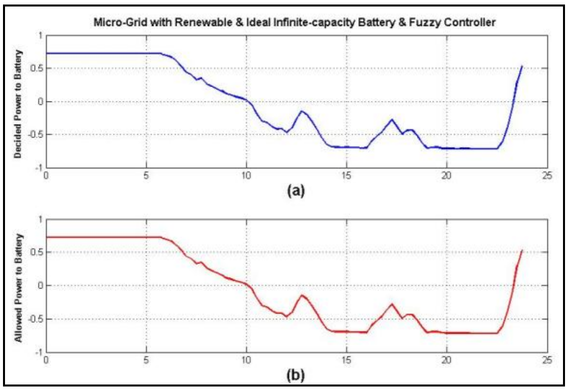


Figure 8. ***Output of the Fuzzy Controller, i.e. measure of the amount of power given to/taken from storage unit; scenario 2; (a) Theoretically allocated (b) Practically feasible.***

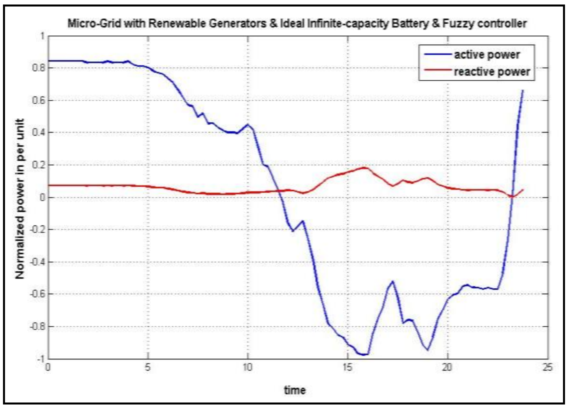


Figure 9. ***Power Flow of Bus 2 connected to Utility; scenario 2.***

Figure 8 parts a and b are matched to each other and this clearly shows that any value decided by the Fuzzy Controller for the power to be given to Battery or to be taken from it can be practical since battery unit assumed in scenario 2 is of infinite capacity. Figure 9 shows that active power is taken from the utility during first half of the day, and in the second half of day the active power is mostly being sold to the grid which can be deduced by the negative value of the blue curve in figure 9. The point is that the first part of the active power diagram is raised dramatically due to fuzzy decision making which means that the system is absorbing more active power from the grid during low-price hours and stores the power in the storage unit. Also, the second part of the active power diagram has fallen more in comparison to the same section of figure 6 which denotes on increase in the amount of power drawn from storage unit and using this power for partially charging the load and also selling the excess power to the grid during high-price hours. This strategy results in reduction of cost function value or in other words increases the profit.

Remembering that the pricing periods are assumed to be 15 minute periods and one day is 24 hours overally there will be 96 periods of pricing during one day period. The summation of payment/profit and the loss during each of the periods will give us the overall value of cost function for one day. The process can be extended to one week, one month, one year etc. Simulation results for scenario 3 in which ideal finite-capacity storage is added on bus 2 in Micro-Grid network are represented in figures 10 to 12.

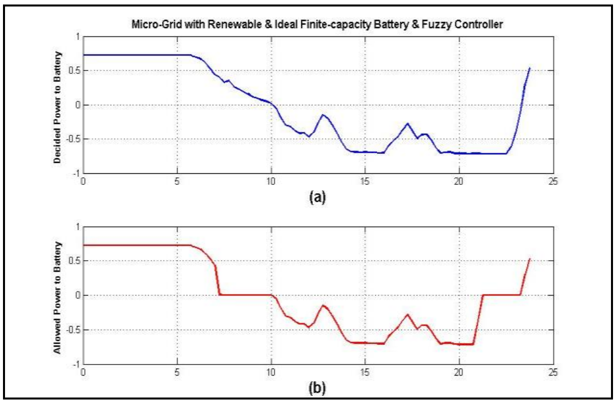


Figure 10. ***Output of the Fuzzy Controller; scenario 3; (a) Theoretically allocated (b) Practically feasible.***

Figure 10 parts a and b are not matched to each other and this shows the fact that the values decided by the Fuzzy Controller for the power to be given to Battery or be taken from it might not be practical since battery unit assumed in scenario 3 is of finite capacity and the maximum and minimum limits of stored energy should be taken into account.

Output of the fuzzy inference engine which represents the power rate given to battery is shown in figure 11. Whenever the value of this variable is positive it means that power is delivered to the storage unit and if the power is drawn from the storage unit, the value will be negative.

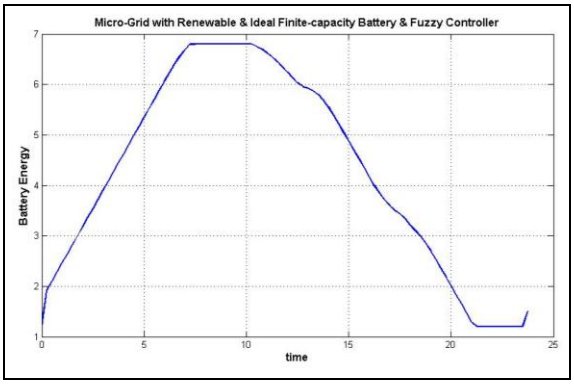


Figure 11. ***Measure of Energy stored in Battery; scenario 3.***

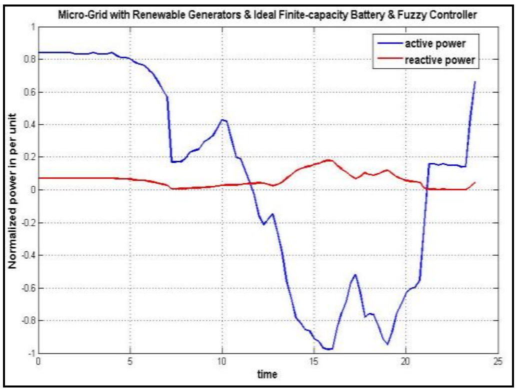


Figure 12. ***Power Flow of Bus 2 connected to Utility; scenario 3.***

The Center of Gravity, i.e. Centroid, defuzzification method is used for computing the crisp values of the output variable from the union of the Fuzzy rules. The formula used for defuzzification is shown in Eq. 2

$$y_{crisp} = \frac{\sum_{i=1}^{n} \left(\max_j(\mu)_i \times y_i \right)}{\sum_{i=1}^{n} \left(\max_j(\mu)_i \right)}. \tag{2}$$

Where y_{crisp} stands for crisp value of output variable. *i* changes between 1 and *n*, and refers to the number of discrete point at which the calculation is being done. *j* changes between 1 and the number of membership functions of output variable which in this case is 5, and represents the number of membership function curve for which we are getting the membership value of i^{th} point in the universe of discourse of the output variable. Therefore, $max_j(\mu_i)$ represents the final membership value of the i^{th} point in the universe of discourse of output, i.e. y_i. Equation 3 shows the relation between Balance, Distribution Loss and the overall Cost of Electricity.

$$Balance = Cost - Loss \tag{3}$$

$$Loss = \sum_{t=1}^{T} (\Pr(t) . S_L(t)) \tag{4}$$

Where Cost is calculated using Equation 1 and represents the amount that the microgrid owner has to pay to the main grid, if Cost > 0, or will get from the main grid, if Cost < 0. Loss stands for the overall sum of multiplication of the electricity price and wasted power on distribution branches for all 15 minute periods, i.e. $S_L(t)$. Loss will always be greater than or equal to zero. Balance will then be the measure of the amount than microgrid owner had to pay to the main grid or the amount of revenue that the microgrid owner will get from the main grid in case the power network were lossless.

Table 1

Simulation results for Loss, Cost and Balance

	Loss	Cost	Balance
Scenario 1	0.1339	1.2294	1.0955
Scenario 2	6.6039	-14.8711	-21.4750
Scenario 3	6.6039	-13.3021	-19.9059

In table 1 and Figure 13, total values of distribution loss, cost, and balance on one typical day for the three scenarios mentioned in section III are summarized. It must be noted that the values in the table are unit-less, and they can be regarded as measures for payment that the end-user should make to the utility because of regular operation of Micro-Grid, or profits earned due to improved operation and control of the Micro-Grid. The shaded cell represents the final cost or final revenue of the practical case using Fuzzy controller.

With no loss of generality, it is assumed that the reactive power has one tenth the value of active power.

We can see that scenario 2 will provide the consumer with the most possible profit on balance and this is because of the fact that the battery unit used in scenario 2 is assumed to be of infinite capacity. Therefore there will be chance for utmost storage of power in the battery whenever required and the battery can provide that stored power completely to the Micro-Grid for appropriate usage any time. This is not a practical case though. In scenario 3 which is the practical case compared to the second scenario, battery storage unit is assumed to be of limited capacity and therefore, maximum and minimum limits of the stored energy in the battery might prevent the control system to apply the decided action on the storage unit thoroughly. This might cause a drop in the benefits that consumer will obtain using this approach as it can be seen by comparing the values of Balance for the two scenarios 2 and 3. However, by improvements in the battery production technologies this issue can be solved to good extents.

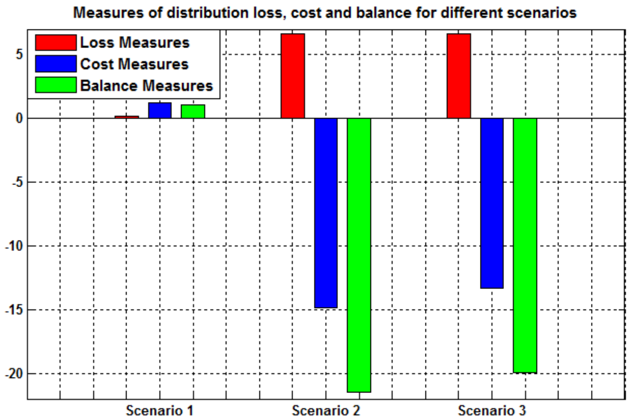


Figure 13. ***Measures of Loss, Cost and Balance for different scenarios.***

6. Conclusion

The proposed Fuzzy-Logic based control method is applied for Battery Management in Micro-Grid Systems. In the micro-grid system three buses are considered as renewable generator and storage, utility, and load (smart house). The goal was to reduce the balance which is based on distribution loss and cost. The Micro-Grid was simulated under three scenarios. Simulation results obtained for Micro-Grid under scenario 2 where the ideal infinite-capacity storage is involved with the Fuzzy controller outperform the other two scenarios. However this is not practical. In third scenario, ideal limited-capacity storage was involved and the results were satisfactory. Therefore, using fuzzy controller it is possible to reduce the cost of the Micro-Grid system, and even let the customers make profit from selling the excess power to the utility.

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TO THE SEPARATION OF STRONG MIXING OF PARTITION OF CLASSES

M.M. Kamilov, M.Kh. Hudayberdiev, A.Sh. Khamroev, Z.B. Mingliqulov

TUIT, 100084, Str. Amir Temur 108,Tashkent, Uzbekistan
kamilov_m@mail.ru, mirzaakbarhh@gmail.com

Abstract: *The report is devoted to improvement of algorithms for separating functions by Bezier curve, which are based on the algorithm design with optimal classifying objects. The developed algorithm performs classification in the systems with complex order.*

Keywords: *intellectual analysis of data, computer algebra, pattern recognition, Bezier curve.*

Introduction

In the course of contemporary technological revolution, studies related to the perspectives of automating of wide range of solutions, so-called intellectual tasks that until now could only be solved by men who were in the center of attention. Therefore a few successful attempts have been done in programming the game of chess, weather prediction, theorem proving, speech recognition, diagnosis of disease, identification of images of human, processing small-formatted documents (bank cheques, postal notices, receipts, etc.), etc. [1-4]. The solution of many these tasks requires the ability of classifying different input data. The proposed parametric method "teaching with a tutor" is based on the method with using Bezier curves.

Purpose of improving the algorithm of separating functions is using methods of computer algebra, which is based on the design of the algorithm, classifies data optimum. Some aspects of this general theory are consequences of the statistics branches that deal with classifying results of measures. New aspects have appeared in connection with researches in the field of intellectual analysis of data and Data Mining.

Formulation of the problem

We assume that in each data set under the classification there is m sets of real numbers $s_1, s_2, ..., s_j, ..., s_m$, $(s_j \in R)$, which we call the objects, and some numbers from these sets we call components of this object $S_j = (x_1, x_2,..., x_i,..., x_n)$, $j = \overline{1,m}$ and $i = \overline{1,n}$, $(i, j \in N, x_i \in E^n)$. Suppose there are K_ℓ classes $(1 \le \ell \in N, K_\ell \in E^n)$ that need to divide the objects $K_u \cap K_g = \varnothing$, $u \ne g,\ u, g = \overline{1,\ell}$.

It is required to construct an algorithm $a : S_j \to K_\ell$ which approximates the target dependence in the whole space of objects [1,4,5].

Method of the solution

One of these numbers, for instance, K_ℓ may correspond to the class of objects related to the not definite decision. It makes "zero" class. In this work E^2 is considered by means of Euclid space. Then set of points are separated from each other by the curves which will be called the dividing curves thereafter. The set of points the dividing curve separates in E^2, and corresponds to one of the classes of K_ℓ will be called solution domains. The proposed algorithm is constructed in order to solve the principles using Bezier curves. To construct the separating curve, firstly, we find middle points M_i ($i = \overline{1,n}$) among the values of the boundary points of the corresponding classes by the known methods. We construct a Bezier curve by the middle points found using the following formula:

$$B(t) = \sum_{i=0}^{n} C_i^n (1-t)^{n-i} t^i M_i$$

here C_i^n - binomial coefficient, M_i - mean points among the values of the boundary points of corresponding classes.

Results of experiment

Let's look at the algorithm of separating into classes by the cubic Bezier curves:

At first step, algorithm is supposed to select S_j objects which located on borders of the classes K_ℓ, ($\ell = 2$).

Second step, algorithm is supposed to determine the average points M_i in the medium classes.

Third step, algorithm is supposed to draw a line of cubic Bezier curve through the midpoints of K_ℓ classes:

$$B_j(t) = \sum_{i=0}^{n} C_i^n (1-t)^{n-i} t^i M_i,$$

$$(t = (0;1),\ n = 3).$$

Fourth step, the cubic Bezier curve is completed: $B^*(t) = \sum_{j=1}^{m} B_j(t)$.

Fifth step, decision rule is composed based on the Bezier curves clasification:

If $B(\vec{S}_i^*) > B^*(t)$, then $\vec{S}_i^* \in K_1$, otherwise $\vec{S}_i^* \in K_2$ class.

Sixth step, if result is satisfactory the algorithm finishes its function, otherwise algorithm backs to the first step.

Below the results of two different algorithms Fig. 1 „Support Vector Machine“ and Fig.2. „The cubic Bezier curves“ are showed:

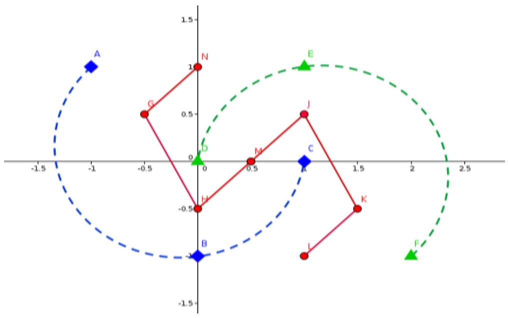

Figure 1. ***Support Vector Machine (SVM).***

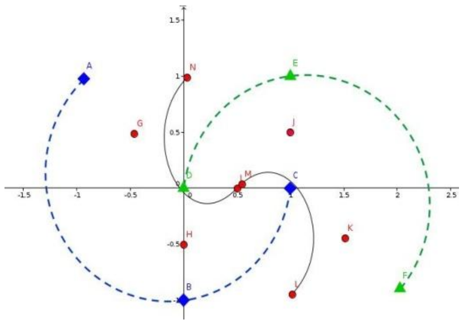

Figure 2. ***SVM-Bc (Support Vector Machine algorithm is improved using cubic Bezier curves function).***

Conclusions

In this work, we proposed one of the possible methods of solving the problem of Pattern Recognition using SVM algorithm principles and composed the decision rule applying Bezier curves classification. After using Bezier curves classification, we achieved: a) efficiency and accuracy of the calculation of the reduction of algorithm SVM; b) high quality of the Pattern Recognition process. We may apply the resulting algorithm of separating objects to complex order occasions. This algorithm will be very useful for Data analyzing systems.

Acknowledgment

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FUZZY MODELING ON BASE OF GRANULAR COMPUTING

Witold Pedrycz

Department of Electrical & Computer Engineering University of Alberta, Edmonton Canada
And Systems Research Institute, Polish Academy of Sciences Warsaw, Poland
e-mail: wpedrycz@ualberta.ca

Abstract

Fuzzy modeling has enjoyed a rapid and multifaceted growth resulting in a plethora of architectures, design methodologies, algorithms, and practically relevant case studies. Within this setting, fuzzy models concerning time series form one of the visible areas in which the technology of fuzzy sets plays an important role and support a formation of a user-friendly and interactive modeling environment.

In this study, we introduce a general framework of fuzzy modeling of time series by engaging key concepts of Granular Computing. Several conceptual development levels of the model are formed and discussed: (a) granulation of time and feature space in which a given time series is described, (b) formation of higher-level information granules being linguistic descriptors of

information granules formed at the lower level, (c) characterization of time series through the linguistic descriptors obtained at the previous step, and (d) a construction of a granular model of higher order formed as a web of interrelationships of the linguistic descriptors.

These developments are accomplished with the use of several key concepts of Granular Computing, especially the principle of justifiable granularity (crucial to the design of a construction of information granules) and population-based optimization tools. The user centricity aspects of the proposed modeling setup are stressed both in terms of ensuing visualization schemes as well as in the form of natural language statements composed of linguistic descriptors.

MODIFIED RECOGNITION OPERATORS BASED ON THE OF POTENTIAL'S PRINCIPLE

M.M. Kamilov, Sh.Kh. Fazilov, O.N. Mirzaev

100125, Tashkent, Uzbekistan
Centre for the development of software and hardware-program complexes of
Tashkent University of Information technologies

Keywords: *pattern recognition, pattern recognition operators, features' correlation, elementary threshold rule, representative feature, correlation model.*

1. Introduction

The analysis of literary sources, in particular [1-4] shows that the development of pattern recognition is divided into two stages. In the first stage the establishment and study of pattern recognition algorithms aimed at solving specific application problems are examined. The value of these algorithms is determined, above all, by the experimental results achieved in solving specific problems. In the second stage of the nature of research in the field of pattern recognition has changed somewhat, and opportunity to transition from individual algorithms to build models - the family of algorithms for a unified description of methods for solving classification problems - arose.

At present, the series of models of pattern recognition algorithms [1-8], such as models based on shared function, the models constructed on the basis of mathematical statistics and probability theory, models are based on the principle of capacity; models based for calculating estimates are profoundly developed and studied in details. However, the analysis of these models shows that they are focused on solving problems, where objects are described in the space of independent (or weakly dependent) features. For this reason, the question of the development and the study of models of recognition algorithms aimed at solving problems of diagnosis, prognosis and classification of objects in a high dimension feature space conditions is crucial.

The purpose of this paper is to construct a model of recognizing operators, taking into account large-scale feature space. To achieve the goal, the model of the modified recognizing operators, which has the key point of the allocation of a set of preferred features is developed. The model of recognizing operators based on the potentials' principle is chosen as a base model [1,2,4,7].

It should be noted that in solving practical problems of recognition, where objects are defined in the feature space of small dimension, the proposed algorithm gives poor results. This is explained by the fact that in this situation, the features correlations are weak, and it is not quite easy to recognize them for the operator. However, this algorithm works better for high dimension feature space condition than the original. Thus, this available information about the problem under consideration shows us which developed models of the operators of recognizing a right to address it.

2. Statement of the Problem

Based on [2], we introduce some concepts and notations. Let Γ be set of possible objects, which consist of l disjoint subsets $K_1, K_2, ..., K_l$, $K_i \cap K_j = \emptyset, i \neq j,\ i, j \in \{1,...,l\}$. It is assumed the division of Γ is not complete, only some initial information J_0 about classes is given.

Let the objects $S_1,...,S_i,...,S_m$ $(\forall S_i \in \Gamma,\ i=\overline{1,m})$ are given. We introduce the following notation:

$$\tilde{S}^m = \{S_1,...,S_i,...,S_m\},\ \ \tilde{K}_j = \tilde{S}^m \cap K_j,\ C\tilde{K}_j = \tilde{S}^m \setminus \tilde{K}_j.$$

Then the initial information J_0 may given in this form

$$J_0 = \{S_1,...,S_i,...,S_m;\ \ \tilde{\alpha}(S_1),...,\tilde{\alpha}(S_i),...,\tilde{\alpha}(S_m)\}$$

where $\tilde{\alpha}(S_i)$ - information vector of the object S_i, it is given as

$$\tilde{\alpha}(S_i) = (\alpha_{i1},...,\alpha_{ij},...,\alpha_{il}),\ \alpha_{ij} = \begin{cases} 1,\ \text{if}\ S_i \in \tilde{K}_j; \\ 0,\ \text{if}\ S_i \notin \tilde{K}_j. \end{cases}$$

The set of information vectors corresponding to the objects $\tilde{S}^m$ forms information matrix $\|\alpha_{ij}\|_{m\times l}$.

Each object $S \in \Gamma$ in the space of initial features (X ($X = (x_1,...,x_i,...,x_n)$)) corresponds to the description of the (numerical response) of the object $J(S) = (a_1,...,a_i,...,a_n)$.

Consider an arbitrary set of objects $\tilde{S}^q = \{S_1^{'},...,S_q^{'}\}$ ($\tilde{S}^q \subset \Gamma$). Let the objects $\tilde{S}^q$ defined in the space X. The dimension of feature space n is large enough (for example, $n > 200$). The task is to construct such an algorithm A that computes the value of the predicate $P_j(S_i^{'})$ of the initial information J_0. In other words, the search algorithm A takes the set $(J_0, \tilde{S}^q)$ to the matrix $\|\beta_{ij}\|_{qxl}$ ($\beta_{ij} = P_j(S_i^{'})$, $P_j(S_i^{'})$="$S_i^{'} \in K_j$") [2]:

$$A(J_0, \tilde{S}^q) = \|\beta\|_{qxl},\quad \beta \in \{0,1,\Delta\}. \tag{1}$$

Here β_{ij} is interpreted as follows. If $\beta_{ij} = \Delta$, then the algorithm is not able to calculate the value of the predicate $P_j(S_i^{'})$. If $\beta \in \{0,1\}$ then β_{ij} is the value of the predicate $P_j(S_i^{'})$, calculated by the algorithm A for the object $S_i^{'}$ by using its numerical characteristics.

In [2] it is proved that any recognition algorithm A can be represented as a sequential execution of two operators B and C:

$$A = B \circ C, \tag{2}$$

where B - recognizing operator ($B(J_0,\tilde{S}^q)) = \|b_{ij}\|_{q\times l}$, b_{ij} - the real numbers); C - the decision rule ($C(\|b_{ij}\|_{q\times l}) = \|\beta_{ij}\|_{q\times l}$, $\beta_{ij} \in \{0,1,\Delta\}$).

The literature discusses various decision rules, however, as shown in [2], we can confine ourselves to certain rules with the following parameters c_1 and c_2, which is called a threshold decision rule.

In condition to (2) of (1) can be reformulated as a problem of constructing a recognition of the operator $B(J_0,\tilde{S}^q)$, which computes the value of the information vector using the decision rule:

$$C(b_{ij}) = \begin{cases} 1,\ \text{if} & b_{ij} < c_1, \\ 0,\ \text{if} & b_{ij} > c_2, \\ \Delta,\ \text{if} & c_1 \le b_{ij} \le c_2. \end{cases}$$

Thus, recognizing operators discussed in the section of solution method, with a decision rule (3) form a model of pattern recognition algorithms in a high-dimensional feature space.

3. Solution method

In the paper we discuss a new approach to the problem of recognizing the construction of recognition operators defined in the feature space of high dimension. Based on this approach, a model of modified recognizing operators, based on the principle building is offered. The main idea of the proposed model is the formation of the space of independent and preferred features, followed by calculating estimates of belonging objects defined in this space. Set of recognizing operators includes the following steps:

1. Forming up subsets of strongly correlated features. Let $\Xi_q \quad (q=\overline{1,n'})$ - a subset of strongly correlated features. Distance measure $L(\Xi_p,\, \Xi_q)$ between subsets Ξ_p and Ξ_q could be given by using different methods, for example [9]:

$$L(\Xi_p,\, \Xi_q) = \frac{1}{N_p \cdot N_q} \sum_{x_i \in \Xi_p} \sum_{x_j \in \Xi_q} \eta(x_i,\, x_j)\,,$$

where N_p, N_q - number of features included in the subsets Ξ_p, Ξ_q respectively; $\eta(x_i,\, x_j)$ - a function that characterizes the strength of mutual correlations between the features x_i and x_j.

As the result of this stage we get the set of "uncorrelated" subsets of strongly correlated features $W_A = \{\Xi_1, \Xi_2, ..., \Xi_{n'}\}$.

2. Defining of representative features in each subset of strongly correlated features. In this stage the search for representative features is carried out. In the process of representative features' formation it is required that each extracted feature be typical representative of the extracted subset of the strongly correlated features. After completing this stage we get reduced features space dimension of which is much smaller than initial space ($n' < n$). From now we define formed features space by Y ($Y = (y_1, ..., y_{n'})$).

3. Defining preferred features. Selection of preferred features from representative features $\{y_1, ..., y_i, ..., y_{n'}\}$, defined in the previous stage is carried out on the base of dominancy of each feature, which divides objects of the set $\tilde{S}^m$ into two subsets $\tilde{K}_j$ and $C\tilde{K}_j$ [11]:

$$\Re_{ij} = \frac{\hat{N}_2 \sum_{j=1}^{2} \sum_{S \in \tilde{K}_j} \sum_{S_u \in \tilde{K}_j} (a_i - a_{iu})^2}{\hat{N}_1 \sum_{S \in \tilde{K}_j} \sum_{S_u \in C\tilde{K}_j} (a_i - a_{iu})^2},$$

where $\hat{N}_1 = (m_1(m_1-1) + m_2(m_2-1))/2$, $\hat{N}_2 = m_1 \times m_2$, $m_1 = \left|\tilde{K}_j\right|$, $m_2 = \left|C\tilde{K}_j\right|$.

The smaller the value $\Re_{ij}$, the greater the preference gets the appropriate feature in separation of objects belonging to $\tilde{K}_j$. In calculating $\Re_{ij}$ it is suggested that S and S_u – are different objects (i.e. $S \neq S_u$).

Preferred feature, which is denoted by $\overline{\chi}_j$ ($\overline{\chi}_j = (\chi_1, \chi_2, ..., \chi_{n'})$), is determined in this stage for each subset $\tilde{K}_j$. Next, we consider only the preferred features.

4. Defining functions of differences $d(S_u, S_v)$ between objects S_u and S_v. At this stage, the difference function which characterizes the difference between objects S_u and S_v in new space of the preferred features $\overline{\chi}$ are given. It should be noted that the space $\overline{\chi}$ is formed by reducing the dimension of feature space X. In constructing the function $d(S_u S_v)$ we use the following principle: "the greater the value of functions $d(S_u S_v)$, the greater the difference between these objects."

Suppose we are given two objects S_u and S_v in the space $\overline{\chi}$:

$$S_u = (a_{u1},...,a_{uk}) \quad \text{and} \quad S_v = (a_{v1},...,a_{vk}) .$$

The difference between these objects is defined in the following ways:

a. Suppose we are given n- dimensional vector $\overline{\varepsilon}$, where $\overline{\varepsilon} = (\varepsilon_1,...,\varepsilon_i,...,\varepsilon_k)$. We introduce the predicate

$$d_i(\varepsilon_i) = \begin{cases} 0, \text{if } |a_{ui} - a_{vi}| \le \varepsilon_i; \\ 1, \text{else}. \end{cases}$$

Then the difference function between objects is defined as the number indicating the number of executed predicates

$$d(S_u, S_v) = \sum_{i=1}^{k} d_i(\varepsilon_i) .$$

b. It is known [2] that not all the features that describe the objects are equal in importance in solving practical problems of pattern recognition. This difference between feature importance is taken into account by introducing a new parameter λ_i $(i = \overline{1,k})$, which characterizes the importance of the feature $\overline{\chi}$. In this case, the function $d(S_u, S_v)$ is defined as:

$$d(S_u, S_v) = \sum_{i=1}^{k} \lambda_i d_i(\varepsilon_i) .$$

5. Setting the proximity function $\phi(S, S_v)$ *between objects* S_u *and* S_v. At this stage, the function of proximity between objects S_u and S_v using the potential functions $\phi(S_u, S_v)$ [1,2,4,7] is defined.

We introduce a positive function $\phi(S_u, S_v)$ ($S_u, S_v \in \overline{\chi}$), which decreases with increasing distance of the object S_v from the object S_u. Each object S_v in space $\overline{\chi}$ corresponds to a point , which is denoted as S_v. The function $\phi(S_u, S_v)$ plays the role of the potential charge located at point S_v when S_u [2] is fixed.

As typical examples of the potential functions we can give the following [1,4]:

1) $\phi(S_u, S_v) = \exp(-\xi d(S_u, S_v))$,

2) $\phi(S_u, S_v) = \dfrac{1}{1 + \xi d(S_u, S_v)}$,

3) $\phi(S_u, S_v) = abs(\sin(\xi d(S_u, S_v)) / (\xi d(S_u, S_v)))$,

where ξ - the parameter of the algorithm.

6. Calculation of assessment belonging object S *to the class* K_j. At this stage the score is calculated (in the form of total capacity) for S relative objects belonging to the class K_j. In addition, each class of objects is characterized by its total potential.

Assume that the objects $S_{m_{j-1}+1}, S_{m_{j-1}+2},...,S_{m_j}$ belong to the class K_j ($\{S_{m_{j-1}+1}, S_{m_{j-1}+2},...,S_{m_j}\} = \widetilde{S}^m \cap K_j$). Consider the total potential for an object S of class objects K_j. Let the calculated values of potential functions be $\phi(S_{m_{j-1}+1}, S), \phi(S_{m_{j-1}+2}, S),..., \phi(S_{m_j}, S)$. As the total potential for the class we assume the function

$$\phi_j(S) = \sum_{S_u \in \widetilde{K}_j} \gamma_u \phi(S_u, S), \quad \widetilde{K}_j = \widetilde{S}^m \cap K_j ,$$

where γ_u - the parameter of the algorithm.

Thereby, we have defined the model of modified recognizing operators, founded on principle potential. Should say that any operator B from this models is completely defined by task of the set parameter $\pi = (\{N_q\}, n', k, \{\varepsilon_i\}, \{\lambda_i)\}, \xi, \{\gamma_u\})$. The collection of all recognizing operators from the proposed models shall mark by $B(\pi, S)$. Search for the best algorithm is implemented in the parameter space π, taking into account the values of the threshold parameters c_1, c_2 decision rule (3).

4. Experimental results

For practical use, and verification of the considered algorithms we have designed functional circuits of recognition programs. On the basis of the proposed algorithms we developed recognition software complex using Object Pascal language in Delphi. The efficiency of the developed software is tested on a model example. Baseline data on identifiable objects for this problem have been generated in the space of dependent traits.

The number of classes in the experiment is 2. The volume of training sample - 200 realizations (100 realizations for each image). The volume control sample - 200 realizations (100 realizations for each image). Number of characters in the tests is 200.

In the sphere of the considered model examples (the test) 10 experiments were carried out (ie 10 times the simulated sample with the given parameters). For the model example we calculated average evaluation of the effectiveness of pattern recognition algorithms in all experiments.

The results of these experiments have revealed all the preferred features and have built an efficient algorithm based on the selected features. Analysis of the results of solving some model problems with the proposed algorithm shows the advantage of these algorithms in terms of speed and accuracy of recognition in the case of descriptions of objects in the feature space of high dimension.

Experimental tests of the model in solving the example have shown a higher effectiveness of the proposed algorithms compared to classical algorithms of pattern recognition, based on the principle of the potentials (recognition accuracy is 10% higher).

5. Conclusions

On the basis of the study the modified recognition operators based on the principle of potentials are developed. The application of developed operators can help to improve the recognition accuracy in the space of large dimension, and to expand the scope of applied problems. This model significantly reduces the number computing operations with the recognition of an unknown object and can be used to create computer systems aimed at solving applied problems of computer vision, medical and technical diagnosis, and biometric identification.

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FUZZY MODELING

Burhan Türkşen

Department of Industrial Engineering, TOBB Economics and Technology University , Ankara Turkey, Department of Mechanical and Industrial Engineering, University of Toronto, Ontario, M5S 3G8, Canada

Abstract: *We review first the two Fuzzy Rule Based System models known as Sugeno-Yasukawa and Tagaki-Sugeno approaches which are essentially extensions of Zadeh`s fuzzy rulebase model. Next essential structures of Türkşen and Celikyılmaz-Türkşen approaches are reviewed in eight versions as examples of Fuzzy Regression models originally proposed by Türkşen and further developed Celikyılmaz-Türkşen A comparative analyses is presented for these fuzzy rule base models and fuzzy regression models based on their application to two different datasets, (i) Daily Stock Dataset, and (ii) Income Prediction Dataset.*

Background

As a background, we review three distinct approaches which are:

(a) Sugeno-Yasukawa [3] approach where both the right hand sides and the left hand sides of a fuzzy rule base are determined either by experts or by fuzzy clustering algorithms such as FCM (Bezdek,[1]).

(b) Tagaki-Sugeno [5] approach where fuzzy sets of the left hand sides of a fuzzy rule base are determined either by experts or by fuzzy clustering algorithms such as FCM (Bezdek,[1]) and the right hand sides are regression functions determined by function estimation methods.

(c) Türkşen [6] and Celikyılmaz-Türkşen [2] approach where a classical regression is enhanced by introduction membership values and their transformations to improve the regression constant and hence the introduction of fuzzy regression functions in place of fuzzy rule bases where a fuzzy clustering algorithm such as FCM (Bezdek,[1]) or IFCM (Celikyilmaz -Türkşen [2]) is used to deteremine the number of such fuzzy regressions required for an affective solution.

Comparative analyses results

Comparative analyses of the result obtained from different fuzzy system models, i.e., fuzzy rule base models, fuzzy regression function models, are presented. In these comparisons, for this purpose, we have used two different datasets, (i) Daily Stock Dataset, and (ii) Income Prediction Dataset. In the fuzzy regression system models, the membership functions are estimated using two different FCM clustering methods. One of them is the standard FCM clustering which was proposed by Bezdek [1]. The other one is IFCM which is the one developed by Çelikyılmaz and Turksen [2] and which is an improved FCM clustering method which enhances the membership values' predictive performance in estimating the fuzzy regression functions to infer the output. The fuzzy regression functions which were proposed by Türkşen and which are further developed by Çelikyılmaz and Türkşen are various versions of regression type fuzzy functions. We will refer the standard FCM of Bezdek as **FCM** and our proposed FCM algorithm as **IFCM , Improved FCM**

In this paper, we investigate a selection of ten fuzzy system models applied on these two different dataset are as follows:

(1) **SYT1I**: Sugeno-Yasukawa Position Type Reasoning Model with Mamdani Type-1 Inference.

(2) **TST1I**: Tagaki-Sugeno Fuzzy System Model with Type-1 Inference.

(3) **FF-LSE-U :** Fuzzy Functions with Least Squares Estimation Fuzzy System Model. The memberships are calculated using FCM clustering method. The fuzzy functions are estimated using only membership values and their transformations.

(4) **FF-LSE-UX :** Fuzzy Functions with LSE Fuzzy System Model. The memberships are calculated using FCM clustering method. The fuzzy functions are estimated using membership values, their transformations and original input variables.

(5) **FF-SVM-U :** Fuzzy Functions with Support Vector Machines for Regression (SVM) Fuzzy System Model. The memberships are calculated using FCM clustering method. The fuzzy functions are estimated using only membership values and their transformations.

(6) **FF-SVM-UX :** Fuzzy Functions with SVM Fuzzy System Model. The memberships are calculated using FCM clustering method. The fuzzy functions are estimated using membership values, their transformations and original input variables.

(7) **FFLSE-IFCM-U:** Fuzzy Functions with LSE Fuzzy System Model. The memberships are calculated using IFCM clustering method. The fuzzy functions are estimated using only membership values and their transformations.
(8) **FF-LSE-IFCM-UX :** Fuzzy Functions with LSE Fuzzy System Model. The memberships are calculated using IFCM clustering method. The fuzzy functions are estimated using membership values, their transformations and original input variables.
(9) **FFLSE-IFCM-T2I-U:** Fuzzy Functions with LSE Fuzzy System Model with Type2 inference using memberships from IFCM clustering. The fuzzy functions are estimated using only membership values and their transformations.
(10) **FFLSE-IFCM-T2I-UX:** Fuzzy Functions with LSE Fuzzy System Model with Type2 inference using memberships from IFCM clustering. The fuzzy functions are estimated using membership values, their transformations and original input variables.
Next we present various investigations of these models in this paper for daily stock market and income prediction models in the rest of this paper.

Daily stock market and income prediction datasets:

Daily Stock Dataset contains 10 input variables and one output variable. The dataset is divided into training and testing parts. The training and testing datasets contain 50 observations each.
The Income Prediction dataset contains two scalar inputs and income as an output. The training and testing datasets contain 1000 and 2000 observations.

(1) Fuzzy rule base system models:

The Daily Stock training dataset is partitioned into half, dataA and dataB for model identification of Sugeno-Yasukawa models. The Sugeno-Yasukawa Position Type Reasoning algorithm, SYT1I, is applied to the groupA and groupB datasets and the fuzzy model is formed through the structure identification and parameter identification methods using these datasets. The algorithm searches for the optimum parameters. Sugeno-Yasukawa variable selection method is also implemented and the SYT1I models are formed with the selected variables for the daily stock dataset. SYT1I selected 6 inputs. The same algorithm was applied to the Income Prediction dataset. No variable selection is applied since there are only two input variables.
The same training and testing dataset is used to form Takagi-Sugeno model [5] with Type-1 Inference. 10 variables of the daily stock dataset are used to run the model. Then a Random Forest (RF) Regression method is applied to select the optimum model variables. The RF model selected 4 input variables. Using only these input variables, the Tagaki-Sugeno model was re-run. For the income prediction dataset, Takagi-Sugeno model used both the variables as inputs.
Both the SYT1I and TST1I models requires *(m,c)* fuzzy clustering parameters. A wide range of values, m=1.1, …,3 and c=2,4,,..,10 is covered to find the optimum model parameter. The best model results from these datasets are displayed in Table 1 and Table 2 below.

Table 1

Daily Stock Dataset Rule Base Model Results

	SYT1I	TST1I	
m	1.2	1.1	
c	10	10	
RMSE(train)	8.67	4.2	
RMSE(test)	10.67	12.48	

Table 2

Income Prediction Dataset Fuzzy Rule Base Model Results

	SYT1I	TST1I
m	1.2	1.1
c	10	10
RMSE(train)	0.79	0.75
RMSE(test)	0.78	0.75

The output variable in Income Prediction dataset is the Income which has a range of *y* *[5K-100K]*. Since RMSE is used for performance measure, we present the normalized output results for income prediction dataset. The estimated output in the stock dataset is de-normalized for RMSE calculations.

(2) System Models with Fuzzy Regression Functions

Fuzzy Regression Function Models start with the FCM clustering algorithm where one tries to estimate the membership functions. The number of clusters and the degree of fuzziness are the two unknown parameters which one should identify during the structure identification part of the modeling. Using the membership values as inputs, one then estimates the fuzzy regression functions for each cluster and finds an estimated output for each cluster. To get a single estimated output value of a particular observation, the output values of that particular observation in each cluster are weighted with their membership values in each cluster. The sum of each output value in each cluster reveals the overall crisp output of the particular observation using fuzzy regression function models. The fuzzy regression functions can be estimated using a simpler function estimation method such as least squares regression where one tries to minimize the deviation of each estimated output value using regression from the actual value, or using complex nonlinear estimation method such as support vector regression. We show the results of our applications of the two different sets of fuzzy functions models where LSE and SVM's are separately conducted to estimate the fuzzy functions of the Fuzzy Function System Models.

(2)(a) Fuzzy Regression Functions with LSE Models: The model parameters that optimize the fuzzy regression function models when LSE is used to estimate the fuzzy regression functions are the weighting exponent, *m,* and the cluster centers, *c.* The range of *m* and *c* are: *m=1.1,…,2.6* and *c=2,…,10.* After the membership values are estimated for each pair, one set of fuzzy regression functions are estimated for each cluster, using membership values and their transformations as predictors in a model, FF-LSE-U. As well, the original inputs are also augmented to the memberships which form the other set of fuzzy models, FF-LSE-UX. Both models are re-rerun for the selected optimum variables using random forest regression variable selection method. For the daily stock dataset. x2, x4, x8 and x10 were determined by the model as important variables. For the Income prediction dataset, we have used both of the inputs. The model results are as follows:

Table 3

Daily Stock Dataset for Fuzzy Functions with LSE models

	FF-LSE-U	FF-LSE-UX
m	1.7	1.7
c	10	10
RMSE(train)	5.69	4.12
RMSE(test)	6.012	5.21

Table 4

Income Prediction Dataset for Fuzzy Functions with LSE models

	FF-LSE-U	FF-LSE-UX
m	1.2	1.2
c	10	10
RMSE(train)	0.77	0.77
RMSE(test)	0.76	0.76

(2)(b) Fuzzy Functions with SVM Models: In this investigation two outputs of the dataset are estimated using fuzzy functions models. In this case, the fuzzy functions are determined using support vector regression algorithm. In these models, the standard fuzzy clustering algorithm is applied to the input space variables. The relation between the output variable and the memberships in the input space are represented using LSE models. However, if one wants to see if the relation can be represented better in a feature space then the inputs and the membership values are mapped onto an infinite dimensional feature space through a kernel function. For this purpose we have used radial basis kernel functions such that the vectors are map non-linearly. For the support vector

regression algorithm, some additional parameters are required to be set prior to the model formation. One of them is the regularization parameter, Creg, which regularizes the objective function of the support vector regression. This balances the weights given to each observation and the estimated error of the model. The second is the epsilon value which is the acceptable deviation between the actual and the estimated output, $|y_a-y_e|<\varepsilon$. It should also be set prior to the application of the algorithm. In these Fuzzy Function models, standard FCM algorithm is used. The fuzzy functions are estimated using the membership values and their transformations together with the original input variables. The daily stock dataset was also run for the selected input variables as well. i.e., 4 inputs were identified as important variables using random forest regression method prior to the model runs. The range of the parameters are as follows: ε=0.1, 0.2, ...,0.5, Creg= 2^{-5}, 2^{-3}, 2^{-2},,.. 2^{+3}, 2^{+5}, m=1.1,…2.6, c=2,..,10.
The results are displayed in the following table:

Table 5

Daily Stock dataset results with Fuzzy Functions with Support Vector Machines

	FF-SVM-U	FF-SVM-UX
m	1.1	1.1
c	10	10
Creg	32	32
epsilon	0.1	0.1
RMSE(train)	6.03	5.64
RMSE(test)	5.25	4.27

Table 6

Income Prediction dataset results with Fuzzy Functions with Support Vector Machines

	FF-SVM-U	FF-SVM-UX
m	1.3	1.3
c	9	9
Creg	2	2
epsilon	0.1	0.1
RMSE(train)	0.78	0.78
RMSE(test)	0.77	0.77

(2)(c) Fuzzy Functions with LSE Models using new FCM Clustering: In this approach the same parameters are used as in section (2)(a) to model the daily stock price and income prediction datasets. In this case, the new proposed FCM clustering method is used to estimate the membership values. An additional parameter is introduced for the new FCM model

Table 7

Daily Stock Price Dataset for FF-LSE with new FCM method

	FF-LSE-IFCM-U	FF-LSE-IFCM-UX
m	1.5	1.5
c	7	7
lambda	5	5
RMSE(train)	5.4	4.67
RMSE(test)	5.79	5.51

Table 8

Income Prediction Dataset Results for FF-LSE new FCM method

	FF-LSE-IFCM-U	FF-LSE-IFCM-UX
m	1.3	1.3
c	10	10
lambda	3	3
RMSE(train)	0.43	0.67
RMSE(test)	0.48	0.70

which regularizes the minimization of the within cluster distance and maximization of the between cluster distance and minimization of the deviation of the actual and estimated output values when the output values are estimated using the LSE method where the memberships and their transformations are used as inputs. This is the minimization of the objective function for the FCM algorithm. The regularization parameter is lambda and it is heuristically determined. For the lambda values, we have used 0.25, 0.5, 1,3,5, 10. The selected inputs are the ones used in section (2)(a) and (2)(b) and are again used in the daily stock dataset model. The results are as follows:

(2)(d) Fuzzy Functions with SVM Models using new FCM Clustering: In this investigation we used the new FCM algorithm and the fuzzy functions are estimated using SVM, Support Vector Machine, regression algorithm. It ought to be noted that, the second term of the new FCM algorithm estimates a fuzzy function using membership values as inputs. In this approach, instead of LSE method, SVM method is used in estimating the fuzzy functions. The model results for all the selected variables in two datasets are as follows:

Table 9

Daily Stock dataset results for FF-SVM using new FCM method with and without variable selection methods

	FF-SVM-IFCM-U	FF-SVM-IFCM-UX
m	1.5	1.5
c	9	9
lambda	1	1
Creg	32	32
epsilon	0.3	0.3
RMSE(train)	4.80	2.71
RMSE(test)	6.51	3.91

Table 10

Income Prediction Dataset for FF-SVM using new FCM method

	FF-SVM-IFCM-U	FF-SVM-IFCM-UX
m	1.5	1.5
c	9	9
lambda	3	3
Creg	2	2
epsilon	0.2	0.2
RMSE(train)	0.53	0.68
RMSE(test)	0.54	0.68

(2)(e) Fuzzy Functions with LSE Models using new Type-2 FCM Clustering and Type-2 Inference: Type-2 FCM clustering starts with a higher upper weighing exponent, e.g., $m=7$, and smaller lower weighing exponent *e.g.*, $m=1.1$ and during each step of the iteration, the m-values are updated towards, where the new cluster validity values, cviFF, are lower. The cviFF is the performance measure of the fuzzy functions is estimated at each iteration using the membership functions found for the *m-lower* and *m-upper* values. Hence in a sense, two FCM models are constructed with Type-2 FCM clustering algorithm which are also related to each other. As well, at each one of the iteration, a validation model is constructed for another *m* value which is actually the *mid-m* value of the *m-upper and m-lower values*, to speed up the process. For instance, when an upper or a lower *m* value model error converges before the other one gets converged, no change is applied to the converged *m* value. Since the other *m* value is still updated, it also changes the *midm* value at each one of the iterations. Therefore even if one *m* model gets converged, its cviFF is still compared to the *midm*, and if its cviFF is smaller than the mid model then cviFF assigned the *midm* value because the optimum model is towards where the *midm* is. The process starts out by measuring the cviFF of mid, lower and upper m values and which ever is greater than the mid cviFF, then that *m* value is assigned the mid*m* value and the process continues. The lower m values can only increase and the upper m values can only decrease. At each iteration the learning rate is constant, $\Delta m=(m_{final}-m_{init})/T_{max}$ where “mfinal” and “minit” are the initial m-upper and m-lower values. Tmax is the maximum iteration number of FCM algorithm, e.g., 300. The FCM converges when the change in both objective functions of upper and lower values is negligible.

After one finds the upper and lower m values of the Type-2 model, one builds FF-LSE with IFCM model to find upper and lower output values. As a result, Type-2 FCM clustering method determines two *m* values which indicate the upper and lower *m* values of the specified Fuzzy System model. One then calculates the output values *y*-lower* and *y*-upper* for the upper and lower m values using FF-LSE with new FCM clustering.

If the model requires a single output value to be estimated, then one may use different type reduction methods proposed in the literature. One of them for instance is taking the average of the two outputs to come up with a single output value which we have implemented in our studies.

The Type-2 FCM clustering is applied to Daily stock price dataset for the selected variables and the Income Prediction model sing the two inputs. The fuzzy models are constructed using only membership values and their transformations **FFLSE-IFCM-T2I-U** and both the memberships and original input variables, **FFLSE-IFCM-T2I-UX**. The model results are listed below:

Table 11

FFLSE models for Daily Stock Price Dataset with the *m* interval from Type-2 FCM

	FF-LSE-IFCM-T2I-U	FF-LSE-IFCM-T2I-UX
m	[1.19-1.3]	[1.16-1.3]
c	10	9
lambda	3	1
RMSE(train)	2.75	3.18
RMSE(test)	4.34	5.26

Table 12

FFLSE models for Income Prediction Dataset with the *m* interval from Type-2 FCM

	FF-LSE-IFCM-T2I-U	FF-LSE-IFCM-T2I-UX
m	[1.11-1.23]	[1.11-1.23]
c	10	10
lambda	3	3
RMSE(train)	0.47	0.65
RMSE(test)	0.52	0.67

(2)(f) Fuzzy Functions with SVM Models using new Type-2 FCM Clustering and Type-2 Inference: In this approach, the SVM regression method is applied with the estimated fuzzy functions, either during the Type-2 FCM clustering or during the fuzzy model identification. It should be recalled that SVM has two parameters, creg and epsilon.A wide range of values are searched for these parameters, i.e., ε=0.1, 0.2, ...0.5, Creg= 2^{-5}, 2^{-3}, 2^{-2},,.. 2^{+3}, 2^{+5}. The *m* interval are searched using the Tpe-2 FCM clustering method for the cluster centers of c=3,..,10.The results of the daily stock price dataset using the selected variables and income prediction dataset for 2 input variables are displayed below:

Table 13

Daily Stock price dataset results for FF-SVM with new FCM where the *m* values are from Type-2 FCM clustering model

	FF-SVM-IFCM-T2I-U	FF-SVM-IFCM-T2I-UX
m	[1.13-1.35]	[1.13-1.35]
c	9	10
lambda	3	5
Creg	2	2
epsilon	0.2	0.2
RMSE(train)	3.27	2.95
RMSE(test)	3.84	3.40

Table 14

Income Prediction Dataset results for FF-SVM with new FCM where the *m* values are from Type-2 FCM clustering model

	FF-SVM-IFCM-T2I-U	FF-SVM-IFCM-T2I-UX
m	[1.15-1.27]	[1.15-1.27]
c	10	10
lambda	3	3
Creg	2	2
epsilon	0.2	0.2
RMSE(train)	0.51	0.66
RMSE(test)	0.54	0.68

Conclusions:

In both of the datasets, the fuzzy regression models outperform the fuzzy rule base models. The best fuzzy regression models are found when the memberships are from the new IFCM clustering method. This is also an indication that the new IFCM algorithm is capable of finding the good representation of membership values to predict the output variable. It should be pointed out that, using only membership values as predictors can perform better than when only the original inputs are used. This supports our hypothesis that the membership values' predictive power enhances performances measures in development of system models.

Type 2 Fuzzy Models on the other hand shows outstanding performances. One can always improve their performance with more powerful type reduction methods. One of the type reduction methods that could have been used is to conduct another heuristic search in between the tight interval of *m-upper* and *m-lower* values. Since Type2 clustering captures this interval as the optimum interval where the error is minimized, we still can find the best model using any m value between the specified *m* intervals and improve the performance of a given model.

There is one important concept that one should keep in mind when modeling Fuzzy Regression Models with the new clustering algorithm. That is, the new IFCM algorithm improve the FCM's particular property of not being robust due to the initial cluster settings. The researchers, applying FCM or IFCM algorithms are recommended that one should run FCM or IFCM models considerable amount of times to get more robust results. Hence, one should train the models a considerably many repetitions, before coming to a conclusion. For this reasoning in our experiments, we have run every model at least10 times to determine the optimum fuzzy regression functions while keeping the initial settings, i.e., initial centers, etc, for every model used in the testing stage.

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FUZZY APPROACH TO THE PROBLEM OF PREDICTION OF RISK REDUCTION FERTILE SOIL

T.F. Bekmuratov, D.T. Mukhamediyeva

Center for development of software products and hardware-software complexes for TUIT,
Durmon yuli-25 street, 100125, Tashkent, Uzbekistan
Ph. +99871 262-71-55, dilnoz134@rambler.ru

***Keywords**: Fuzzy set, forecast, risk, poorly formalized process, fertility, soil.*

1. Introduction

Forecasting is an important component of modern information technology decision-making for the design of complex systems (fuel, energy, water, agricultural, information and communication, etc.) and managing under uncertainty. The effectiveness of a solution is measured by events arising after the adoption and implementation. Therefore, prediction and evaluation of the effects of sales (outcomes) alternatives to the decisions taken at the stage of their formation and the analysis allows for a correct selection of the best solutions and significantly reduce the risk of adverse outcomes.

The subject of this paper is to study the problem of forecasting the risk of reducing the fertility of the soil, depending on various input factors, modes of irrigation and fertilization, soil types and breeding varieties of cotton, as well as weather conditions.

Considered the problem of forecasting parameters are uncertain environment: an incomplete source of data, inaccuracy and vagueness (vagueness) their values, the variability of weather conditions, the influence of subjective factors. The effectiveness of prediction in such circumstances is determined by practical considerations arising from the degree of adequacy of the models used, allowing to predict with perfect accuracy is not, and within the specified error. Therefore, the formation and evaluation of input data for prediction models should follow the principle of reasonable completeness and accuracy, determined by the degree of complexity of the process analyzed. This is due to the fact that because of the objectively existing limitations on the accuracy of obtaining the source data can not reduce the prediction error is below a certain level, regardless of the forecasting model used.

To meet the challenges of forecasting in terms of certainty and stochasticity using known methods and algorithms: an extrapolation of experimental data and statistics using parametric models.

In circumstances where the original factors given in the form of diffuse (fuzzy) characteristics, are widely used for forecasting are other approaches based on intelligent technologies, "Soft Computing» - «Soft Computing», in particular, based on the use of fuzzy set theory [1-7].

2. The wording of the general problem

In the formulation of a general model of fuzzy forecasting task to reduce the risk of soil fertility is described by the fuzzy model, Sugeno-type [4.9] and the fuzzy regression model.

Sugeno-type model is a set of fuzzy production rules (linguistic expressions) of the form (1).

Number of rules in the expert knowledge of the matrix (EMR) characterizes the dependence of the terms that describe the output parameter values from the baseline sowing crops and vegetation, described by a specific combination (of all possible) values of the terms of the input parameters. The system of production rules (1) is the basis for decision-making system for prognostic evaluation of soil fertility in an uncertain mode of sowing and growing season.

The problem of finding the parameters of the fuzzy coefficients of regression model can be solved by reducing it to a linear programming problem. Suppose that the linear model $y = a_0 + a_1 x_1 + a_2 x_2 + ... + a_m x_m$ - coefficients estimates a_i and the input data x_i are given in a fuzzy way.

$$
\begin{array}{ll}
\text{IF } [(x_1 = \beta_1^{j1}) И (x_2 = \beta_2^{j1}) И ... И (x_n = \beta_n^{j1})] & \text{(with weight } w_{j1}) \\
\text{OR } [(x_1 = \beta_1^{j2}) И (x_2 = \beta_2^{j2}) И ... И (x_n = \beta_n^{j2})] & \text{(with weight } w_{j2}) \\
\vdots & \\
\text{OR } [(x_1 = \beta_1^{jp_j}) И (x_2 = \beta_2^{jp_j}) И ... И (x_n = \beta_n^{jp_j})] & \text{(with weight } w_{jp_j}) \\
\vdots & \\
\text{OR } [(x_1 = \beta_1^{jk_j}) И (x_2 = \beta_2^{jk_j}) И ... И (x_n = \beta_n^{jk_j})] & \text{(with weight } w_{jk_j}) \\
\text{THEN } y_j = b_{j,0} + b_{j,1} \cdot x_1 + b_{j,2} \cdot x_2 + ... + b_{j,n} \cdot x_n \text{ for all } j = \overline{1,m}, &
\end{array}
\qquad (1)
$$

where: $j = \overline{1,m}$ - the number of rules $\beta_i^{jp_j}$ - a linguistic term, which is estimated in a string x_i variable-conjunction with a number $p_j = \overline{1,k_j}$ of rules $j-$ the number of rows, conjunctions, k_j corresponding to the class of opinions, values are estimated by linear dependence y_j; w_{jp_j} - the number in the range [0,1], which characterizes weight of statements with a number jp_j. As the terms $\beta_i^{jp_j}$ are commonly used quantifiers such as: Very low (OH), Low (H), Below Average (NA), Medium (C) above the mean (SD), High (H), Very High (V).

We find the parameters of the model, the membership function is defined in the Gaussian form. Let a_i - Gaussian fuzzy number in fuzzy linear regression model with the parameter set $(\tilde{a}_i, c_i)$. Here $\tilde{a}_i$ - the center of fuzzy numbers, c_i - latitude interval, $c_i > 0$. Suppose that x_i - the input data, which are Gaussian fuzzy numbers.

Let the membership function of the input data are given as follows:

$$
\mu(x) = \begin{cases} e^{-\frac{1}{2}\frac{(x-\tilde{a})^2}{c_1^2}}, & x \le \tilde{a}, \\ e^{-\frac{1}{2}\frac{(x-\tilde{a})^2}{c_2^2}}, & x > \tilde{a}. \end{cases}
$$

Then these fuzzy numbers are defined by three parameters: $(c_1, \tilde{a}, c_2)$ and here $\tilde{a}_i$ - the center of fuzzy number, c_1 - the breadth of the left interval c_2 - the breadth of the right of the interval.

In this case, the problem is formed as follows: find the parameters $(\tilde{a}_i, c_i)$ of the coefficients a_i, that the following conditions:

a) Let y_k in the equation corresponds to the interval found with the degree of not less than α, $0 < \alpha < 1$

b) the degree of latitude interval α is minimal.

Interval estimation of the degree of α is the following:

$$d_\alpha = y_2 - y_1.$$

The values of y1 and y2 are determined from the system

$$\begin{cases} \alpha = \exp\left(-\dfrac{1}{2}\dfrac{(y_2-\tilde{a})^2}{c_2^2}\right), \\ \alpha = \exp\left(-\dfrac{1}{2}\dfrac{(y_1-\tilde{a})^2}{c_1^2}\right). \end{cases}$$

Hence $y_2 = c_2\sqrt{-2\ln\alpha}+\tilde{a}$, $y_1 = c_1\sqrt{-2\ln\alpha}+\tilde{a}$, $d_\alpha = -2\ln\alpha(c_2+c_1)$.

Condition a) can be written as

$$\mu(y_k)\ge\alpha \Rightarrow \begin{cases} y_k \le \tilde{a}_k + c_{2k}\sqrt{-2\ln\alpha}, \\ y_k \ge \tilde{a}_k - c_{1k}\sqrt{-2\ln\alpha}. \end{cases}$$

Then the formulated problem takes the following form:

Search

$$\min\sum_{k=1}^{m} d_\alpha^k = \min\sum_{k=1}^{m}(c_{2k}+c_{1k})\sqrt{-2\ln\alpha}$$

with constraints

$$\begin{cases} y_k \le \tilde{a}_k + c_{2k}\sqrt{-2\ln\alpha}, \\ y_k \ge \tilde{a}_k - c_{1k}\sqrt{-2\ln\alpha}. \end{cases}$$

To find the model parameters, the function of which is bell-shaped membership is required to solve the following linear programming problem:

$$\begin{cases} \sum_{k=1}^{m}(c_{1k}+c_{2k})\sqrt{\dfrac{1-\alpha}{\alpha}} \to \min, \\ y_k \le \tilde{a}_k + c_{2k}\sqrt{\dfrac{1-\alpha}{\alpha}}, \\ y_k \ge \tilde{a}_k + c_{1k}\sqrt{\dfrac{1-\alpha}{\alpha}}. \end{cases}$$

After finding the parameters $\tilde{a}_k$, c_{1k}, c_{2k} of a given species is determined by the fuzzy model.

3. Computing Experiment

A two-step procedure for constructing models to predict the risk of decline in soil fertility - with the help of fuzzy knowledge base of Sugeno and the regression model. In the first phase synthesized fuzzy rules from experimental data using subtractive clustering method, the mountain and set up the parameters of fuzzy model. Subtractive clustering can be used as standalone rapid method for the synthesis of fuzzy rules from data. Synthesized fuzzy model is the starting point for learning. An important advantage of clustering for the synthesis of fuzzy models is that the rules of the knowledge base obtained by the object-oriented. This reduces the possibility of "combinatorial explosion" - a catastrophic increase in the knowledge base for a large number of input variables.

Soil fertility is characterized by the common components of fertility, as the supply of moisture, the amount of humus, nitrogen and phosphorus.

On the basis of experimental data is made depending on the numerical expression of risk reduction in soil fertility of its components:

$$y=\frac{\sum_{i=1}^{n}\mu_{a_{0i}}a_{0i}}{\sum_{i=1}^{n}\mu_{a_{0i}}}+\frac{\sum_{i=1}^{n}\mu_{a_{1i}}a_{1i}}{\sum_{i=1}^{n}\mu_{a_{1i}}}x_1+\frac{\sum_{i=1}^{n}\mu_{a_{2i}}a_{2i}}{\sum_{i=1}^{n}\mu_{a_{2i}}}x_2+\frac{\sum_{i=1}^{n}\mu_{a_{3i}}a_{3i}}{\sum_{i=1}^{n}\mu_{a_{3i}}}x_3+\frac{\sum_{i=1}^{n}\mu_{a_{4i}}a_{4i}}{\sum_{i=1}^{n}\mu_{a_{4i}}}x_4+$$
$$+\frac{\sum_{i=1}^{n}\mu_{a_{5i}}a_{5i}}{\sum_{i=1}^{n}\mu_{a_{5i}}}x_5+\frac{\sum_{i=1}^{n}\mu_{a_{6i}}a_{6i}}{\sum_{i=1}^{n}\mu_{a_{6i}}}x_6+\frac{\sum_{i=1}^{n}\mu_{a_{7i}}a_{7i}}{\sum_{i=1}^{n}\mu_{a_{7i}}}x_7+\frac{\sum_{i=1}^{n}\mu_{a_{8i}}a_{8i}}{\sum_{i=1}^{n}\mu_{a_{8i}}}x_8. \quad (2)$$

The model parameters are defined as fuzzy subsets, defined membership functions of the subsets:

$$a_i=\{\mu_{a_i},(a_i',a_i'')\}.$$

In the computational experiment used the following membership function:

$\mu_{a_0}=e^{25\cdot10^{2}(x+0.93)^{2}}$, $a_0\in[-0{,}95;-0{,}91]$; $\mu_{a_1}=e^{25\cdot10^{2}(x+0.25)^{2}}$, $a_1\in[-0{,}27;-0{,}23]$;

$\mu_{a_2}=e^{25\cdot10^{8}(x+0.002)^{2}}$, $a_2\in[-0{,}0022;-0{,}0018]$; $\mu_{a_3}=e^{25\cdot10^{8}(x-0.004)^{2}}$, $a_3\in[0{,}0035;0{,}0039]$;

$\mu_{a_4}=e^{25\cdot10^{6}(x-0.004)^{2}}$, $a_4\in[0{,}0028;0{,}0032]$; $\mu_{a_5}=e^{25\cdot10^{2}(x+0.49)^{2}}$, $a_5\in[-0{,}51;-0{,}47]$;

$\mu_{a_6}=e^{25\cdot10^{2}(x-0.13)^{2}}$, $a_6\in[0{,}11;0{,}15]$; $\mu_{a_7}=e^{25\cdot10^{4}(x+0.05)^{2}}$, $a_7\in[-0{,}052;-0{,}048]$;

$\mu_{a_7}=e^{25\cdot10^{4}(x+0.04)^{2}}$, $a_8\in[0{,}038;0{,}042]$.

Soil fertility is determined by the mass fraction of humus (in%) in the soil, which in turn depends on the values of the following: x_1- volumetric mass of soil (g/cm^3); x_2 - the depth of plowing (cm); x_3 - standard input of phosphorus (kg / ha); x_4 - rate of entry of potassium (kg / ha); x_5 - the proportion of nitrogen in the soil,%; x_6 - share of organic carbon in soil,% ; x_7 - average temperature in the day (%); x_8 - soil moisture (%).

According to equation (2), with an increase in the proportion of organic carbon in soil composition, soil moisture, phosphorus and potassium rates per unit increase in the proportion of humus in the soil by an average of [0.11, 0.15] [0.038, 0.042], [0.0035, 0.0039] [0.028, 0.032], respectively. Increasing soil bulk density, the amount of nitrogen in it and the depth of plowing unit decrease in the proportion of humus in the soil by an average of [0.23, 0.27] [0.47, 0.51] and [0.0018, 0, 0022], respectively.

4. Conclusion

A model predicting the risk of decline in soil fertility. In the model used in approximating the model of two types: type Sugeno fuzzy model and fuzzy regression model. The results of numerical experiments have shown (Fig. 1) higher efficiency of forecasting models based on the Sugeno (prediction error (0,0-3)%) compared with the prediction by the regression model (error - (2-9,5)%)

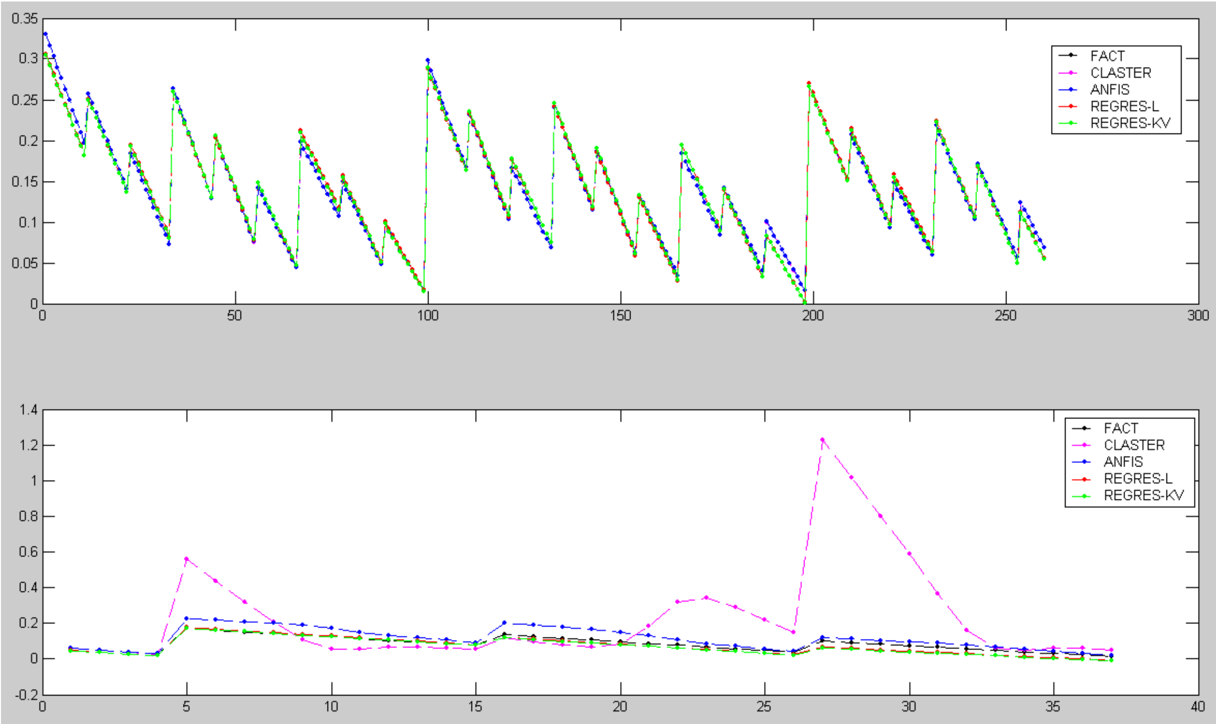

Figure 1. ***The results predict the risk of decline in soil fertility.***

A promising line of research on the above issues is to develop methods for solving problems of prediction using a combination of "Soft Computing"-technologies: fuzzy sets, neural networks and genetic algorithms.

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ONLINE CONTROL OF MANUFACTURING PROCESSES UTILIZING CASE-BASED REASONING AND FUZZY SEARCH

Manfred Grauer, Sachin Karadgi, Ulf Müller, Daniel Metz, Walter Schäfer

Information Systems Institute, University of Siegen, 57076 Siegen, Germany
{grauer, karadgi, mueller, metz, jonas}@fb5.uni-siegen.de

Abstract. *Nowadays, manufacturing processes are widely automated, and hence, incorporate several automation systems. These systems produce enormous amounts of real-time data presenting feedbacks, positions, and alerts, among others. This data is stored as historical data in a process database. Historical can be utilized for offline processes like product tracking and genealogy, and so forth. However, historical data is not been utilized to control the manufacturing processes online. The current contribution proposes an approach to overcome the aforementioned drawback. The methodology consists of three steps. First, offline identification of critical control-related parameters of manufacturing processes and defining a case base utilizing previously identified process parameters. Second, update the case base with real-time data acquired from automation systems during execution of manufacturing processes. Finally, employ fuzzy search to retrieve similar cases from the case base and revise the retrieved cases to control the manufacturing processes. An industrial case study is presented to validate the proposed methodology.*

Keywords: *fuzzy search, historical data, manufacturing process.*

Introduction

Not just since financial crisis, enterprises are confronted with an increasing pressure to manufacture products with high quality, reduced lead times, low cost and mass customization, and at the same time, increase shareholders' profitability. Due to increased complexity of products and their related manufacturing processes, these challenges are further compounded with events occurring on shop floor like non-adherence to product specifications and resource breakdown. Hence, enterprises attempt to overcome the previously mentioned challenges by enhancing the monitoring and control of their manufacturing processes.

An enterprise can be classified in several manufacturing execution system (MES) levels [1]: (i) enterprise control level, (ii) manufacturing control level and (iii) manufacturing level. Business processes are predominantly located at the enterprise control level and concerned with achieving the enterprise's long-term strategies. Business applications (e.g., enterprise resource planning (ERP) system) generate planned performance values (i.e., TO-BE values) essential to sustain competitive advantages. In addition, these planned performance values are transactional and generated in non-real time i.e., months or weeks [2]. Automation systems are available at manufacturing level (i.e., shop floor) to perform manufacturing processes and realize aforementioned enterprise's strategic goals. Enormous amount of data is generated by these systems during process execution in real-time i.e., seconds or milliseconds, indicating actual performance (i.e., AS-IS values) of the manufacturing system.

Knowledge is embedded into enterprise processes (i.e., business and manufacturing processes) by enterprise members [3] and described through process data. These process data is updated online during execution of enterprise processes in terms of feedbacks. Research has been attempted to integrate TO-BE and AS-IS values for online control of enterprise processes [4], [5]. These integrated values are stored in relational databases or log files as historical data for offline analysis like calculation of key performance indicators (KPIs).

However, historical data is not been utilized for online control of enterprise processes. During manufacturing, enterprises are confronted with non-adherence to product specifications which is the focus of the current contribution. Deviations in manufacturing process parameters (e.g., required temperature is not achieved) is one of the principal reasons for this non-adherence. In addition, products not assessed immediately after their manufacturing for adherence to specifications but after a certain period result in reduced productivity. Deferred inspection of product quality may be due to constraints in manufacturing systems or enterprises' quality strategy. Also, prolonged unobserved deviations lead to reduced resource availability. Finally, decision-making process (e.g. concerning products' quality) can be a complex task spread across different MES levels, and depends upon the quantity and quality of information. Unfortunately, historical data has not been utilized to enhance these decision-making processes. Overall, delays in acknowledging automation systems' deviations and inefficient (proactive) decision-making processes result in dwindling of productivity. Therefore, it is necessary to recognize the automation systems' deviations online, intercept these deviations and control the manufacturing processes as well as predicting their outcomes.

Extensive research has been carried out at Information Systems Institute of the University of Siegen in the area of fuzzy search for product data, and consequently, various search algorithms have been developed. These algorithms can be adapted for online control of manufacturing processes. The current contribution is organized as follows. Section 2 introduces similarity search techniques, and presents state-of-the-art related to the use of historical data in manufacturing. Section 3 elaborates a novel research methodology for enhancing the online monitoring and control of manufacturing processes using case-based reasoning (CBR) and fuzzy search. To validate the elaborated methodology, an industrial case study is been described in Section 4. Finally, conclusion is mentioned in Section 5.

Related Work

In many instances, design practices consist on experiences and these experiences are adapted to solve new design problems [6]. At the Information Systems Institute, extensive research has been carried out in the area of fuzzy search and as a result, various search algorithms have been developed to identify similar products from databases [7], [8], [9]. The developed fuzzy search is based on CBR. CBR consists of four phases: (i) RETRIEVE the most similar solved case(s), (ii) REUSE the retrieved case(s) to solve the current case, (iii) REVISE the reused solution and (iv) RETAIN the solution to be used in future [10].

The major challenge of the retrieve phase is to find the most similar case(s). Hence, fuzzy logic has been applied to various industrial problems and is an often used approach to deal with uncertainty and vagueness in data [11], [12]. The process data provided by automation systems and their sensors is typically subjected to many changes and often vague. Therefore, an adequate method is required, which compensates the vagueness and uncertainty of process data. Fuzzy logic has shown its ability to support the retrieval process and to overcome the before mentioned difficulties [13], [14], [15].

For retrieving most similar cases, several similarity and distance metrics for various data types have been developed. Edit distance and Smith-Waterman similarity measures are used for comparing alphanumeric data [16]. The Euclidean distance is used to determine the distance between numerical values. In addition, Hamming distance can be used to estimate the distance between two input values of equal length for numerical, binary, or alphanumerical data. To assess structural similarities (e.g., between bills of materials), a graph-based distance measure has been applied [17]. Retrieved cases can be selected for reuse if their similarity fulfils a predefined similarity threshold. Aforementioned similarity and distance metrics, and retrieval methods have been applied to product data [9]. In the current contribution, these metrics and retrieval methods need to be adapted to identify similar process data from historical data.

Apart from utilizing the historical data for offline analysis, historical data has been utilized to create inspection reports and predict maintenance behaviour in manufacturing. An approach was proposed for automated creation of inspection reports by detecting deviations between realization logs written by CNC machines during execution of instructions and approved manufacturing instructions [18]. A methodology for designing a reconfigurable prognostics platform was presented to assess and predict the performance of machine tools [19]. The presented methodology consists of Watchdog Agent®, which converts multi-sensory data into machine performance-related information assisted with historical data. In addition, a technique was elaborated capable of achieving higher long-term prediction accuracy by comparing signatures of degradation processes with historical records using measures of similarity [20]. Likewise, diagnostic and prognostic systems were presented to estimate the remaining useful life of engineered systems [21], [22].

Research Approach

A methodology is elaborated to realize an online control of manufacturing processes. This methodology incorporates the perception of the manufacturing systems' deviations, intercepts these deviations and controls the manufacturing processes using online analysis of historical data in correlation with a rule-based system (RBS) and workflow management system (WMS). The envisaged methodology encompasses three process steps.

The first process step consists of offline analysis of automation systems and their manufacturing processes, and identification of their critical control-related process parameters (e.g., temperature). In addition, suitable weights are assigned to these identified parameters, which assist in calculating overall similarity of the retrieved cases. The cases are managed in a case base whose structure has to be defined based on the identified parameters. The values of the identified parameters are acquired online from the automation systems during execution of the manufacturing processes, and have to be stored in the case base. Finally, for real-time process values, sufficient similar cases are retrieved from the case base and adapted to control the manufacturing processes online. The aforementioned process steps are elaborated in the following sub-sections.

Analysis and Identification of critical control-related Process Parameters

Today's automation systems are complex, and several inputs are required by these systems to execute the manufacturing processes. For monitoring and control of these manufacturing processes, it is essential to analyze the used automation systems and their manufacturing processes to identify critical control-related process parameters.

Analysis and identification of critical control-related process parameters can be achieved by employing methods from data mining in combination with structured interviews. Filter and wrapper approaches utilized during data mining can be applied to reduce the number of parameters [23]. In addition, analysis and identification of process parameters can be supported by reengineering techniques and creating data flow diagrams (DFDs) to illustrate automation systems' interdependencies [24]. For inspection of sufficient data quality, determined parameters can be checked using histogram based methods [25]. In some instances, it is advantageous to validate previously identified control-related parameters and perhaps reduce number of identified parameters using structured interviews with domain experts. However, it is sometimes sufficient to perform only structured interviews with domain experts to identify critical control-related process parameters.

While identifying and analyzing the critical control-related parameters, weights need to be assigned to these identified process parameters to reflect their significance during similarity computation. Hence, weights are used for calculation of overall similarity between real-time data of a manufacturing process and cases from the case base. Finally, the case base has to be structured using the selected critical control-related parameters and mostly, this case base is a subset of historical data.

Data Acquisition during Process Execution

To enhance online monitoring and control of manufacturing processes, integration within and across various MES levels (s. Section 1) is mandatory. In this regard, an IT-framework for enterprise integration (EI) has been envisaged [4]. This IT-framework provides the basic architecture for the current contribution. AS-IS values (e.g., applied pressure) from the automation systems are available online via an OPC server. These values are integrated with their corresponding TO-BE values (e.g., required pressure) from an ERP system, and are made available in an EI layer. Besides storing these integrated values in relational databases for product tracking and genealogy, the values are used for online control of enterprise processes using traceable objects [5]. Traceable objects represent control-relevant objects like orders, products and resources. They are instantiated simultaneously with a corresponding workflow instance in a WMS along with TO-BE values. In addition, during execution of actual manufacturing processes, AS-IS values generated by automation systems are used to update the status of traceable objects. The changes in traceable objects' status are analyzed online by a RBS, which is in charge of controlling the manufacturing processes by dispatching necessary control data to automation systems.

Online Control of Manufacturing Processes

The envisaged IT-framework utilizes a RBS and WMS for control of manufacturing processes. Nevertheless, it does not utilize historical data for online control of these processes. As a consequence, the control of manufacturing processes tends to be reactive. To overcome this drawback, fuzzy similarity detection unit (FSDU) is been introduced in current contribution to utilize historical data as depicted in Fig. 1. The FSDU is based on CBR technique and incorporates all phases of CBR as detailed below.

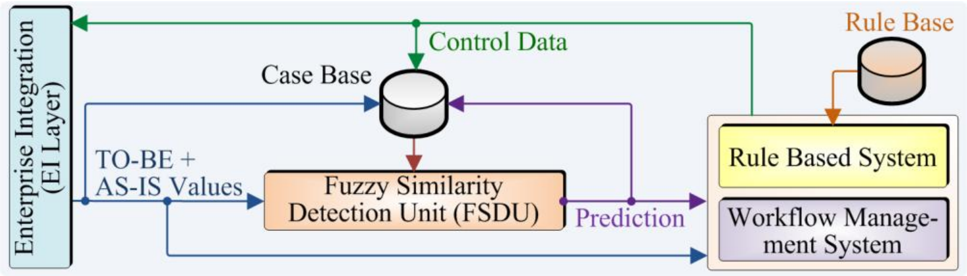

Figure 1. ***Proposed methodology for online control of manufacturing processes.***

RETRIEVE: Automation systems generate enormous amount of data and therefore, a case base built upon these data tends to be large. A case base contains *m* stored cases (i.e., c_1, … c_i, … c_m) and each case is described by *n* critical control-related process parameters (i.e., p_1, … p_j, … p_n) as defined in Section 3.1. Integrated data (designated as new case c') from EI layer is made available online to FSDU. Next, compare each retrieved case c_i with new case c' and determine the overall similarity as described in Eq. (1). First, calculate individual similarity for all critical parameters using any of the distance measures mentioned in Section 2 and then proceed with determining overall similarity $os(c',c_i)$ using weights w_j (s. Section 3.1). Finally, select those retrieved cases which fulfill the predefined threshold (e.g., 95%).

$$os(c',c_i) = \frac{\sum_{j=1}^{n} w_j \cdot sim(p'_j, p_{i,j})}{\sum_{j=1}^{n} w_j} \quad for\ i = 1,\cdots,m \tag{1}$$

REUSE: Knowledge is defined as a "combination of information and human context that enhances the capacity for decisions" [26]. Hence, it is essential to analyze the retrieved cases, and identify previous decisions, consequence of these decisions and context surrounding the decisions. The identified information encompassed in the retrieved cases can be utilized to predict the outcome of the current manufacturing process (i.e., process is stable or unstable). To do so as well as to predict if the current manufactured product will adhere to product specifications, it is necessary to analyze the similar cases retrieved from the case base. If the majority of similar cases has failed then the current product is likely to fail also. In addition, the outcome of the current manufacturing process can be expressed by a prediction indicating if the product will adhere to product specifications or not. To improve the process quality and to prevent that further products fail the configuration of the manufacturing process can be adapted by analyzing the retrieved cases to determine which parameters are responsible for the failure of the process. Hence, differences between failed and succeeded cases are investigated utilizing distance metrics on individual parameters. Finally, the prediction and determined responsible process parameters are stored together with the corresponding integrated data in the case base (s. Fig. 1).

REVISE: The prediction, determined responsible process parameters and the integrated data are evaluated in a RBS and WMS for online control of the manufacturing processes. Prediction and determined responsible process parameters are exploited for tweaking the current manufacturing process parameters to provide optimized future process runs and process outcome respectively.

RETAIN: Outcome of the RBS and WMS (i.e., control data) is also retained along with the associated integrated data to be used in future.

Case Study - Online Control of a Molding Process

The proposed methodology is a concept and attempts are been made to validate it in an industrial scenario with emphasis on a sand molding machine. The molding machine in consideration is a dedicated machine with a high production rate (around manufacturing 250 molds per hour), and controls downstream as well as upstream manufacturing processes. This machine simultaneously produces upper and lower molds at time t_1 according to mounted dies as illustrated in Fig. 2. The lower mold is manually assessed for conformance at time t_2 along its process route (i.e., after a certain number of lower molds have been produced) and sand cores are placed in the accepted mold. The late manual inspection is mainly due to constraints in the manufacturing system. Finally, upper and lower molds are assembled irrespective of the conformance result and molten material is poured into the mold assembly at time t_3 where lower mold adheres to conformance specifications.

Analyzing the aforementioned scenario, manual inspection happens later along the process route at time t_2. However in case of rejection, a certain number of lower and upper molds would have been already produced (i.e., between time t_1 and t_2) which possibly will have a high probability of being rejected and could result in non-utilization of upper mold due to constraint in manufacturing system. As a consequence, monitoring and control of the mold manufacturing process is reactive and results in a reduced production rate and increased wastage of resources (e.g., sand, energy). To overcome this drawback, FSDU is introduced (i.e., just after time t_1) to retrieve similar cases online during mold manufacturing process execution (i.e., lower mold). The retrieved information is used to predict if the current process is stable or unstable.

Numerous inputs (e.g., clamp pressure, shaft speed, and valve settings) are necessary to specify the mold manufacturing process and these inputs define the TO-BE values (i.e., configuration of manufacturing process). During execution of mold manufacturing process, control devices of the molding machine generate real-time data indicating the actual values applied i.e., AS-IS values. TO-BE and AS-IS values are integrated and stored in a relational database. Consequently, a row is created in the relational database for each mold. Further, critical control-related process parameters are identified and used to structure the case base. This case base is a subset of abovementioned relational database. Currently, structured interview with the production manager is used to identify these process parameters. Once sufficient data is stored in the relational database, data mining techniques described in Section 3.1 can be employed to refine the set of control-related process parameters. Finally, these control-related process parameters are assigned with a weight of one.

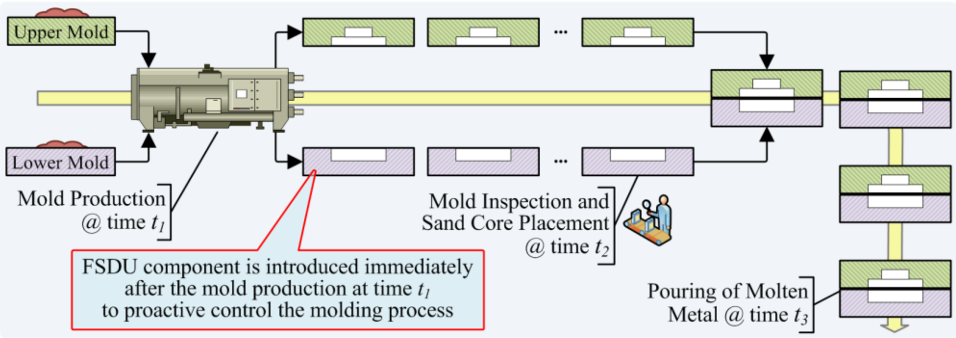

Figure 2. ***Validation of proposed methodology in sand casting enterprise.***

The control-related process parameters of the retrieved cases c_i and the new case c' are subjected to online similarity or distance computation. Different distance measures are employed to determine the difference for numerical and binary data respectively. Finally, overall similarity $os(c',ci)$ is determined as described in Eq. (1). Further, only the cases whose overall similarity is above the predefined threshold of 95% are selected to predict if the current process is stable or unstable. Also depending upon the prediction, the inputs of mold manufacturing process tweaked to produce lower molds with a better quality, and thereby, avoiding future rejects.

Conclusions

The current paper has proposed a novel methodology for control of manufacturing processes by utilizing historical data. The methodology involves three process steps. First, offline analyzing and identifying critical control-related parameters of manufacturing processes, assigning weights to these parameters, and defining the structure of a case base. Second, updating the case base (i.e., historical data) with real-time process data acquired from automation systems during execution of manufacturing processes. Finally, fuzzy similarity detection unit (FSDU) can be employed to retrieve similar cases from the case base and adapting the current case to control the manufacturing processes. Further, the proposed methodology is been validated to control the manufacturing process of a molding machine.

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APPLICATION OF ARTIFICIAL IMMUNE SYSTEMS TO SOLVE OPTIMIZATION PROBLEMS

D.T. Mukhamediyeva, R.X. Shodimetov

100125, Tashkent, Uzbekistan Center for development of software products and hardware-software complexes for TUIT, Durmon yuli-25 street, Ph. +99871 262-71-55, dilnoz134@rambler.ru

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1. Introduction

As you know, the problem of optimizing the middle and high dimension is not possible to find an optimal solution for the short (reasonable) time for the task. So instead of exact, usually used approximate algorithms that allow us to find near-optimal rational solution.
To find approximate solutions to apply a set of algorithms [7].

2. Approaches to solving optimization problems

Hopfield and Tank have shown an approximate approach to finding solutions to the problems with high combinatorial complexity, based on the Hopfield network [5]. For solving the problem appears Hopfield network. In it, each neuron is denoted by two indices x and i, where x represents the city, and the i-th position in the route, ie - Is the output of a neuron in which the city is located on the x i-th position of the route.

The energy function satisfying these conditions may be:

$$E = \frac{A}{2}\sum_{x}\sum_{i}\sum_{j\neq i} z_{xi}z_{xj} + \frac{b}{2}\sum_{x}\sum_{i}\sum_{y\neq x} z_{yi}z_{xi} + \frac{C}{2}\left(\left(\sum_{x}\sum_{i} z_{xi}\right) - n\right)^2$$
$$+\frac{D}{2}\sum_{x}\sum_{i}\sum_{y} r_{xy}z_{xi}(z_{yi+1}+z_{yi-1})$$

Genetic algorithms are a type of evolutionary computation. As a rule, they are used to find solutions to the problems with a large combinatorial complexity, which is difficult to find the solution analytically. In the classical genetic algorithm solution is coded by a binary sequence. This method is suitable for cases where the change of one bit in the solution in most cases leads to a slight change in the objective function [1,3].

In problems on graphs, the solution is the route - a sequence of vertices. Changing a single vertex in the route can dramatically affect the value of the objective function. Therefore, these tasks are performed on the operation sequences of integers denoting the number of vertices. Fitness function is the length of the route.

Ant algorithms are based on modeling the interactions of ants in ant colonies. Ant colony is a complex distributed system is not centralized. Each ant (in fact is an agent in multi-agent system) performs simple repetitive actions, having a minimum of information and interact with a small number of ants and other small areas of the environment. However, the whole system solves complex problems of optimization of routes, is very close to optimal solutions, adapting to changing conditions outside.

Interaction between the ants is their means of direct and indirect exchange of information. Direct exchange is in direct contact and indirect changes in the environment one ant and recognition of these changes by others. On the basis of indirect exchange and simulated ant algorithms. To change the environment the ants sprayed pheromone scent which remains in the soil for some time.

At the initial stage of the algorithm the ants choose a random direction, trying to reach the goal (find food), marking pheromones on his way. Those ants that had all met the goal, respectively, back before anyone else in the same way, increasing the content of pheromone on the route. After a few iterations shortest route will be very different from all other variants of the path [7]. Adaptability to external changes is due to evaporation of pheromones. If the shortest path meets the obstacle, the ant randomly chooses another path, so after a while there is a new shortest route. Ant algorithm, as opposed to genetic, adapt more quickly to changes in external conditions.

3. The implementation of the algorithm of artificial immune systems for solving the routing

There are currently actively developing artificial immune systems (AIS) as a new trend in computational intelligence. At the same immune algorithms (IA) are widely used in various fields of intellectual processing. The properties of AIS, such as pattern recognition, diversity, learning, memory, distributed detection, etc., allow you to use the immune principles for solving such problems as pattern recognition, data mining, computer security, error detection, classification, optimization, etc. [4].

In AIS uses the natural ability of the immune system to produce new types of antibodies and to select the most suitable one for interaction with antigen trapped in the body. To explain the immunological mechanisms are different theories - the theory of the immune network, the principles of clonal and negative selection.

The natural immune system consists of a large number of security elements, molecules and organic compounds that support the body in a healthy condition, struggling with the disease, the cause of employee illness. The protective elements used in the natural immune system, called lymphocytes (white blood cells), the main task - the fight against antigens, molecules belonging to the alien bodies, such as bacteria or viruses that have been introduced into the body.

The protective reaction of the body in combating the disease is that it begins to produce cells (antibodies) that can recognize and neutralize the antigens. Cells were obtained as a result of the mutation process, are very similar to antigens, have longer life and remain in the body in case the attack is repeated in the future (memory cells). While cloning is directly proportional to the percentage of similarity to antigens, the percentage of mutations is inversely proportional to a similarity, however, the closer the cells to the antigen, the lower the percentage of its mutations. C on the other hand, if the similarity between the antigen and the cells were very low, a high percentage of mutations used in the hope to increase the value of similarity.

For evolutionary algorithms known [4] that the convergence to the global optimum in the optimization problem is achieved if there is confidence that the algorithm finds a solution in a finite number of steps, and if such a decision would be later in the population. Since the state transitions of evolutionary algorithms are stochastic, deterministic concept of convergence can not be used to determine the validity of such algorithms. There are two widely used measures of stochastic convergence of evolutionary algorithms - a complete coincidence and the coincidence of the value [4]:

In general, one step of the immune algorithm is as follows:

$$\forall i \in \{1,...,m) : x_i^{'} = mut(clon(x_1,...,x_n)),$$

$$(x_1^{''},...,x_k^{''}) = aging(x_1,...,x_n, x_1^{'},...,x_m^{'}),$$

$$(y_1,...,y_n) = sel(x_1^{''},...,x_k^{''}),$$

where $(x_{,}...,x_n) \in X^n$ - the current population of antibodies; $(x_1^{'},...,x_m^{'})$ - a population of antibodies, resulting from the cloning and mutation; $(x_1^{''},...,x_k^{''})$ - antibodies that are removed from the population; $(y_1,...,y_n)$ - antibodies that are added to the current population.

Agency has the following operators: cloning, mutation, and selection of aging. Let us consider these statements.

The operator generates a new generation of cloned copies of the antibodies in the future population. Known basic operators Cloning: a) a static cloning operator, which simply copies each of B-cells, producing a transient population, and b) the proportional cloning operator, which clones B cells proportion to their antigenic similarity, and c) the operator of probabilistic cloning, according to which B cells are selected from the current generation as a function of the probability of clonal selection.

The mutation operator acts according to the existing population of clones, using an antibody specific to each individual the number of mutations carried out randomly.

Aging operator eliminates old individuals. Static aging operator uses an age parameter for the maximum number of generations of antibodies that are allowed to remain in the population. When the antibody is older, it is removed from the system, even if it may be quite suitable for subsequent iterations.

When clonal expansion clonal antibody inherits its parent's age. After the mutation step only those antibodies that have the highest affinity value, will be the age of 0. Elite version of this operator is obtained by taking the best antibodies in the generation of the population with the age of 0.

Elite version of this operator is obtained by taking the best from a population of antibody generation.

The operator replaces the worst selection of antibodies in the population with new random antibodies.

To solve the problem of routing algorithms using artificial immune system is necessary to compare the biological objects and processes of their mathematical counterparts.

Antigens, indicating in terms of immune system substances from the environment, comply with the terms of the problem - a set of vertices. B-lymphocytes correspond to agents moving through the vertices of the graph, cloning and destroying themselves, using the algorithms of the positive and negative selection. The agent starts its way into the starting vertex, with each iteration of the algorithm it has the ability to clone himself. Getting to the top of which he has visited, the agent destroys itself in accordance with the rules of positive selection. After the completion of bypass by the rule of negative selection agent is selected from the smallest path length.

It is obvious that the population of agents will increase exponentially. To avoid this, we introduce a parameter that limits the maximum number of agents: the cloning of new agents will only occur if the population there are empty seats. To reduce the amount of useless agents, the length of routes which exceeded the current best result before the end of the path, we write the current minimum length of the path when creating a new agent. If the path of the agent exceeds this value, it deletes itself.

As a rule, the optimal path routing problem consists of edges connecting vertices of the next, so the logical choice would be the new vertices with equal probability, and depends on the removal of the current (more and less likely). Agent is running for re-transmission path contains your previous route.

Algorithm for the actions of one agent in pseudocode as follows:

1. If the route already traversed before - go to the next summit, otherwise go to one of the vertices of the graph (the probability of selection depends on the distance from the current vertex);
2. If the agent has been in the top - the self-destruct;
3. Increase the length of the size of the traversed path;
4. If the length exceeds a well-known agent, at least - self-destruct;
5. If the population space is available - to clone themselves, changing the last vertex in a random clone;
6. Go to step 1.

4. Conclusion

Considered in this paper, an algorithm and software based on artificial immune systems, with respect to the classical routing problem showed good results (Fig. 1). The program interface consists of the characteristics of immune algorithm in accordance with an embodiment, developer information, a brief background (User Manual).

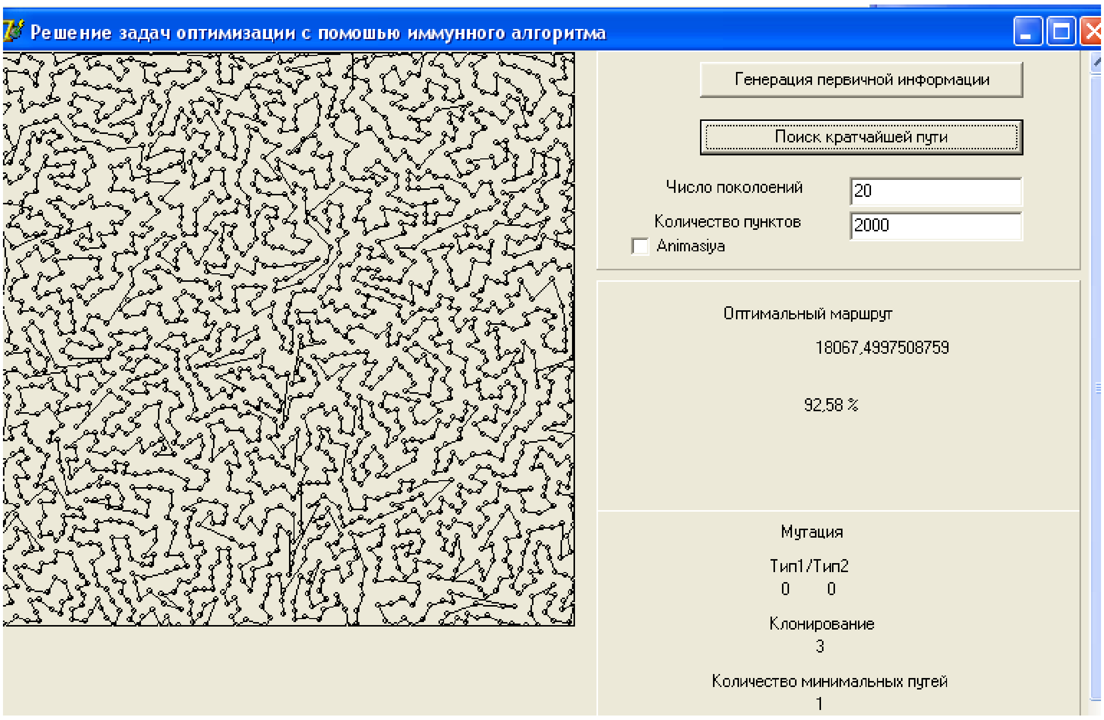

Figure 1. ***Solving routing using immune algorithm.***

Analyzing the simulation results we conclude that the optimal number of routes can be considered 200, the number of generations, there is no need to repeat the algorithm for more than 500 times (generations) to get a good result.

In the future we plan to continue to study the application of these methods to problems of routing, their dynamic and distributed versions.

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DECISION MODELING UNDER INTERVAL AND IMPRECISE INFORMATION

Vladik Kreinovich, Rafik Aliev, Oleg H. Huseynov

[1,2] *Department of Computer-Aided Control Systems Azerbaijan State Oil Academy, Baku, Azerbaijan,*
raliev@asoa.edu.az, oleg_huseynov@yahoo.com
[1] *Azerbaijan Association of "Zadeh's Legacy", Baku, Azerbaijan*
[3] *Department of Computer Science, University of Texas at El Paso El Paso, Texas 79968, USA, vladik@utep.edu*

***Abstract**. Traditional decision theory is based on a simplifying assumption that for each two alternatives, a user can always meaningfully decide which of them is preferable. In reality, often, when the alternatives are close, the user is either completely unable to select one of these alternatives, or selects one of the alternatives only "to some extent". How can we extend the traditional decision theory to such realistic interval and fuzzy cases? In their previous papers, the first two authors proposed a natural generalization of the usual decision theory axioms to interval and fuzzy cases, and described decision coming from this generalization. In this paper, we make the resulting decisions more intuitive by providing commonsense operational explanation.*

Introduction. Traditional decision theory is based on a simplifying assumption that for each two alternatives, a user can always meaningfully decide which of them is preferable. In reality, often, when the alternatives are close, the user is either completely unable to select one of these alternatives, or selects one of the alternatives only ``to some extent''. How can we extend the traditional decision theory to such realistic interval and fuzzy cases?

In their papers [1, 2, 3, 4, 5, 6, 7, 8, 9], summarized in [10], the first two authors proposed a natural generalization of the usual decision theory axioms to interval and fuzzy cases, and described decision coming from this generalization.

In this paper, we make the resulting decisions more intuitive by providing commonsense operational explanation. This paper is structured as follows: first, we recall the main ideas and results of the traditional decision theory. We then consider the case when in addition to deciding which of the two alternatives is better, the user can also reply that he/she is unable to decide between the two close alternatives; this leads to interval uncertainty. Finally, we consider the general case when the user makes fuzzy statements about preferences.

Traditional decision theory: brief reminder. Following [11,13,14], let us describe the main ideas and results of the traditional decision theory.

Main assumption behind the traditional decision theory. Let us assume that for every two alternatives A' and A'', a user can tell:

- whether the first alternative is better for him/her; we will denote this by $A'' < A'$;
- or the second alternative is better; we will denote this by $A' < A''$;
- or the two given alternatives are of equal value to the user; we will denote this by $A' = A''$.

The notion of utility. Under the above assumption, we can form a natural numerical scale for describing attractiveness of different alternatives. Namely, let us select a very bad alternative A_0 and a very good alternative A_1, so that most other alternatives are better than A_0 but worse than A_1. Then, for every probability $p \in [0,1]$, we can form a lottery $L(p)$ in which we get A_1 with probability p and A_0 with the remaining probability $1-p$.

When $p = 0$, this lottery simply coincides with the alternative A_0: $L(0) = A_0$. The larger the probability p of the positive outcome increases, the better the result, i.e., $p' < p''$ implies $L(p') < L(p'')$. Finally, for $p = 1$, the lottery coincides with the alternative A_1: $L(1) = A_1$. Thus, we have a continuous scale of alternatives $L(p)$ that monotonically goes from A_0 to A_1.

We have assumed that most alternatives A are better than A_0 but worse than A_1: $A_0 < A < A_1$. Since $A_0 = L(0)$ and $A_1 = L(1)$, for such alternatives, we thus get $L(0) < A < L(1)$. We assumed that every two alternatives can be compared. Thus, for each such alternative A, there can be at most one value p for which $L(p) = A$; for others, we have $L(p) < A$ or $L(p) > A$. Due to monotonicity of $L(p)$ and transitivity of preference, if $L(p) < A$, then $L(p') < A$ for all $p' \le p$; similarly, if $A < L(p)$, then $A < L(p')$ for all $p' > p$. Thus, the supremum (= least upper bound) $u(A)$ of the set of all p for which $L(p) < A$ coincides with the infimum (= greatest lower bound) of the set of all p for which $A < L(p)$. For $p < u(A)$, we have $L(p) < A$, and for for $p > u(A)$, we have $A < L(p)$. This value $u(A)$ is called the *utility* of the alternative A.

It may be possible that A is equivalent to $L(u(A))$; however, it is also possible that $A \ne L(u(A))$. However, the difference between A and $L(u(A))$ is extremely small: indeed, no matter how small the value $\varepsilon > 0$, we have $L(u(A) - \varepsilon) < A < L(u(A) + \varepsilon)$. We will describe such (almost) equivalence by $\equiv$, i.e., we write that $A \equiv L(u(A))$.

How can we actually find utility values. The above definition of utility is somewhat theoretical, but in reality, utility can be found reasonably fast by the following iterative bisection procedure.

We want to find the probability $u(A)$ for which $L(u(A)) \equiv A$. On each stage of this procedure, we have the values $\underline{u} < \overline{u}$ for which $L(\underline{u}) < A < L(\overline{u})$. In the beginning, we have $\underline{u} = 0$ and $\overline{u} = 1$, with $|\overline{u} - \underline{u}| = 1$.

To find the desired probability $u(A)$, we compute the midpoint $\tilde{u} = \dfrac{\underline{u} + \overline{u}}{2}$ and compare the alternative A with the corresponding lottery $L(\tilde{u})$. Based on our assumption, there are three possible results of this comparison:

- if the user concludes that $L(\tilde{u}) < A$, then we can replace the previous lower bound $\underline{u}$ with the new one $\tilde{p}$;
- if the user concludes that $A < L(\tilde{u})$, then we can replace the original upper bound $\overline{u}$ with the new one $\tilde{u}$;
- finally, if $A = L(\tilde{u})$, this means that we have found the desired probability $u(A)$.

In this third case, we have found $u(A)$, so the procedure stops. In the first two cases, the new distance between the bounds $\underline{u}$ and $\overline{u}$ is the half of the original distance. By applying this procedure k times, we get values $\underline{u}$ and $\overline{u}$ for which $L(\underline{u}) < A < L(\overline{u})$ and $|\overline{u} - \underline{u}| \le 2^{-k}$. One can easily check that the desired value $u(A)$ is within the interval $[\underline{u}, \overline{u}]$, so the midpoint $\tilde{u}$ of this interval is an $2^{-(k+1)}$-approximation to the desired utility value $u(A)$.

In other words, for any given accuracy, we can efficiently find the corresponding approximation to the utility $u(A)$ of the alternative A.

How to make decisions under interval uncertainty: Hurwicz optimism-pessimism criterion. The problem of decision making under such interval uncertainty was first handled by the future Nobelist L. Hurwicz in [12].

We need to assign, to each interval $[\underline{u}, \overline{u}]$, a utility value $u(\underline{u}, \overline{u})$.

No matter what value u we get from this interval, this value will be larger than or equal to $\underline{u}$ and smaller than or equal to $\overline{u}$. Thus, the equivalent utility value $u(\underline{u}, \overline{u})$ must satisfy the same inequalities: $\underline{u} \le u(\underline{u}, \overline{u}) \le \overline{u}$. In particular, for $\underline{u} = 0$ and $\overline{u} = 1$, we get $0 \le \alpha_H \le 1$, where we denoted $\alpha_H \stackrel{\text{def}}{=} u(0,1)$.

We have mentioned that the utility is determined modulo a linear transformation $u' = a \cdot u + b$. It is therefore reasonable to require that the equivalent utility does not depend on what scale we use, i.e., that for every $a > 0$ and b, we have

$$u(a\cdot \underline{a}+b, a\cdot \overline{u}+b) = a\cdot u(\underline{u},\overline{u})+b.$$

In particular, for $\underline{u}=0$ and $\overline{u}=1$, we get

$$u(b, a+b) = a\cdot u(0,1)+b = a\cdot \alpha_H + b.$$

So, for every $\underline{u}$ and $\overline{u}$, we can take $b=\underline{u}$, $a=\overline{u}-\underline{u}$, and get

$$u(\underline{u},\overline{u}) = \underline{u}+\alpha_H\cdot(\overline{u}-\underline{u}) = \alpha_H\cdot\overline{u}+(1-\alpha_H)\cdot\underline{u}.$$

This expression is called *Hurwicz optimism-pessimism criterion*, because:

- when $\alpha_H=1$, we make a decision based on the most optimistic possible values $u=\overline{u}$;
- when $\alpha_H=0$, we make a decision based on the most pessimistic possible values $u=\underline{u}$;
- for intermediate values $\alpha_H\in(0,1)$, we take a weighted average of the optimistic and pessimistic values.

So, if we have two alternatives A' and A'' with interval-valued utilities $[\underline{u}(A'),\overline{u}(A')]$ and $[\underline{u}(A''),\overline{u}(A'')]$, we recommend an alternative for which the equivalent utility value is the largest. In other words, we recommend to select A' if $\alpha_H\cdot\overline{u}(A')+(1-\alpha_H)\cdot\underline{u}(A') > \alpha_H\cdot\overline{u}(A'')+(1-\alpha_H)\cdot\underline{u}(A'')$ and A'' otherwise.

Which value α_H should we choose? An argument in favor of $\alpha_H=0.5$. Which value α_H should we choose?

To answer this question, let us take an event E about which we know nothing. For a lottery L^+ in which we get A_1 if E and A_0 otherwise, the utility interval is $[0,1]$, thus, from a decision making viewpoint, this lottery should be equivalent to an event with utility $\alpha_H\cdot 1+(1-\alpha_H)\cdot 0=\alpha_H$.

Similarly, for a lottery L^- in which we get A_0 if E and A_1 otherwise, the utility interval is $[0,1]$, thus, this lottery should also be equivalent to an event with utility $\alpha_H\cdot 1+(1-\alpha_H)\cdot 0=\alpha_H$.

We can now combine these two lotteries into a single complex lottery, in which we select either L^+ or L^- with equal probability 0.5. Since L^+ is equivalent to a lottery $L(\alpha_H)$ with utility α_H and L^- is also equivalent to a lottery $L(\alpha_H)$ with utility α_H, the complex lottery is equivalent to a lottery in which we select either $L(\alpha_H)$ or $L(\alpha_H)$ with equal probability 0.5, i.e., to $L(\alpha_H)$. Thus, the complex lottery has an equivalent utility α_H.

On the other hand, no matter what is the event E, in the above complex lottery, we get A_1 with probability 0.5 and A_0 with probability 0.5. Thus, this complex lottery coincides with the lottery $L(0.5)$ and thus, has utility 0.5. Thus, we conclude that $\alpha_H=0.5$.

Which action should we choose? Suppose that an action has n possible outcomes $S_1,\ldots,S_n$, with utilities $[\underline{u}(S_i),\overline{u}(S_i)]$, and probabilities $[\underline{p}_i,\overline{p}_i]$. How do we then estimate the equivalent utility of this action?

We know that each alternative is equivalent to a simple lottery with utility $u_i=\alpha_H\cdot\overline{u}(S_i)+(1-\alpha_H)\cdot\underline{u}(S_i)$, and that for each i, the i-th event is -- from the viewpoint of decision making -- equivalent to $p_i=\alpha_H\cdot\overline{p}_i+(1-\alpha_H)\cdot\underline{p}_i$. Thus, from the viewpoint of decision making, this action is equivalent to a situation in which we get utility u_i with probability p_i. We know that the utility of such a situation is equal to $\sum_{i=1}^{n} p_i\cdot u_i$. Thus, the equivalent utility of the original action is equivalent to

$$\sum_{i=1}^{n} p_i\cdot u_i = \sum_{i=1}^{n}(\alpha_H\cdot\overline{p}_i+(1-\alpha_H)\cdot\underline{p}_i)\cdot(\alpha_H\cdot\overline{u}(S_i)+(1-\alpha_H)\cdot\underline{u}(S_i)).$$

Observation: the resulting decision depends on the level of detail. We make a decision in a situation when we do not know the exact values of the utilities and when we do not know the exact values of the corresponding probabilities. Clearly, if gain new information, the equivalent utility may change. For example, if we know nothing about an alternative A, then its utility is $[0,1]$ and thus, its equivalent utility is α_H. Once we narrow down the utility of A, e.g., to the interval $[0.5,0.9]$, we get a different equivalent utility $\alpha_H \cdot 0.9 + (1-\alpha_H)\cdot 0.5 = 0.5 + 0.4\cdot\alpha_H$. On this example, the fact that we have different utilities makes perfect sense.

However, there are other examples where the corresponding difference is not as intuitively clear. Let us consider a situation in which, with some probability p, we gain a utility u, and with the remaining probability $1-p$, we gain utility 0. If we know the exact values of u and p, we can then compute the equivalent utility of this situation as the expected utility value $p\cdot u + (1-p)\cdot 0 = p\cdot u$.

Suppose now that we only know the interval $[\underline{u},\overline{u}]$ of possible values of utility and the interval $[\underline{p},\overline{p}]$ of possible values of probability. Since the expression $p\cdot u$ for the expected utility of this situation is an increasing function of both variables:

- the largest possible utility of this situation is attained when both p and u are the largest possible: $u=\overline{u}$ and $p=\overline{p}$, and
- the smallest possible utility is attained when both p and u are the smallest possible: $u=\underline{u}$ and $p=\underline{p}$.

In other words, the resulting amount of utility ranges from $\underline{p}\cdot\underline{u}$ to $\overline{p}\cdot\overline{u}$.

If we know the structure of the situation, then, according to our derivation, this situation has an equivalent utility $u_k = (\alpha_H\cdot\overline{p} + (1-\alpha_H)\cdot\underline{p})\cdot(\alpha_H\cdot\overline{u} + (1-\alpha_H)\cdot\underline{u})$ (k for *k*now). On the other hand, if we do not know the structure, if we only know that the resulting utility is from the interval $[\underline{p}\cdot\underline{u},\overline{p}\cdot\overline{u}]$, then, according to the Hurwicz criterion, the equivalent utility is equal to $u_d = \alpha_H\cdot\overline{p}\cdot\overline{u} + (1-\alpha_H)\cdot\underline{p}\cdot\underline{u}$ (d for *d*on't know). One can check that

$$u_d - u_k = \alpha_H\cdot\overline{p}\cdot\overline{u} + (1-\alpha_H)\cdot\underline{p}\cdot\underline{u} - \alpha_H^2\cdot\overline{p}\cdot\overline{u} - \alpha_H\cdot(1-\alpha_H)\cdot(\underline{p}\cdot\overline{u}+\overline{p}\cdot\underline{u}) - (1-\alpha_H)^2\cdot\underline{p}\cdot\underline{u} =$$
$$\alpha_H\cdot(1-\alpha_H)\cdot\overline{p}\cdot\overline{u} + \alpha_H\cdot(1-\alpha_H)\cdot\underline{p}\cdot\underline{u} - \alpha_H\cdot(1-\alpha_H)\cdot(\underline{p}\cdot\overline{u}+\overline{p}\cdot\underline{u}) =$$
$$\alpha_H\cdot(1-\alpha_H)\cdot(\overline{p}-\underline{p})\cdot(\overline{u}-\underline{u}).$$

This difference is always positive, meaning that additional knowledge decreases the utility of the situation. (This is maybe what the Book of Ecclesiastes means by ``For with much wisdom comes much sorrow"?)

From intervals to general sets. In the ideal case, we know the exact situation s in all the detail, and we can thus determine its utility $u(s)$. Realistically, we have an imprecise knowledge, so instead of a single situation s, we only know a *set* S of possible situations s. Thus, instead of a single value of the utility, we only know that the actual utility belongs to the set $U=\{u(s): s\in S\}$. If this set S is an interval $[\underline{u},\overline{u}]$, then we can use the above arguments to come up with its equivalent utility value $\alpha_H\cdot\overline{u} + (1-\alpha_H)\cdot\underline{u}$.

What is U is a generic set? For example, we can have a 2-point set $U=\{\underline{u},\overline{u}\}$. What is then the equivalent utility?

Let us first consider the case when the set U contains both its infimum $\underline{u}$ and its supremum $\overline{u}$. The fact that we only know the set of possible values and have no other information means that *any* probability distribution on this set is possible (to be more precise, it is possible to have any probability distribution on the set of possible situations S, and this leads to the probability distribution on utilities). In particular, for each probability p, it is possible to have a distribution in which we have $\overline{u}$ with probability p and $\underline{u}$ with probability $1-p$. For this distribution, the expected utility is equal to $p\cdot\overline{u}+(1-p)\cdot\underline{u}$. When p goes from 0 to 1, these values fill the whole interval $[\underline{u},\overline{u}]$. Thus, every value from this interval is the possible value of the expected utility. On the other hand, when $u\in[\underline{u},\overline{u}]$, the expected value of the utility also belongs to this interval -- no matter what the probability distribution. Thus, the set of all possible utility values is the whole interval $[\underline{u},\overline{u}]$ and so, the equivalent utility is equal to $\alpha_H\cdot\overline{u}+(1-\alpha_H)\cdot\underline{u}$.

When the infimum and/or supremum are not in the set S, then the set S contains points as close to them as possible. Thus, the resulting set of possible values of utility is as close as possible to the interval $[\underline{u},\overline{u}]$ -- and so, it is reasonable to assume that the equivalent utility is as close to $u_0=\alpha_H\cdot\overline{u}+(1-\alpha_H)\cdot\underline{u}$ as possible -- i.e., coincides with this value u_0.

From sets to fuzzy sets: main idea. What if utility is a fuzzy number, described by a membership function $\mu(u)$? One of the natural interpretations of a fuzzy set is via its nested intervals α-cuts $u(\alpha)=[\underline{u}(\alpha_H),\overline{u}(\alpha_H)]=\{u:\mu(u)\geq\alpha\}$. For example, when we are talking about a measurement error of a given measuring instrument, then we know the guaranteed upper bound, i.e., the guaranteed interval that contains all possible values of the measurement error. In addition to this guaranteed interval, experts can usually pinpoint a narrower interval that contains the measurement error with some certainty; the narrower the interval, the smaller our certainty. Thus, we are absolutely sure (with certainty 1) that the actual value u belongs to the α-cut $u(0)$; also, with a degree of certainty $1-\alpha$, we claim that $x\in u(\alpha)$. Thus, if we select some small value $\Delta\alpha$ and take $\alpha=0,\Delta\alpha,2\Delta\alpha,\ldots$, we conclude that:

- with probability $\Delta\alpha$, the set of possible values of u is the interval $[\underline{u}(0),\overline{u}(0)]$;
- with probability $\Delta\alpha$, the set of possible values of u is the interval $[\underline{u}(\Delta\alpha),\overline{u}(\Delta\alpha)]$;
- ...
- with probability $\Delta\alpha$, the set of possible values of u is the interval $[\underline{u}(\alpha),\overline{u}(\alpha)]$;
- ...

For each interval, the equivalent utility value is $\alpha\cdot\overline{u}(\alpha)+(1-\alpha)\cdot\underline{u}(\alpha)$. The entire situation is a probabilistic combination of such intervals, so the resulting equivalent utility is equal to the expected value of the above utility, i.e., to

$$\alpha\cdot\int_0^1\overline{u}(\alpha)d\alpha+(1-\alpha)\cdot\int_0^1\underline{u}(\alpha)d\alpha.$$

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APPROACH TO PROBLEM SOLVING MULTICRITERIAL OPTIMIZATION WITH FUZZY AIM

D.T. Mukhamediyeva

100125, Tashkent, Uzbekistan Center for development of software products and hardware-software complexes for TUIT, Durmon yuli-25 street, Ph. +99871 262-71-55, dilnoz134@rambler.ru

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1. Introduction

The classical problem of mathematical programming models are deterministic decision-making. In a theoretical sense, they are sufficiently well studied in the framework of [1-3]. However, the real applied problems are much more complicated than that provided by classical performances. This complexity is due to the need to consider many criteria when making decisions, creating a class of multiobjective optimization problems. Exceptional value for the solution of such problems is the Pareto principle, under which the optimal solution should be selected among the Pareto-optimal points, which form part of compromise, and the selection of the final decision shall be based on additional information. Note that the Pareto principle is not universal, and applies only when a number of axioms. And even if these axioms are satisfied, the construction of the Pareto set can cause significant difficulties [4-7]. At the heart of another approach to solving multicriteria optimization problems is the idea of successive concessions, based on ranking criteria in order of decreasing importance, and one-criterion decision problem in which the most important criterion takes the extreme value, and the other restrictions are imposed. The disadvantage of this approach lies in the complication of the constraints and the need to analyze different versions of the problem. The transition to a one-criterion problem is possible and in aggregating the individual criteria for a generalized (integral) criterion with a suitable convolution [8-10]. When the visual attractiveness of such an approach raises a number of issues: it is unclear how to determine the type of aggregation, it is difficult or impossible to justify the principle of evaluation of its parameters (weights, exponents, etc.) is problematic interpretation of the results [11-12].

2. Formulation of the problem of multicriteria optimization

In formulating the problem as a multiobjective optimization requirements for the optimal solution is introduced to meet a mandatory condition of all private criteria and constraints, namely, at the optimum all the functions belonging to the set of optimal solutions must be different from zero and that the optimum criteria are met to the greatest extent possible. At the same time increasing the value of the generalized criterion should not exceed some value in improving quality at the expense of others. In the terminology of decision theory, the latter requirement is equivalent to the origin point of optimum Pareto set [6].

The problem of multicriteria optimization in matrix form is as follows:

$$f(x) = [f_1(x), f_2(x), ..., f_q(x)]^T \to \min ,$$
$$Ax \le b ,\tag{1}$$
$$x \in R^n ,$$

where:

$$f_k(x) = \sum_{j=1}^{n} c_{kj} x_j ,$$
$$k \in Q = \{1,2,...,q\},\ c_{kj} \in R ,$$
$$A = (a_{i,j}) \in R^{m \times n} .$$

The problem with fuzzy multi-criteria optimization goal involves finding those $x \in R^n$ that satisfy the following conditions:

$$f_k(x) \le \tilde{g}_k , \qquad k = 1,2,..., q,$$
$$Ax \le b ,\tag{2}$$
$$x \in R^n ,$$

where $\tilde{g}_k$ - c fuzzy set membership function

$$\mu_k(f_k(x)) = \begin{cases} 1, & f_k(x) \le g_k , \\ 1 - \dfrac{f_k(x) - g_k}{t_k}, & g_k \le f_k(x) \le g_k + t_k , \\ 0, & f_k(x) \ge g_k + t_k . \end{cases}\tag{3}$$

The solution of the fuzzy problem (2) can be converted to a clear solution

$$\alpha \to \max,$$
$$\mu_k(f_k(x)) \ge \alpha,\tag{4}$$
$$Ax \le b ,$$
$$x \in R^n ,$$

where α - level (cut) of fuzzy sets $\tilde{g}_k$.

3. Finding the Pareto optimal solutions of multiobjective optimization problems with fuzzy aim

The solution $x^0 \in R^n$ is called Pareto optimal solution if all $x^1 \in R^n$ the condition $\mu_k(f_k(x^1)) \le \mu_k(f_k(x^0))$ and at least one $x^1 \in R^n$ condition $\mu_S(f_S(x^1)) < \mu_S(f_S(x^0))$. The solution $x^0 \in R^n$ is optimal by the criterion of Pareto-type, if there is, better by a Pareto-type than that $x^0 \in R^n$.

We introduce the concept be improved by solving $x^0 \in R^n$ the Pareto type in fuzzy environment: the solution $x^0 \in R^n$ is said to be improved if there is a solution $x^1 \in R^n$ that is best $x^0 \in R^n$ for Pareto-type criterion.

The solution to the situation be improved taking fuzzy multipurpose decision $f(x) = [f_1(x), f_2(x), ..., f_p(x)]$ if and only if there exists a vector $\gamma \in R^Q$ such that the inequalities

$$\mu_k(f_k(x^0)) \le c^k ,\ \mu_s(f_s(x^0)) < c^s\tag{5}$$

for all $k \in \{1,\dots,Q\}$ and at least one $s \in \{1,\dots,Q\}$, where $c^k = c - \gamma_k$, $c = \max\limits_{x^1} \min\limits_k \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right]$, where $c^k \in R$, $c^s \in R$ and $c \in R$.

Suppose that the required inequalities are satisfied, then by definition $c^k \in R$, for which $x^1 \in R^n$ there is true $c \le \mu_k\left(f_k\left(x^1\right)\right) + \gamma_k$, and hence $c^k \le \mu_k\left(f_k\left(x^1\right)\right)$. Then, for all $k \in \{1,\dots,Q\}$ the inequalities $\mu_S\left(f_S\left(x^0\right)\right) \le c^k \le \mu_k\left(f_k\left(x^1\right)\right)$ and at least one $s \in \{1,\dots,Q\}$ inequality $\mu_s\left(f_s\left(x^0\right)\right) < c^s \le \mu_s\left(f_s\left(x^1\right)\right)$. These inequalities show that the solution $x^0 \in X$ improved.

Let the solution $x^0 \in R^n$ be improved and $x^1 \in R^n$ that is the solution that better solutions $x^0 \in R^n$ to the Pareto criterion. Put $\gamma_k = \mu_s\left(f_s\left(x^1\right)\right) - \mu_k\left(f_k\left(x^1\right)\right)$ all $k \in \{1,\dots,Q\}$, where the $s \in \{1,\dots,Q\}$ inequality $\mu_s\left(f_s\left(x^1\right)\right) > \mu_s\left(f_s\left(x^0\right)\right)$ Then $\max\limits_k \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] = \min\limits_{x^1} \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] = \mu_s\left(f_s\left(x^1\right)\right)$.

Given that all γ of R^Q $\min\limits_k \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] \le c$, we obtain $\mu_k\left(f_k\left(x^0\right)\right) + \gamma_k \le \mu_k\left(f_k\left(x^1\right)\right) + \gamma_k \le \max\limits_k \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] = \min\limits_{x^1} \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] \le c$ for all $k \in \{1,\dots,Q\}$ and $\mu_s\left(f_s\left(x^0\right)\right) + \gamma_s < \mu_s\left(f_s\left(x^1\right)\right) + \gamma_s \le c$ or at least one $s \in \{1,\dots,Q\}$. It follows from inequalities (5).

Decision $x^0 \in R^n$ making in the situation be improved multi-purpose solutions if and only if there exists a vector γ of the set $\Gamma = \left\{\gamma \in \mathrm{R}^Q : \max\limits_k \mu_k\left(f_k\left(x^1\right)\right) - \min\limits_{x^1} \mu_\rho\left(f_\rho\left(x^1\right)\right) \ge \gamma_\rho - \gamma_k,\ (\rho, k = 1,\dots,Q, \rho \ne k)\right\}$ such that the inequalities $\mu_k\left(f_k\left(x^0\right)\right) \le c^k$ and $\mu_s\left(f_s\left(x^0\right)\right) < c^s$. The validity of these inequalities follows from the considerations

$$\left[\mu_k\left(f_k\left(x^0\right)\right) + \gamma_k\right] \le \left(\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right) \le \max_k \left[\mu_k\left(f_k\left(x^1\right)\right) + \gamma_k\right] = \min_{x^1} \left[\mu_\rho\left(f_\rho\left(x^1\right)\right) + \gamma_\rho\right] \le c \ ,$$

for everyone $k, \rho \in \{1,\dots,Q\}$, $\left(\mu_s\left(f_s\left(x^0\right)\right) + \gamma_s\right) < \left(\mu_s\left(f_s\left(x^1\right)\right) + \gamma_s\right) \le c$.

It follows that if the evaluation of the functional $\left\{\mu_k\left(f_k\left(x^1\right)\right)\right\}_{k=1}^{Q}$ obtained after the application of the natural normalization, then the domain D has the form:

$$\Gamma = \left\{\gamma \in \mathrm{R}^Q; \left|\gamma_\rho - \gamma_k\right| \le 1,\ \ k, \rho = 1,\dots,Q; \rho \ne k\right\}.$$

Thus, the question of Pareto optimality multipurpose solutions $x^0 \in R^n$ by Pareto be improved or reduced to establishing the existence or absence of the vector $\gamma \in \Gamma$ for which the inequalities $\mu_k\left(f_k\left(x^0\right)\right) \le c^k$ $\mu_s\left(f_s\left(x^0\right)\right) < c^S$.

Thus, in order to be improved or the decision $x^1 \in R^n$ was Pareto optimal, it is necessary to satisfy or were inconsistent inequality: $\mu_k\left(f_k\left(x^1\right)\right) \le \max\limits_{\gamma \in \Gamma} \left\{\max\limits_{x^2} \min\limits_\rho \left[\mu_\rho\left(f_\rho\left(x^2\right)\right) + \gamma_\rho\right] - \gamma_k\right\}, (k = 1,\dots,Q)$.

The validity of these inequalities follows from the following considerations:

$$\mu_k\left(f_k\left(x^0\right)\right) + \gamma_k \le \mu_k\left(f_k\left(x^1\right)\right) + \gamma_k \le \max_{x^2} \left[\mu_k\left(f_k\left(x^2\right)\right) + \gamma_k\right] = \min_\rho \left[\mu_\rho\left(f_\rho\left(x^2\right)\right) + \gamma_\rho\right] \le$$

$$\le \max_{x^2} \min_\rho \left[\mu_\rho\left(f_\rho\left(x^2\right)\right) + \gamma_\rho\right] \le \max_{\gamma \in \Gamma} \left\{\max_{x^2} \min_\rho \left[\mu_\rho\left(f_\rho\left(x^2\right)\right) + \gamma_\rho\right]\right\}$$

$$\left(\mu_S\left(f_S\left(x^0\right)\right) + \gamma_S\right) < \left(\mu_S\left(f_S\left(x^1\right)\right) + \gamma_S\right) \le \max_{\gamma \in \Gamma} \left\{\min_{x^2} \min_\rho \left(\mu_s\left(f_s\left(x^2\right)\right) + \gamma_\rho\right)\right\}$$

for all $(\rho, k = 1,\dots,Q, \rho \ne k)$ or at least one $s \in \{1,\dots,Q\}$.

Let $\mu_k\left(f_k\left(x^1\right)\right)$ - membership function $f_k\left(x^1\right)$, defined as in (3) and $x^0 \in R^n$ the optimal solution improves task

$$\sum_{k=1}^{Q} \gamma_k \to \max \ ,$$

$$\begin{gathered} \mu_k(f_k(x)) - \gamma_k \geq \alpha^* \;\; k = 1,\ldots,Q, \\ x \in X, \;\; \gamma_k \geq 0. \end{gathered} \tag{6}$$

Then the solution $x^0 \in R^n$ is Pareto - optimal solution of problem (1).
Assume the contrary. Let $x^0 \in R^n$ not a Pareto - optimal solution (1). Then there exists a solution $x^1 \in R^n$ such $f_k(x^1) \leq f_k(x^0)$ that for all ($k = 1,\ldots,Q$) and $f_s(x^1) < f_s(x^0)$ for some $s \in \{1,\ldots,Q\}$. As $\gamma_k, k = 1,\ldots,Q$ a positive example and $x^0 \in R^n$ satisfies the following equations:

$$\mu_k(f_k(x^0)) - \gamma_k = \alpha^*, \;\; k = 1,\ldots,Q \;\text{ and }\; \sum_{k=1}^{Q} \gamma_k = \sum_{k=1}^{Q} \mu_k(f_k(x^0)) - Q\alpha^*.$$

Still exists $f_k(x^1) \leq f_k(x^0)$ at all ($k = 1,\ldots,Q$) and $f_s(x^1) \leq f_s(x^0)$ for some *s*. This leads to the following inequalities:

$$\sum_{k=1}^{Q} \gamma_k = \sum_{k=1}^{Q} \mu_k(f_k(x^0)) - Q\lambda^* = \sum_{\substack{k=1 \\ k \neq S}}^{Q} \mu_k(f_k(x^0)) + \mu_S(f_S(x^0)) - Q\lambda^* <$$

$$< \sum_{\substack{k=1 \\ k \neq S}}^{Q} \mu_k(f_k(x)) + \mu_S(f_S(x)) - Q\lambda^*.$$

This means that the solution (6) $x^0 \in X$ is not optimal. This contradiction shows that the solution $x^0 \in R^n$ is Pareto - optimal solution of problem (1).

4. Computing experiment

Consider the following example, taken from [12]. To solve the multiobjective problem

$$\begin{cases} z_1(x) = 4x_1 - 6x_2 \to \min, \\ z_2(x) = -2x_1 - x_2 \to \min, \\ -x_1 + x_2 \leq 3, \\ x_2 \leq 5, \\ x_1 + x_2 \leq 10, \\ x_1 \leq 8, \end{cases} \tag{7}$$

with fuzzy goals

$$g_1 = 20; \qquad g_2 = -9$$

and tolerances

$$t_1 = 2; \qquad t_2 = 2.$$

Form the membership functions

$$\mu_1(z_1(x)) = \begin{cases} \dfrac{2r - z_1(x)}{2}, & z_1(x) \leq 2r, \\ 0, & z_1(x) \geq 2r, \end{cases}$$

$$\mu_1(z_1(x)) = \begin{cases} \dfrac{-7 - z_2(x)}{2}, & z_1(x) \leq -7, \\ 0, & z_1(x) \geq -7. \end{cases}$$

Then the model (7) takes the following form:

$$\begin{cases} \alpha \to \max, \\ \frac{1}{2}\left(2 - \left(4x_1 - 6x_2\right)\right) \geq \lambda, \\ \frac{1}{2}\left(7 - \left(-2x_1 - x_2\right)\right) \geq \lambda, \\ -x_1 + x_2 \leq 3, \\ x_2 \leq 5, \\ x_1 + x_2 \leq 10, \\ x_1 \leq 8. \end{cases}$$

The solution of this model is

$$x^* = \left(x_1^*, x_2^*\right) = \left(4{,}5; 0\right)$$

Optimal value $\alpha^* = 1$ and the value of the objective function

$$z\left(x^*\right) = 18, \qquad z\left(x^*\right) = -9.$$

Consider the existence of a vector $\gamma = \left(\gamma_1, \gamma_2\right)$ that can improve a solution x^*.
To do this we solve the following problem:

$$\begin{cases} \gamma_1 + \gamma_2 \to \max, \\ 4x_1 - 6x_2 + 2\gamma_1 \leq 20, \\ -2x_1 - x_2 + 2\gamma_2 \leq -9, \\ -x_1 + x_2 \leq 3, \\ x_2 \leq 5, \\ x_1 + x_2 \leq 10, \\ x_1 \leq 8. \end{cases} \tag{8}$$

The solution of the model (8) is

$$x^{**} = \left(x_1^{**},\ x_2^{**}\right) = (2;5)$$

optimal value:

$$\gamma_1 = 21; \qquad \gamma_2 = 0$$

and the value of the objective function

$$z_1(x^{**}) = -22;$$
$$z_2(x^{**}) = -9.$$

Thus there exists a vector $\gamma = \left(\gamma_1, \gamma_2\right)$, where the Pareto-optimal solution be improved

$$z_1\left(x^{**}\right) < z_1\left(x^*\right),$$
$$z_2\left(x^{**}\right) = z_2\left(x^*\right).$$

5. Conclusion

Thus, the question of Pareto $x^0 \in R^n$ optimality multipurpose solutions by Pareto be improved or reduced to establishing the existence or absence of the vector $\gamma \in \Gamma$ for which the inequalities $\mu_k\left(f_k\left(x^0\right)\right) \leq c^k \quad \mu_s\left(f_s\left(x^0\right)\right) < c^S$.

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COMPARATIVE ANALYSIS OF UNCERTAINTY MEASURES

R.A. Aliev*, O.H. Huseynov**

**Joint MBA Program (USA, Azerbaijan) 20 Azadlig Ave., AZ1010 Baku, Azerbaijan ,*
Tel: +99412 493 45 38, Fax: +99412 598 45 09, E-mail: raliev@asoa.edu.az
***Department of Computer-Aided Control Systems Azerbaijan State Oil Academy Baku, Azerbaijan,*
raliev@asoa.edu.az, oleg_huseynov@yahoo.com

Abstract. *Decision making environment including alternatives, states of nature, outcomes and probabilities is characterized by uncertainty. Uncertainty may be of various types – probabilistic or possibilistic, objective or subjective. However, these are primitive, that is, constituent types of uncertainty. Real-world is characterized by a second-order uncertainty which is a mix of these constituent types. The principal cases of second-order uncertainty are fuzzy probabilities, second-order probabilities, imprecise probabilities etc. Indeed, real-world information is often described in natural language due to partial truth, vagueness and imprecision. This requires to develop new approaches for mathematical modeling of uncertainty. In the present paper we discuss the numerical existing uncertainty measures and suggest a fuzzy number-valued fuzzy measure to be used in decision analysis with linguistically described states of nature and probabilities. Comparative analysis of the suggested measure with the numerical existing uncertainty measures is conducted*

Keywords: *probability, possibility, second-order uncertainty, uncertainty measures, fuzzy measure, fuzzy number-valued fuzzy measure, linguistic probabilities*

1. Introduction

Decision making environment is characterized by presence of uncertainty in alternatives, states of nature and outcomes. Uncertainty may be of various types – probabilistic or possibilistic, objective or subjective. However, these are primitive, that is, constituent types of uncertainty. Real-world uncertainty is a second-order uncertainty as a mix of these constituent types. The principal cases of second-order uncertainty are fuzzy probabilities, second-order probabilities, imprecise probabilities, type-2 fuzzy sets etc. Indeed, real-world information is often described in natural language that represents partial truth, vagueness and imprecision inherent in decision environment. This requires developing approaches for dealing with second-order uncertainty to construct more adequate decision models. In the present paper we suggest a fuzzy number-valued fuzzy measure that is more adequate to capture information underlying NL-described probabilities. The suggested measure is also able to take into account imprecision and vagueness inherent in states of nature themselves. We conduct comparative analysis of the suggested measure with the numerical existing measures of uncertainty. We also conduct wide analysis of the numerical existing measures of uncertainty.

The paper is structured as follows. Section 1 is devoted to additive probability measures. In Section 2 we discuss non-additive measures. Section 3 is devoted to fuzzy measures and the suggested fuzzy-valued fuzzy measure. In Section 4 we conduct comparative analysis of the suggested measure with the numerical existing measures.

2. Objective and subjective probabilities

Uncertainty is intrinsic to decision making environment. No matter whether we deal with numerical or non-numerical events, we are not completely sure in their occurrence. Numerical events are commonly regarded as values of a random variable. Non-numerical events can be encoded by, for example, natural numbers and then treated as values of a random variable. To formally take into account uncertainty in decision analysis, we need to use some mathematical constructs which will measure quantitatively an extent to what that or another event is likely to occur. Such constructs are called measures of uncertainty. The most famous measure is the probability measure. Probability measure assigns its values to events to reflect degrees to which events are likely to occur. These values are called probabilities. Probability is a real number from [0,1], and the more likely an event to occur the higher is its probability. Probability equal to 0 implies that it is impossible for an event to occur or we are completely sure that it cannot occur, and probability equal to 1 means that an event will necessary occur or we are completely sure in its occurrence. The axiomatization of the standard probability measure was suggested by Kolmogorov[1]. Prior to proceeding to the Kolmogorov's axiomatization, let us introduce the necessary concepts. The first concept is the space of elementary events. Elementary event, also called an atomic event, is the minimal event that may occur, that is, an event that cannot be divided into smaller events. Denote S the space of elementary events and denote $s \in S$ an elementary event. A subset $H \subseteq S$ of the space of elementary events $s \in S$ is called an event. An event H occurs if any $s \in H$ occurs. The next concept is a σ-algebra of subsets denoted $\mathcal{F}$:

Definition σ-algebra[1]. A set $\mathcal{F}$, elements of which are subsets of S (not necessarily all) is called σ-algebra if the following hold:

(1) $S \in \mathcal{F}$

(2) if $H \in \mathcal{F}$ then $H^c \in \mathcal{F}$

(3) if $H_1, H_2, ... \in \mathcal{F}$ then $H_1 \cup H_2 \cup ... \in \mathcal{F}$

Now let us proceed to the Kolmogorov's axiomatization of a probability measure.

Definition 2. Probability measure[1]. Let S be a space of elementary events and $\mathcal{F}$ is a σ-algebra of its subsets. The probability measure is a function $P : \mathcal{F} \to 0,1$ satisfying:

(1) $P(H) \geq 0$ for any $H \in \mathcal{F}$.

(2) For any set $H_1, H_2, ... \in \mathcal{F}$ with $H_i \cap H_j, ... \varnothing$: $P(\bigcup_{i=1}^{\infty} H_i) = \sum_{i=1}^{\infty} P(H_i)$

(3) $P(S) = 1$

The first condition is referred to as non-negativity. The second condition is referred to as additivity condition. The third condition implies that the event S will necessary occur. Conditions (1)-(3) are called probability axioms. From (1)-(3) it follows $P(\varnothing) = 0$ which means that it is impossible that no elementary event $s \in S$ will occur. Let us mention that probability of a union $H \cup G$ of two arbitrary events is $P(H \cup G) = P(H) + P(G) - P(H \cap G)$. When $H \cap G = \varnothing$ one has $P(H \cup G) = P(H) + P(G)$.

Definition 2 provides mathematical structure of a probability measure. Consider now natural interpretations of a probability measure. There exist two main types of probabilities: objective probabilities and subjective probabilities. Objective probabilities, also called empirical probabilities, are quantities which are calculated on the base of real evidence: experimentations, observations, logical conclusions. They also can be obtained by using statistical formulas. Objective probabilities are of two types: experimental probabilities and logical probabilities. Experimental probability of an event is a frequency of its occurrence. For example, a probability that a color of a car taken at random in a city is white is equal to the number of white cars divided by the whole number of the cars in the city. Logical probability is based on a reasonable conclusion on a likelihood of an event. For instance, if a box contains 70 white and 30 black balls, a probability that a ball drawn at random is white is 70/100=0.7.

The use of objective probabilities requires very restrictive assumptions. For experimental probabilities the main assumptions are as follows:

(1) Experimentation (or observations) must take place under the same conditions and it must be assumed that the future events will also take place under these conditions. Alternatively, there need to be present clear dynamics of conditions in future;

(2) Observations of the past behavior must include representative data (e.g., observations must be sufficiently large).

As to logical probabilities, their use must be based on quite reasonable conclusions. For example, if to consider the box with balls mentioned above, an assumption must be made that the balls are well mixed inside the box (not a layer of white balls is placed under the layer of black balls) to calculate probability of a white ball drawn as 70/100=0.7.

From the other side, as Kahneman, Tversky and others showed[2], even if objective probabilities are known, beliefs of a DM don't coincide with them. As being perceived by humans, objective probabilities are affected by some kind of distortion – they are transformed into so-called decision weights and mostly small probabilities are overweighted, whereas high probabilities are underweighted. The overweighting and underweighting of probabilities also are different for positive and negative outcomes[3].

Subjective probability is a degree of belief of an individual in the likelihood of an event. Formally, subjective probabilities are values of a probability measure. From interpretation point of view, subjective probability reflects an individual's experience, perceptions and is not based on countable and, sometimes, detailed facts like objective probability. Subjective probabilities are more appropriate and 'smart' approach for measuring likelihood of events in real-life problems because in such problems the imperfect relevant information conflicts with the very strong assumptions underlying the use of objective probabilities. Real-life relevant information is better handled by experience and knowledge that motivates the use of a subjective basis.

Subjective probability has a series of disadvantages. One of the main disadvantages is that different people would assign different subjective probabilities. It is difficult to reason uniquely accurate subjective probabilities among those assigned by different people. Indeed, given a lack of information, people have to guess subjective probabilities as they suppose. As it is mentioned in [4], using subjective probabilities is a "symptom of the problem, not a solution". Subjective probability is based not only on experience but also on feelings, emotions, psychological and other factors which can distort its accuracy. The other main disadvantage is that subjective probability, due to its preciseness and additivity, fails to describe human behavior under ambiguity.

2 Non-additive measures

The use of the additive probability measure is unsuitable to model human behavior conditioned by uncertainty of the real-world, psychological, mental and other factors. In presence of uncertainty, when true probabilities are not exactly known, people often tend to consider each alternative in terms of the worst case within the uncertainty and don't rely on good cases. In other words, most of people prefer those decisions for which more information is available. This behavior is referred to as ambiguity aversion – people don't like ambiguity and wish certainty. Even when true probabilities are known, most people exhibit non-linear attitude to probabilities – change of likelihood of an event from impossibility to some chance or from a very good chance to certainty are treated much more strongly than the same change somewhere in the range of medium probabilities. Therefore, attitude to values of probabilities is qualitative.

Due to its additivity property, the classical (standard) probability measure cannot reflect the above mentioned evidence. Axiomatizations of such evidence required to highly weaken assumptions on a DM's belief which was considered as the probability measure. The resulted axiomatizations are based either on non-uniqueness of probability measure or on non-additivity of a measure of uncertainty reflecting humans' beliefs. The first axiomatization of choices based on a non-additive measure was suggested by Schmeidler[5]. This is a significant generalization of additive measures-based decisions because the uncovered non-additive measure inherited only normalization and monotonicity properties from the standard probability measure.

Nowadays non-additive measures compose a rather wide class of measures of uncertainty. Below we list non-additive measures used in decision making under ambiguity. For these measures a unifying term *non-additive probability* is used.

We will express the non-additive probabilities in the framework of decision making under ambiguity. Let S be a non-empty set of states of nature and $\mathcal{F}$ be a family of subsets of S. We will consider w.l.o.g. $\mathcal{F} = 2^S$.

The definition of a non-additive probability is as follows[5].

Definition 3[5]. Non-additive probability. A set function $v:\mathcal{F} \to [0,1]$ is called a non-additive probability if it satisfies the following:

(1) $v(\varnothing)=0$

(2) $\forall H,G \in \mathcal{F}$, $H \subset G$ implies $v(H) \le v(G)$

(3) $v(S)=1$

The non-additive probability is also referred to as *Choquet capacity*. Condition (2) is called monotonicity with respect to set inclusion and conditions (1) and (3) are called normalization conditions. Thus, a non-additive probability does not have to satisfy $v(H \cup G)=v(H)+v(G)$. A non-additive probability is called *super-additive* if $v(H \cup G) \ge v(H)+v(G)$ and *sub-additive* if $v(H \cup G) \le v(H)+v(G)$, provided $H \cap G = \varnothing$.

There exist various kinds of non-additive probability many of which are constructed on the base of a set C of probability measures P over S. The one of the well known non-additive probabilities is the *lower envelope* $v_*:\mathcal{F} \to [0,1]$ which is defined as follows:

$$v_*(H)=\min_{P \in C} P(G) \tag{1}$$

The dual concept of the lower envelope is the *upper envelope* $v^*:\mathcal{F} \to [0,1]$ which is defined by replacing $\min$ operator in (1) by $\max$ operator. Lower and upper envelopes are respectively minimal and maximal probabilities of an event $H \subset S$. Therefore, $v_*(H) \le P(H) \le v^*(H), \forall H \subset S, P \in C$. Lower envelope is super-additive, whereas upper envelope is sub-additive. A non-additive probability can also be defined as a convex combination of $v_*(H)$ and $v^*(H)$: $v(H)=\alpha v_*(H)+(1-\alpha)v^*(H)$, $\alpha \in [0,1]$. The parameter α is referred to as a degree of ambiguity aversion. Indeed, α is an extent to which belief $v(H)$ is based on the smallest possible probability of an event H; $1-\alpha$ is referred to as a degree of ambiguity seeking.

The generalizations of lower and upper envelopes are *lower* and *upper probabilities* which are respectively super-additive and sub-additive probabilities. Lower and upper probabilities, denoted respectively $\underline{v}$ and $\overline{v}$, satisfy $\underline{v}(H)=1-\overline{v}(H^c)\ \forall H \in S$, where $H^c = S \setminus H$.

The special case of lower envelopes and, therefore, of lower probabilities are *2-monotone Choquet capacities*, also referred to as *convex capacities*. A non-additive probability is called 2-monotone Choquet capacity if it satisfies

$$v(H \cup G) \ge v(H)+v(G)-v(H \cap G),\ \forall H,G \subset S$$

A generalization of *2-monotone* capacity is an *n-monotone* capacity. A capacity is an *n-monotone*, if for any sequence $H_1,...,H_n$ of subsets of S the following holds:

$$v(H_i \cup ... \cup H_n) \ge \sum_{\substack{I \subset \{1,...,n\} \\ I \ne \varnothing}} (-1)^{|I|-1} v\left(\bigcap_{i \in I} H_i\right)$$

A capacity which is *n-monotone* for all n is called *infinite monotone capacity* or a *belief function*.

The belief function theory, also known as Dempster-Shafer theory, or mathematical theory of evidence, or theory of random sets, was suggested by Dempster in [6], and developed by Shafer in[7]. Belief functions are aimed to be used for describing subjective degrees of belief to an event, phenomena, or object of interest. We will not explain this theory but just mention that it was not directly related to decision making. As it was shown in Ref. [8,9], axiomatization of this theory is a generalization of the Kolmogorov's axioms of the standard probability theory. Due to this fact, a value of a belief function denoted $Bel()$ for an event H can be considered as a lower probability, that is, as a lower bound on a probability of an event H. An upper probability in the belief function theory is termed as a *plausibility function* and is denoted Pl. So, in the belief functions theory probability $P(H)$ of an event H is evaluated as $Bel(H) \le P(H) \le Pl(H)$.

The motivation of using non-additive probabilities in decision making problems is the fact that information on probabilities is imperfect, which can be incomplete, imprecise, distorted by psychological factors etc. Non-additive measure can be determined from imprecise objective or subjective probabilities of states of nature. Impreciseness of objective probabilities can be conditioned by the lack of information ruling out determination of actual exact probabilities (as in Ellsberg experiments). Impreciseness of subjective probabilities can be conditioned by natural impreciseness of human beliefs. Let us consider the case when imprecise information is represented in form of interval probabilities. Given a set of states of nature $S = \{s_1, s_2, ..., s_n\}$, interval probabilities are defined as follows[10]

Definition 4[10]. Interval probability The intervals $\bar{P}(s_i) = [p_{*i}, p_i^*]$ are called the interval probabilities of S if for $p_i \in [p_{*i}, p_i^*]$ there exist $p_1 \in [p_{*1}, p_1^*], \ldots, p_{i-1} \in [p_{*i-1}, p_{i-1}^*]$, $p_{i+1} \in [p_{*i+1}, p_{i+1}^*]$ $, \ldots, p_n \in [p_{*n}, p_n^*]$ such that

$$\sum_{i=1}^{n} p_i = 1$$

From this definition it follows, in particular, that interval probabilities cannot be directly assigned as numerical probabilities. The issue is that in the case of interval probabilities, the requirement to numerical probabilities to sum up to one must be satisfied throughout all the probability ranges. Sometimes, interval probabilities $\bar{P}(s_i) = \bar{P}_i$ can be directly assigned consistently to $n-1$ states of nature $s_1, s_2, ..., s_{j-1}, s_{j+1}, ..., s_n$, and on the base of these probabilities, an interval probability $\bar{P}(s_j) = \bar{P}_j$ for the rest one state of nature s_j will be calculated. For example, consider a set of states of nature with three states $S = \{s_1, s_2, s_3\}$. Let interval probabilities for s_2 and s_3 be assigned as follows:

$$\bar{P}_2 = [0.2, 0.3],\ \bar{P}_3 = [0.5, 0.6]$$

Then, according to the conditions in Definition 4, $\bar{P}_1$ will be determined as follows:

$$\bar{P}_1 = [1 - 0.3 - 0.6, 1 - 0.2 - 0.5] = [0.1, 0.3].$$

Given interval probabilities $\bar{P}_i = [p_{*i}, p_i^*]$ of states of nature $s_i, i = 1,...,n$ a value $v_*(A)$ of a lower probability for an event A can be determined as follows:

$$\begin{aligned} & v_*(A) = \min \sum_{s_i \in A} p_i \\ & s.t. \\ & \sum_{i=1}^{n} p_i = 1 \\ & p_i \le p_i^* \\ & p_i \ge p_{*i} \end{aligned} \tag{2}$$

A value $v^*(A)$ of an upper probability for an event A can be determined by replacing *min* operator by *max* operator in the above mentioned problem. Consider an example. Given interval probabilities $\bar{P}_1 = [0.1, 0.3]$, $\bar{P}_2 = [0.2, 0.3]$, $\bar{P}_3 = [0.5, 0.6]$, the values of the lower and upper probabilities v_* and v^* for $A=\{s_1,s_3\}$, obtained as solutions of the problem (2) are $v_*(A)=0.7$ and $v^*(A)=0.8$.

The above mentioned uncertainty measurescan be listed in terms of the increasing generality between the probability measure and the Choquet capacity as follows:

probability measure $\Rightarrow$ belief function $\Rightarrow$ convex capacity$\Rightarrow$lower envelope $\Rightarrow$ lower probability $\Rightarrow$ Choquet capacity

Based on this, we can conclude that probability measure models human beliefs as purely additive likelihoods, whereas Choquet capacity models the largest spectrum of non-additivity of human beliefs which may be conditioned by ambiguity attitudes, psychological, mental and other influential factors.

An important extension of capacities was suggested by Grabisch and Labreuche for the framework of multicriteria decision making[11]. They provide a motivating example showing a very intuitive choice which can not be described by means of a Choquet capacity. The example concerns evaluating overall skills of students in a high school on the base of their grades in mathematics (M), physics (P), and literature (L). The director as a decision maker considers that mathematics and physics are more important than literature. At the same time, the director would disagree with sufficient flaw in literature no matter what skills are exhibited in M and P. Yet another natural issue underlying the director's reasoning is that M and P are of a redundance as mathematics is a language of physics. Based on all the above mentioned issues, the reasoning of a director is described by the following rules of choice[211]:

Rule 1: For a student good in M, L is more important than P

Rule 2: For a student bad in M, P is more important than L

Consider the following students SA, SB, SC, SD with the marks in M, L, P varying in-between 0 and 20 (Table 1):

Table 1

Students' grades

S	M	P	L
SA	15	18	6
SB	15	16	8
SC	6	13	2
SD	6	11	4

Rules 1 and 2 can be used for easy comparison of the students:

According to Rule 1, $\mathrm{SB} \succ \mathrm{SA}$
According to Rule 2, $\mathrm{SC} \succ \mathrm{SD}$

These common preferences can not be described neither by Choquet integral not by Cumulative Prospect Theory (CPT). As it is shown in [11], the use of Choquet integral requires the capacity v to satisfy contradictory conditions:

$$\mathrm{SC} \succ \mathrm{SD} \text{ implies } v(\{\mathrm{M,P}\}) + v(\{\mathrm{P}\}) > 1$$

$$\mathrm{SB} \succ \mathrm{SA} \text{ implies } v(\{\mathrm{M,P}\}) + v(\{\mathrm{P}\}) < 1$$

To use CPT it is needed to transform the scale [0,20] using a neutral level 10 to the scale [-10,10]. Then, the use of the CPT with the capacities v_1 (for positive part) and v_2 (for negative part) also results in contradiction:

$$\mathrm{SB} \succ \mathrm{SA} \text{ implies } v_1(\{\mathrm{P}\}) > v_2(\{\mathrm{L}\})$$

$$\mathrm{SC} \succ \mathrm{SD} \text{ implies } v_1(\{\mathrm{P}\}) < v_2(\{\mathrm{L}\})$$

The reason that both Choquet integral and CPT fail to represent the considered preferences is that these models are unable to measure comparative importance of two criteria on the base of whether another criterion has positive or negative value. In the considered example, the comparison of importance of P and L depends on the value of M.

In [11], it is suggested a decision model based on a new kind of measure called bi-capacity. Bi-capacity is used to model interaction between 'good' and 'bad' performances with respect to criteria. As compared to capacity, bi-capacity is a two-place set function. The values the bi-capacity takes are from [-1,1]. More formally, the bi-capacity is defined as a set function

$$\eta : W \to [-1,1], \text{ where } W = \{(H,G) : H, G \subset I, H \cap G = \varnothing\}$$

satisfying

$$H \subset H' \Rightarrow \eta(H,G) \le \eta(H',G),\ G \subset G' \Rightarrow \eta(H,G') \le \eta(H,G)$$

and

$$\eta(I,\varnothing) = 1,\ \eta(\varnothing, I) = -1,\ \eta(\varnothing,\varnothing) = 0 .$$

I is the set of indexes of criteria. The attributes in H are satisfied attributes whereas the attributes in G are dissatisfied ones. The integral with respect to bi-capacity as a representation of an overall utility of an alternative $f : I \to R$ is defined as follows:

$$U(f) = \sum_{l=1}^{n} (u(f_{(l)}) - u(f_{(l+1)}))\eta(\{(1),...,(l)\} \cap I^{+}, \{(1),...,(l)\} \cap I^{-}) , \tag{3}$$

provided $u(f_{(l)}) \ge u(f_{(l+1)})$; $I^{+} = \{i \in I : u(f_i) \ge 0\}$, $I^{-} = I \setminus I^{+}$ where $u(f_{(l)})$ is a utility of a value of *(l)*-th criterion for f , $\eta(\cdot,\cdot)$ is a bi-capacity.

In the example above, the choice $\mathrm{SB} \succ \mathrm{SA}$ and $\mathrm{SC} \succ \mathrm{SD}$ on the base rules 1 and 2 is represented by the following inequalities in terms of η :

$$\eta(\{\mathrm{M,P}\},\varnothing) - \eta(\{\mathrm{M,P}\},\{\mathrm{L}\}) > \eta(\{\mathrm{P}\},\varnothing)$$

$$-\eta(\varnothing,\{\mathrm{L}\}) < \eta(\{\mathrm{P}\},\{\mathrm{M,L}\}) - \eta(\varnothing,\{\mathrm{M,L}\})$$

These conditions do not contradict the properties of bi-capacity $\eta(\cdot,\cdot)$. So, bi-capacity based aggregation (3) is able to compare P and L depending on performance in M, which cannot be done no

In special case, when η is equal to the difference of two capacities η_1 and η_2 as $\eta(H,G) = \eta_1(H) - \eta_2(G)$, (3) reduces to the CPT model. In general case, as compared to CPT, (3) is not an additive representation of separately aggregated satisfied and dissatisfied criteria that provides more smart way for decision making.

The disadvantage of a bi-capacity relates to difficulties of its determination, in particular, to computational complexity. In details the issues are discussed in [11].

The bi-capacity-based aggregation which was axiomatized for multicriteria decision making[11] can also be applied for decisions under uncertainty due to formal parallelism between these two problems[12]. Indeed, states of nature are criteria on base of which alternatives are evaluated.

The non-additive measures provide a considerable success in modeling of decision making. However, the non-additive measures only reflect the fact that human choices are non-additive and monotone, which may be due to attitudes to uncertainty, distortion of probabilities etc, but nothing more. However, in real-world it is impossible to accurately determine precisely the 'shape' of a non-additive measure due to imperfect relevant information. Indeed, real-world probabilities of subsets and subsets themselves, outcomes, interaction of criteria, etc are imprecisely and vaguely defined. From the other side, attitudes to uncertainty, extent of probabilities distortion and other behavioral issues violating additivity are also imperfectly known. These aspects rule out exact determination of a uniquely accurate non-additive measure.

3. Fuzzy measures and fuzzy-valued fuzzy measures

In the previous section we considered non-additive measures which are used in the existing decision theories to model non-additivity of DM's behavior. Main shortcoming of using non-additive measures is the difficulty of the underlying interpretation. One approach to overcome this difficulty is to use a lower envelope of a set of priors as a non-additive probability and then to use it in Choquet Expected Utility (CEU) model. However, in real-world problems determination of the set of priors itself meets difficulty of imposing precise constraint determining what prior should be included and what should not be included into this set. In other words, due to lack of information, it is impossible to sharply constraint a range for a probability of a state of nature, that is, to assign accurate interval probability. From the other side, if the set of priors is defined, why to construct lower envelope and use it in the CEU? It is computationally simpler to use the equivalent model – Maximin Expected Utility (MMEU). In this Section, we start with a class of non-additive measures called *fuzzy measures*. Fuzzy measures have their own interpretations that do not require using a set of priors to define them and makes construction of these measures computationally simple. Finally, we will consider an effective extension of non-additive measures called *fuzzy-valued* fuzzy measures which have a good suitability for measuring vague real-world information.

The first fuzzy measure we consider is a *possibility measure*. Possibility means an ability of an event to occur. It was recently mentioned that probability of an event can hardly be determined due to a series of reason, whereas possibility of occurrence of an event is easier to be evaluated. Possibility measure has also its interpretation in terms of multiple priors.

Possibility measure[13] is a non-additive set function $\Pi : \mathcal{F}(S) \to [0,1]$ defined over a σ-algebra $\mathcal{F}(S)$ of subsets of S and satisfying the following conditions:

(1) $\Pi(\varnothing) = 0$

(2) $\Pi(S) = 1$

(3) For any collection of subsets $H_i \in \mathcal{F}(S)$ and any set of indexes I the following holds:

$$\Pi(\bigcup_{i\in I} H_i) = \sup_{i\in I} \Pi(H_i)$$

Possibility measure Π can be represented by *possibility distribution function*, or possibility distribution, for short. Possibility distribution is a function $\pi : S \to [0,1]$ and by means of π possibility measure Π is determined as follows:

$$\Pi(H) = \sup_{s\in H} \pi(s)$$

Condition (2) predetermines normalization condition $\sup_{s\in S} \pi(s) = 1$. Given S as a set of states of nature, possibility measure provides information on possibility of occurrence of an event $H \subset S$. A possibility distribution π_1 is more informative than π_2 if $\pi_1(s) \le \pi_2(s), \forall s \in S$.

The dual concept of the possibility is the concept of necessity. Necessity measure is a set function $N : P(S) \to [0,1]$ that is defined as $N(H) = 1 - \Pi(H^c), H^c = S \setminus H$. This means, for example, that if an event H is necessary (will necessary happen), then the opposite event H^c is impossible.

From the definitions of possibility and necessity measures one can find that the following hold:

1) $N(H) \le \Pi(H)$

2) if $\Pi(H) < 1$ then $N(H) = 0$

3) if $N(H) > 0$ then $\Pi(H) = 1$

4) $\max(\Pi(H), \Pi(H^c)) = 1$

5) $\min(N(H), N(H^c)) = 0$

The possibility differs from probability in various aspects. First, possibility of two sets H and G provided $H \cap G = \varnothing$ is equal to the maximum possibility among those of H and $G : \Pi(H \cup G) = \max(\Pi(H), \Pi(G))$. In its turn probability $H \cap G$ is equal to the sum of those of H and G: $P(H \cup G) = P(H) + P(G)$.

Another difference between possibility measure and probability measure is that the first is compositional that make it more convenient from computational point of view. For example, given $P(H)$ and $P(G)$, we cannot determine precisely $P(H \cup G)$, but can only determine its lower bound which is equal to $\max(P(H), P(G))$ and an upper bound which is equal to $\min(P(H) + P(G), 1)$. At the same time possibility of $H \cup G$ is exactly determined based on $\Pi(H)$ and $\Pi(G): \Pi(H \cup G) = \max(\Pi(H), \Pi(G))$. However, the possibility of an intersection is not exactly defined: it is only known that $\Pi(A \cap B) \le \min(\Pi(A), \Pi(B))$. As to necessity measure, it is exactly defined only for an intersection of sets: $N(H \cap G) = \min(N(H), N(G))$.

Yet another difference is that as compared to probability, possibility is able to model complete ignorance, that is, absence of any information. Absence of any information about H is modeled in the possibility theory as $\Pi(H) = \Pi(H^c) = 1$ and $N(H) = N(H^c) = 0$. From this it follows $\max(\Pi(H), \Pi(H^c)) = 1$ and $\min(N(H), N(H^c)) = 0$.

The essence of the possibility is that it models rather qualitative information about events than quantitative one. Possibility measure only provides ranking of events in terms of their comparative possibilities. For example, $\pi(s_1) \le \pi(s_2)$ implies that s_1 is more possible than s_2. $\pi(s) = 0$ implies that occurrence of s is impossible whereas $\pi(s) = 1$ implies that s is one of the most possible realizations. The fact that possibility measure may be used only for analysis at qualitative, comparative level[14], was proven by Pytyev in [15], and referred to as the principle of relativity in the possibility theory. This principle implies that possibility measure cannot be used to measure actual possibility of an event but can only be used to determine whether the possibility of one event is higher, equal to, or lower than the possibility of another event. Due to this feature, possibility theory is less self-descriptive than probability theory but requires much less information for analysis of events than the latter.

One of the interpretations of possibility measure is an upper bound of a set of probability measures[15,16,17]. Let us consider the following set of probability measures coherent with possibility measure Π :

$$\mathrm{P}(\Pi) = \{P : P(H) \le \Pi(H), \forall H \subseteq S\}$$

Then the upper bound of probability for an event H is

$$\bar{P}(H) = \sup_{P \in \mathrm{P}(\Pi)} P(H)$$

and is equal to possibility $\Pi(H)$. The possibility distribution is then defined as

$$\pi(s) = \bar{P}(\{s\}), \forall s \in S$$

Due to normalization condition $\sup_{s \in S} \pi(s) = 1$, the set $\mathrm{P}(\Pi)$ is always not empty. In [16,17] they show when one can determine a set of probability measures given possibility measure.

Analogous interpretation of possibility is its representation on the base of lower and upper bounds of a set of distribution functions. Let information about unknown distribution function F for a random variable X is described by means of a lower $\underline{F}$ and an upper $\bar{F}$ distribution functions: $\underline{F}(x) \le F(x) \le \bar{F}(x), \forall x \in X$. The possibility distribution π then may be defined as

$$\pi(x) = \min(\bar{F}(x), 1 - \underline{F}(x)).$$

Baudrit and Dubois showed that a set of probabilities generated by possibility distribution π is more informative than a set of probabilities generated by equivalent distribution functions.

In order to better explain what possibility and necessity measures are, consider an example with a tossed coin. If to suppose that heads and tails are equiprobable, then the probabilities of heads and tails will be equal to 0.5. As to possibilities, we can accept that both heads and tails are very possible. Then, we can assign the same high value of possibility to both events, say 0.8. At the same time, as the result of tossing the coin is not intentionally designed, we can state that the necessity of both events is very small. It also follows from $\mathrm{N}(\{heads\}) = 1 - \Pi(\{tails\}), \mathrm{N}(\{tails\}) = 1 - \Pi(\{heads\})$. As this example suggests, we can state that possibility measure may model ambiguity seeking (hope for a good realization of uncertainty), where as necessity measure may model ambiguity aversion.

One of the most practically efficient and convenient fuzzy measures are *Sugeno* measures[19]. Sugeno measure is a fuzzy measure $g : P(S) \to [0,1]$ that satisfies

(1) $g(\varnothing)=0$,

(2) $g(S)=1$;

(3) $H \subset G \Rightarrow g(H) \le g(G)$;

(4) $H_i \uparrow H$ or $H_i \downarrow H \Rightarrow \lim_{i\to+\infty} g(H_i)=g(H)$

From these conditions it follows $g(H \cup G) \ge \max(g(H), g(G))$ and $g(H \cap G) \le \min(g(H), g(G))$. In special case, when $g(H \cup G) = = \max(g(H), g(G))$, Sugeno measure g is the possibility measure. When $g(H \cap G) = \min(g(H), g(G))$, Sugeno measure g is the necessity measure.

The class of Sugeno measures that became very widespread due to its practical usefulness are g_λ measures. g_λ measure is defined by the following condition referred to as the λ-rule:

$$g_\lambda(H \cup G) = g_\lambda(H) + g_\lambda(G) + \lambda g_\lambda(H) g_\lambda(G),\ \lambda \in [-1, +\infty)$$

For the case of $H = S$, this condition is called normalization rule. λ is called normalization parameter of g_λ measure. For $\lambda > 0$ g_λ measure satisfy $g_\lambda(H \cup G) > g_\lambda(H) + g_\lambda(G)$ that generates a class of superadditive measures. For $\lambda > 0$ one gets a class of subadditive measures: $g_\lambda(H \cup G) < < g_\lambda(H) + g_\lambda(G)$. The class of additive measures is obtained for $\lambda = 0$.

One type of fuzzy measures is defined as a linear combination of possibility measure and probability measure. This type is referred to as g_v measure. g_v measure is a fuzzy measure that satisfies the following:

(1) $g_v(\varnothing)=0$

(2) $g_v(S)=1$

(3) $\forall i \in N,\ H_i \in \mathrm{F}\ (S), \forall i \ne j$

(4) $H_i \cap H_j = \varnothing \Rightarrow g_v \left(\bigcup_{i\in N} H_i \right) = (1-v) \bigvee_{i\in N} g_v(H_i) + v \sum_{i\in N} g_v(H_i),\ v \ge 0$

(5) $\forall H, G \in \mathrm{F}\ (S) : H \subseteq G \Rightarrow g_v(H) \le g_v(G)$

g_v is an extension of a measure suggested by Tsukamoto which is a special case obtained when $v \in [0,1]$ [18]. For $v \in [0,1]$ one has a convex combination of possibility and probability measures. For purposes of decision making this can be used to model behavior which is inspired by a mix of probabilistic judgement and an extreme non-additive reasoning, for instance, ambiguity aversion. Such modeling may be good as reflecting that a person is not only an uncertainty averse but also thinks about some ‘average’, i.e. approximate precise probabilities of events. This may be justified by understanding that, from one side, in real-world situations we don’t know exactly the boundaries for a probability of an event. From the other, we don’t always exhibit pure ambiguity aversion by try to guess some reasonable probabilities in situations of ambiguity.

When $v=0$, g_v is the possibility measure and when $v=1$, g_v is the probability measure. For $v=1$, g_v describes uncertainty that differs from both probability and possibility[19].

Fuzzy measures are advantageous type of non-additive measures as compared to non-additive probabilities because they mainly have clear interpretation and some of them are “self-contained”. The latter means that some fuzzy measures, like possibility measure, don’t require a set of priors for their construction. Moreover, a fuzzy measure can be more informative than a set of priors or a set of priors can be obtained from it. Despite of these advantages, fuzzy measures are also not sufficiently adequate for solving real-world decision problems. The issue is that fuzzy measures suffer from the disadvantage of all the widespread additive and non-additive measures: fuzzy measures are numerical representation of uncertainty. In contrast, real-world uncertainty cannot be precisely described – it is not to be caught by a numerical function. This aspect is, in our opinion, one of the most essential properties of real-world uncertainty.

The precise non-additive measures match well the backgrounds of decision problems of the existing theories which are characterized by perfect relevant information: mutually exclusive and exhaustive states of nature, sharply constrained probabilities. However, real-world decision background is much more ‘ill-defined’. Essence of information about states of nature makes them rather blurred and overlapping but not perfectly separated. For example, evaluations like ‘moderate growth’ and ‘strong growth’ of economy cannot be precisely bounded and may overlap to that or another extent. This requires to use fuzzy sets as more adequate descriptions of real objective conditions. Probabilities of states of nature are also fuzzy as they cannot be sharply constrained. This is conditioned by lack of specific information, by the fact that human sureness in occurrence of events stays in form of linguistic estimations like “very likely”, “probability is medium”, “probability is small” etc which are fuzzy. From the other side, this is conditioned by fuzziness of states of nature themselves. When the “strong growth” and “moderate growth” and their likelihoods are vague and, therefore, relations between them are vague – how to obtain precise measure? Natural impreciseness, fuzziness related to states of nature must be kept as the useful data medium in passing from probabilities to a measure – the use of precise measure cannot be sufficiently reasonable and leads to loss of information. From the other side, shape of non-additivity of a DM’s behavior cannot be precisely determined, whereas some linguistic, approximate, but still ground relevant information can be obtained. Fuzziness of the measure in this case serves as a good interpretation.

Thus, a measure which models human behavior under real-world imperfect information should be considered not only as non-additive, but also as fuzzy imprecise quantity that will reflect human evaluation technique based on, in general, linguistic assessments. In this sense a more adequate construction that better matches imperfect real-world information is *a fuzzy number-valued fuzzy measure.* Prior to formally express what is a fuzzy number-valued measure, let us introduce some formal concepts. First concept is a set of fuzzy states of nature $\mathrm{S} = \{\tilde{S}_1,...,\tilde{S}_n\}$, where $\tilde{S}_i, i=1,...,n$ is a fuzzy set defined over a universal set U in terms of membership function $\mu_{\tilde{S}_i}: U \to [0,1]$. The second concept relates to comparison of fuzzy numbers. For two fuzzy numbers $\tilde{A},\tilde{B}$ we say that $\tilde{A} \le \tilde{B}$ if for every $\alpha \in (0,1]$ [20]

$$A_1^\alpha \le B_1^\alpha \text{ and } A_2^\alpha \le B_2^\alpha$$

We consider that $\tilde{A} < \tilde{B}$, if $\tilde{A} \le \tilde{B}$, and there exists an $\alpha_0 \in (0,1]$ such that $A_1^{\alpha_0} < B_1^{\alpha_0}$, or $A_2^{\alpha_0} < B_2^{\alpha_0}$. We consider that $\tilde{A} = \tilde{B}$ if $\tilde{A} \le \tilde{B}$, and $\tilde{B} \le \tilde{A}$ [20].

Denote E_+^1 a set of all fuzzy numbers defined over the unit interval [0,1] and denote F a σ-algebra of subsets of S. A fuzzy number-valued fuzzy measure ((z) fuzzy measure) on F is a fuzzy number-valued fuzzy set function $\tilde{\eta}: \mathrm{F} \to \mathrm{E}_+^1$ with the properties[20]:

(1) $\tilde{\eta}(\varnothing) = 0$;

(2) if $\mathrm{H} \subset G$ then $\eta(\mathrm{H}) \le \eta(\mathrm{G})$;

(3) if $\mathrm{H}_1 \subset \mathrm{H}_2 \subset ..., \mathrm{H}_n \subset ... \in \mathrm{F}$, then $\tilde{\eta}(\bigcup_{n=1}^{\infty} \mathrm{H}_n) = \lim_{n\to\infty} \eta(\mathrm{H}_n)$;

(4) if $\mathrm{H}_1 \supset \mathrm{H}_2 \supset ..., \mathrm{H}_n \in \mathrm{F}$,

and there exists n_0 such that $\tilde{\eta}(\mathrm{H}_{n_0}) \ne \tilde{\infty}$, then $\tilde{\eta}(\bigcap_{n=1}^{\infty} \mathrm{H}_n) = \lim_{n\to\infty} \tilde{\eta}(\mathrm{H}_n)$.

Here limits are taken in terms of supremum metric d [21,22].

So, a fuzzy number-valued fuzzy measure $\tilde{\eta}: \mathrm{F} \to \mathrm{E}_+^1$ assigns to every subset of S a fuzzy number defined over [0,1]. Condition (2) is called monotonicity condition. $\tilde{\eta}: \mathrm{F} \to \mathrm{E}_+^1$ is monotone and is free of additivity requirement.

Let us consider $\tilde{\eta}$ as a fuzzy number-valued lower probability constructed from linguistic probability distribution $\tilde{P}^l$:

$$\tilde{P}^l = \tilde{P}_1/\tilde{S}_1 + \tilde{P}_2/\tilde{S}_2 + ... + \tilde{P}_n/\tilde{S}_n$$

Linguistic probability distribution $\tilde{P}^l$ implies that a state $\tilde{S}_i \in \mathrm{S}$ is assigned a linguistic probability $\tilde{P}_i$ that can be described by a fuzzy number defined over [0,1]. Let us shortly mention that the requirement for numeric probabilities to sum up to one is extended for linguistic probability distribution $\tilde{P}^l$ to a wider requirement which includes degrees of consistency, completeness and redundancy that are described in [28]. Given $\tilde{P}^l$, we can obtain from it a fuzzy set $\tilde{P}^\rho$ of possible probability distributions $\rho(s)$. We can construct a fuzzy-valued fuzzy measure from $\tilde{P}^\rho$ as its lower probability function[25] by taking into account a degree of correspondence of $\rho(s)$ to $\tilde{P}^l$. A degree of membership of an arbitrary probability distribution $\rho(s)$ to $\tilde{P}^\rho$ (a degree of correspondence of $\rho(s)$ to $\tilde{P}^l$) can be obtained by the formula

$$\pi_{\tilde{P}}(\rho(s)) = \min_{i=\overline{1,n}}(\pi_{\tilde{P}_i}(p_i)) \ ,$$

where $p_i = \int_S \rho(s)\mu_{\tilde{S}_i}(s)ds$ is numeric probability of fuzzy state $\tilde{S}_i$ defined by $\rho(s)$. $\pi_{\tilde{P}_i}(p_i) = \mu_{\tilde{P}_i}\left(\int_S \rho(s)\mu_{\tilde{S}_i}(s)ds\right)$ is the membership degree of p_i to $\tilde{P}_i$. To derive a fuzzy-number-valued fuzzy measure $\tilde{\eta}_{\tilde{P}^l}$ we suggest to use the following formulas[23,24,26,27]:

$$\eta(\mathrm{H}) = \bigcup_{\alpha\in(0,1]} \alpha\left[\eta_1^\alpha(\mathrm{H}), \eta_2^\alpha(\mathrm{H})\right] \tag{4}$$

where

$$\eta_1^\alpha(\mathrm{H}) = \inf\left\{ \int_S \rho(s)\max_{\mathrm{S}\in\mathrm{H}} \mu_{\mathrm{S}}(s)ds \,\middle|\, \rho(s)\in P^{\rho^\alpha} \right\},$$

$$\eta_2^\alpha(\mathrm{H}) = \inf\left\{ \int_S \rho(s)\max_{\mathrm{S}\in\mathrm{H}} \mu_{\mathrm{S}}(s)ds \,\middle|\, \rho(s)\in core(\tilde{P}^\rho) \right\}, \tag{5}$$

$$P^{\rho^\alpha} = \rho(s)\Big| \min_{i=\overline{1,n}}(\pi_{\tilde{P}_i}(p_i)) \ge \alpha \ , \ core(\tilde{P}^\rho) = P^{\rho^{\alpha=1}}, \ \mathrm{H}\subset\mathrm{S}$$

The support of $\tilde{\eta}$ is defined as $\operatorname{supp}\tilde{\eta} = cl\left(\bigcup_{\alpha\in(0,1]}\eta^\alpha\right)$. So, $\tilde{\eta}_{\tilde{P}^l}$ is constructed by using $\mu_{\tilde{S}}(s)$ which implies that in construction of the non-additive measure $\tilde{\eta}_{\tilde{P}^l}$ we take into account impreciseness of the information on states of nature themselves.

4. Comparative analysis of the measures of uncertainty

In this section we will discuss features of various existing precise additive and non-additive measures and fuzzy-valued fuzzy measures. The discussion will be conducted in terms of a series of criteria suggested in [17]: interpretation, calculus, consistency, imprecision, assessment, computation. The emphasis will be given to situations in which all the relevant information is described in NL.

Interpretation, Calculus and Consistency. Linguistic probabilities-based fuzzy-valued lower and upper probabilities and their convex combinations have clear behavioral interpretation: they represent ambiguity aversion, ambiguity seeking and their various mixes when decision-relevant information is described in NL. Updating these measures is to be conducted as updating the underlying fuzzy probabilities according to fuzzy Bayes' rule and new construction of these measures from the updated fuzzy probabilities.

Formal validity of the considered fuzzy-valued measures is defined from verification of degrees of consistency, completeness and redundancy of the underlying fuzzy probabilities as initial judgments.

Among the traditional measures, Bayesian probability and coherent lower previsions suggested by Walley[17] (these measures are crisp, non-fuzzy) are only measures which satisfy the considered criteria. Bayesian probability has primitive behavioral interpretation, on base of which the well-defined rules of combining and updating are constructed. Coherent lower previsions have clear and more realistic behavioral interpretation. The rules for updating, combining and verification of consistency of lower previsions are based on the natural extension principle[17,29] which is a general method. However, it is very complex both from analytical and computational points of view.

Possibility theory and the Dempster-Shafer theory, as it is mentioned in [17,29], suffer from lack of the methods to verify consistency of initial judgments and conclusions.

Imprecision. Fuzzy-valued lower and upper previsions and their convex combinations are able to transfer additional information in form of possibilistic uncertainty from states of nature and associated probabilities to the end up measuring of events. As a result, these measures are able to represent vague predicates in NL and partial and complete ignorance as degenerated cases of linguistic ambiguity.

Dempster-Shafer theory is a powerful tool for modeling imprecision and allows to model complete ignorance. However, this theory suffers from series of significant disadvantages[14]. Determination of basic probabilities in this theory may lead to contradictory results. From the other side, under lack of information on some elements of universe of discourse, values of belief and plausibility functions for these elements become equal to zero which means that occurrence of them will not take place. However, this is not justified if the number of observations is small.

Possibility theory is able to model complete ignorance and requires much less information for modeling than probability theory. Possibility measure, as opposed to probability measure, is compositional, which makes it computationally more convenient. However, possibility measure has a serious disadvantage as compared with the probability measure. This theory allows only for qualitative comparative analysis of events – it allows determining whether one event is more or less possible than another, but does not allow determining actual possibilities of events.

Dempster-Shafer theory, lower prevision theory and possibility theory can be considered as special cases of multiple priors representations[14]. In this sense, belief and plausibility functions can be considered as an upper and lower bounds of probability respectively. Possibility theory also can be used for representation of bounds of multiple priors and is used in worst cases of statistical information.

Possibility theory, Dempster-Shafer theory and coherent lower previsions as opposed to Bayesian probabilities are able to model ignorance, impreciseness and NL-based vague evaluations. However, as these theories are based on precise modeling of uncertainty, use of them lead to significant roughening of NL-based information. For example, linguistic description of information on states of nature and their probabilities creates a too high vagueness for these precise measures to be believable or reliable in real-life problems.

Assessment. Fuzzy-valued lower probability is obtained from the linguistic probability assessments which are practical and human-like estimations for real-world problems. Coherent lower prevision can also be obtained from the same sources, but, as a precise quantity, it will be not reliable as very much deviated from vague and imprecise information on states of nature and probabilities. From the other side, fuzzy-valued lower or upper probabilities are computed from fuzzy probabilities.

The other main advantage of fuzzy-valued lower probabilities and fuzzy probabilities constructed for NL-based information is that they, as opposed to all the other measures, don’t require independence or non-interaction assumptions on the measured events, which are not accurate when we deal with overlapping and similar objective conditions.

Computation. The construction of unknown fuzzy probability, the use of fuzzy Bayes’ formula and construction of a fuzzy-valued lower prevision are quite complicated variational or nonlinear programming problems. However, the complexity here is the price we should pay if we want to adequately formalize and compute from linguistic descriptions. However, as opposed to the natural extension-based complex computations of coherent lower previsions which involves linear programming, the computation of fuzzy-valued previsions is more intuitive, although arising the well known problems of nonlinear optimization.

Computations of coherent lower previsions (non-fuzzy) can be reduced to simpler computations of possibility measures and belief functions as their special cases, but it will lead to the loss of information.

Adequacy of the use of a fuzzy-valued lower (upper) probability consists in its ability to represent linguistic information as the only adequate relevant information on dependence between states of nature in real-life problems. The existing non-additive measures, being numerical-valued, cannot adequately represent such information. To some extent it can be done by lower previsions, but in this case one deals with averaging of linguistic information to precise values which leads to loss of information.

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ISSUES DECISION ON THE ASSESSMENT OF RISK IN A TURBULENT

X.A.Primova

100125, Tashkent, Uzbekistan Center for development of software products and hardware-software complexes for TUIT, Durmon yuli-25 street, Ph. +99871 262-71-55, xolida_primova@mail.ru

Keywords: *The adoption of the decision, assessment, prognosis, risk, fuzzy set, a stable solution.*

1. Introduction

For complex processes, characterized by uncertainty (inaccuracy, none-stochastically, incomplete, unclear) in the initial information and situations, internal and external environment, is usually not possible to construct simple mathematical models adequate. Information about the parameters of such processes is expressed by experts in the form of words and sentences, ie in linguistic form. In such cases it is advisable to use the system modeling, decision making and management, using technology tools of soft computing (Soft Computing).

In evaluating alternative decision-making for risk assessment under uncertainty is a problem of development of fuzzy logic models based on fuzzy inference rules. However, a generic method for constructing fuzzy assessment models do not exist. The advantage of fuzzy logic lies in the possibility of using expert knowledge about the object in the form "If the" input ", the" O "." In the process of developing a fuzzy logic model for risk assessment based on the conclusions of fuzzy rules, researchers are often faced with the problem of finding approximate solutions to ill-posed problems. In describing the objectives of the evaluation and prediction of risk models in the form of fuzzy set of fuzzy rules, whose parameters are presented the corresponding membership function, in many cases, these problems are reduced to the ill-posed problems. The problem is posed if the following conditions: 1) the problem has a solution for any admissible initial data, and 2) every input data corresponds to only one solution, and 3) the solution is stable. It was felt that the ill-posed problems can not be met in addressing the physical and technical problems and that the ill-posed problems can not construct an approximate solution in the absence of stability. The expansion of automation in obtaining experimental data has led to a large increase in the volume of data on them the need to establish information about the objects need to be considered ill-posed problems. The development of computer technology and its application to solving mathematical problems has changed the view to the possibility of constructing approximate solutions to ill-posed problems. It should be noted that the methods for solving ill-posed problems of decision support systems are designed only for some special cases of models (for example, models based on classical logic).

The formalization of tasks assessing and predicting risks using fuzzy rules often leads to the formulation of these problems as incorrect. Therefore, the analysis and formalization of ill-posed problems for risk assessment in fuzzy environment, modeling and algorithmic solutions to ensure their relevance to modern decision support systems.

In weak formalized risk assessment systems are widely used methods of "soft computing" forecasting and decision-making, in particular, methods based on fuzzy set theory, fuzzy logic and fuzzy arithmetic. Research in this direction are in the U.S., Canada, England, Japan, Germany, Italy, France, Russia, Ukraine, Azerbaijan and other countries such leading scientists as Zadeh, R.Bellman, E.Mamdani, M.Sugeno, A. Kaufman, D. Dubois, A. Prades, D.A.Pospelov, A.N.Melihov, A.N.Borisov, Karpenko, Zaichenko R.A.Aliev, M.Dzhamshidy, VI Norkin, V.S.Mihalevich and P.S.Knopov [2,3]. Developing the theory of fuzzy sets and its applications have continued to research scientists of Uzbekistan F.B.Abutaliev, T.F.Bekmuratov, M.A.Rahmatullaev, N.A.Ignatev, R.N.Usmonov, D.T.Mukhamedieva [1,4]. In these papers, the technique applying the theory of fuzzy sets for modeling processes and the formation of slaboformalizuemyh decisions based on them.

Of particular note is the work of AN Tikhonov, VY Arsenin for finding approximate solutions to ill-posed problems and work to find A.V.Yazenin unstable solution of the optimization problem [5,6].

2. Building a fuzzy logic model

However, in order not studied the problem of solving ill-posed problems arising in the process of constructing a fuzzy logic model for risk assessment in slaboformalizuemyh systems.

In general, you want to build a model based on fuzzy inference rules:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} - \text{с весом}\, w_{jp}\right) \to y_j = b_{m_0} + b_{m_1} x_1^j + \ldots + b_{m_n} x_n^j .$$

In the process of constructing a model to find such values of the coefficients of the rules $B = (b_{ij}), i = \overline{1,n},\ j = \overline{1,m}$, under which the minimum of the following expression:

$$\sum_{r=\overline{1,M}} \left(y_r - y_r^f\right) \to \min , \tag{1}$$

were y_r^f - the result of fuzzy inference rules with a parameter in the r-th row of the sample (X_r).

The input vector $X_r = (x_{r,1}, x_{r,2}, \ldots, x_{r,n})$ corresponds to the following result of fuzzy inference:

$$y_r^f = \frac{\sum_{j=\overline{1,m}} \mu_{c_j}(X_r)\cdot c_j}{\sum_{j=\overline{1,m}} \mu_{c_j}(X_r)} \quad \text{or} \quad y_r^f = \frac{\int \mu_c\,(X_r)\cdot c\; dc}{\int \mu_c\,(X_r) dc} ; \tag{2}$$

here $c_j = b_{j0} + b_{j1}x_{11} + b_{j2}x_{12} + \ldots\ldots + b_{jn}x_{1n}$ - j-way rules; $\mu_{c_j}(x_r)$ - membership function corresponding to each experimental data:

$$\begin{aligned} \mu_{c_j}(X_r) = {} & \mu_{j1}(x_{r1})\cdot \mu_{j1}(x_{r2})\cdot \mu_{j1}(x_{r3})\cdot \ldots\ldots\cdot \mu_{j1}(x_{rn}) \vee \\ & \vee\, \mu_{j2}(x_{r1})\cdot \mu_{j2}(x_{r2})\cdot \mu_{j2}(x_{r3})\cdot \ldots\ldots\cdot \mu_{j2}(x_{rn}) \vee \\ & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ & \vee\, \mu_{jm}(x_{r1})\cdot \mu_{jm}(x_{r2})\cdot \mu_{jm}(x_{r3})\cdot \ldots\ldots\cdot \mu_{jm}(x_{rn}), \end{aligned}$$

$$\beta_{jr} = \frac{\mu_{c_j}(X_r)\cdot c_j}{\sum_{j=\overline{1,m}} \mu_{c_j}(X_r)} \quad \text{or} \quad \beta_{jr} = \frac{\mu_{c_j}(X_r)\cdot c_j}{\int \mu_c(X_r) dc} .$$

Then (2) can be rewritten as follows:

$$y_r^f = \sum_{j=\overline{1,m}} \beta_{r,j}\cdot c_j = \sum_{j=\overline{1,m}} \left(\beta_{r,j}\cdot b_{j,0} + \beta_{r,j}\cdot b_{j,1}\cdot x_{r,1} + \beta_{r,j}\cdot b_{j,2}\cdot x_{r,2} + \ldots + \beta_{r,j}\cdot b_{j,n}\cdot x_{r,n}\right)$$

We introduce the following notation:

$$Y^f = \left(y_1^f, y_2^f, \ldots, y_M^f\right)^T,$$

$$Y = \left(y_1, y_2, \ldots, y_M\right)^T,$$

$$A = \begin{bmatrix} \beta_{1,1},\ldots,\beta_{1,m}, & x_{1,1}\cdot\beta_{1,1},\ldots,x_{1,1}.\beta_{1,m}, & \ldots, & x_{1,n}\cdot\beta_{1,1},\ldots,x_{1,n}\cdot\beta_{1,m} \\ \vdots & & & \\ \beta_{M,1},\ldots,\beta_{M,m}, & x_{M,1}\cdot\beta_{1,1},\ldots,x_{M,1}\cdot\beta_{1,m}, & \ldots, x_{M,n}\cdot\beta_{M,1},\ldots, & x_{M,n}\cdot\beta_{M,m} \end{bmatrix}.$$

Then the problem (1) can be rewritten in the following matrix form: find a vector in that condition

$$E = (Y - Y^f)^T \cdot (Y - Y^f) \to \min . \tag{3}$$

The solution of (3) corresponds to the solution of the equation

$$Y = A\cdot B . \tag{4}$$

During the development of fuzzy logic models for risk assessment based on fuzzy inference rules, in cases where the problem (4) does not satisfy the correctness, are often faced with the problem of finding an approximate solution of ill-posed problems.

3. Construction of fuzzy-sustainable solutions for different membership functions

The results of the subsequent mathematical analysis to a large extent depend on how adequately used in the initial information about the subject of research in modeling, ie What is the adequacy of the model. In this regard, the main tasks of modeling poorly formalized processes are:

- analysis of compact and noncompact correctness classes, establishing the possibility of obtaining fuzzy and fuzzy-stable solutions of ill-posed problems, formalized in the process of constructing a model of risk assessment using a variety of membership functions;
- development of algorithms for solving unstable problems, formalized in the process of constructing a model of assessment and prediction of risk based on fuzzy sets.

Suppose that the operator $A: z \to U$ is continuous $z \in Z$, then we can build a sustainable solution to the fuzzy membership function defined in the table 1.

Table 1

Construction of fuzzy-sustainable solutions for different membership functions

№ p/p	Membership function	The proof of the possibility of constructing fuzzy-sustainable solutions
1	$\mu(z) = e^{-k\\|Az-u\\|}$	$\forall \alpha \in (0,1],\ k > 1,\ 0 \le z < \infty$, $\varepsilon(\alpha) = -\frac{\ln \alpha}{k}$. One can construct a fuzzy-stable solution in the form $A_\alpha = O_{\varepsilon(\alpha)}(Az),\ \bigcup_\alpha \alpha A_\alpha,\ \lim_{\alpha \to 1} \varepsilon(\alpha) = 0$.
2	$\mu(z) = e^{-k\\|Az-u\\|^2}$	$\forall \alpha \in (0,1],\ k > 1,\ \varepsilon(\alpha) = \sqrt{-\frac{\ln \alpha}{k}}$. One can construct a fuzzy-stable solution in the form $A_\alpha = O_{\varepsilon(\alpha)}(Az),\ \bigcup_\alpha \alpha A_\alpha,\ \lim_{\alpha \to 1} \varepsilon(\alpha) = 0$
3	$\mu(z) = \frac{1}{1 + k\\|Az-u\\|^2}$	$\forall \alpha \in (0,1],\ k > 1,\ \varepsilon(\alpha) = \sqrt{\frac{1-\alpha}{k\alpha}}$. One can construct a fuzzy-stable solution in the form $A_\alpha = O_{\varepsilon(\alpha)}(Az),\ \bigcup_\alpha \alpha A_\alpha,\ \lim_{\alpha \to 1} \varepsilon(\alpha) = 0$.
4	$\mu(z) = \begin{cases} 0, & -\infty < (Az-u) \le -\frac{1}{\sqrt[k]{a}}, \\ 1 - a\left(-(Az-u)\right)^k, & -\frac{1}{\sqrt[k]{a}} \le (Az-u) \le 0, \\ 1 - a(Az-u)^k, & 0 \le (Az-u) \le \frac{1}{\sqrt[k]{a}}, \\ 0, & \frac{1}{\sqrt[k]{a}} \le (Az-u) < \infty. \end{cases}$	$\forall \alpha \in (0,1],\ -\frac{1}{\sqrt[k]{a}} \le z \le 0,\ 0 \le z \le \frac{1}{\sqrt[k]{a}}$, $\varepsilon(\alpha) = \sqrt[k]{\frac{1-\alpha}{a}}$. One can construct a fuzzy-stable solution in the form $A_\alpha = O_{\varepsilon(\alpha)}(Az),\ \bigcup_\alpha \alpha A_\alpha,\ \lim_{\alpha \to 1} \varepsilon(\alpha) = 0$
5	$\mu(z) = \begin{cases} 0, & -\infty < (Az-u) \le -a_2, \\ \frac{a_2 + (Az-u)}{a_2 - a_1}, & -a_2 \le (Az-u) \le -a_1, \\ 1, & -a_1 \le (Az-u) \le a_1 \\ \frac{a_2 - (Az-u)}{a_2 - a_1}, & a_1 \le (Az-u) \le a_2, \\ 0, & a_2 \le (Az-u) < \infty. \end{cases}$	$\forall \alpha \in (0,1],\ -a_2 \le z < -a_1,\ a_1 \le z < a_2$, $\varepsilon(\alpha) = a_2 - (a_2 - a_1)\alpha$, One can construct a fuzzy-stable solution in the form $A_\alpha = O_{\varepsilon(\alpha)}(Az),\ \bigcup_\alpha \alpha A_\alpha,\ \lim_{\alpha \to 1} \varepsilon(\alpha) = 0$.

4. Conclusion

The algorithms and programs for solving unstable problems, formalized in the process of constructing a model of assessment and prediction of risk based on fuzzy sets. In order to assess the effectiveness of the developed software for computer experiment conducted to address the unsustainable problems, formalized in the process of constructing a model of assessment and prediction of risk in slaboformalizuemyh systems.

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IMPRECISE PROBABILITY ANALYSIS

O.H. Huseynov

Department of Computer-Aided Control Systems Azerbaijan State Oil Academy Baku, Azerbaijan,
oleg_huseynov@yahoo.com

Abstract*: Probability theory has a large spectrum of successful applications. However, the assumptions underlying this theory are too strong for real-world information which results in the fact that probabilities cannot often be precisely determined. Imprecise probability is a new challenging area of research and applications when relevant information is characterized by imprecision, vagueness and ambiguity and, as a result, is described in natural language (NL). In the present paper an analysis of the existing directions in the area of imprecise probability. We conclude that fuzzy probabilities are more adequate for describing real-world probability-relevant information.*

Keywords*: imprecise probability, interval probability, multiple priors, fuzzy probability.*

1. Introduction

The probability theory has a large spectrum of successful applications. However, the use of a single probability measure for quantification of uncertainty has severe limitations main of which are the following [1]: 1) precise probability is unable to describe complete ignorance (total lack of information); 2) one can determine probabilities of some subsets of a set of possible outcomes but cannot always determine probabilities for all the subsets; 3) one can determine probabilities of all the subsets of a set of possible outcomes but it will require laborious computations.

Indeed, classical probability imposes too strong assumptions that significantly limit its use even in simple real-world or laboratory problems. Famous Ellsberg experiments and Schmeidler's coin example are good illustrative cases when available information appears insufficient to determine actual probabilities. Good discussion of real-world tasks which are incapable to be handled within probabilistic framework is given in [2].

Imprecise probabilities

In real problems, quality of decision-relevant information does not require the use of a single probability measure. As a result, probabilities cannot be precisely determined and are imprecise. For such cases, they use constraints on a probability of an event A in form of lower and upper probabilities denoted $\underline{P}(A)$ and $\bar{P}(A)$ respectively. That is, a probability $P(A)$ of an event A is not known precisely but supposed to be somewhere between $\underline{P}(A)$ and $\bar{P}(A)$: $P(A) \in [\underline{P}(A), \bar{P}(A)]$ where $0 \le \underline{P}(A) \le \bar{P}(A) \le 1$; in more general formulation, constraints in form of lower and upper expectations for a random variable are used. In special case when $\underline{P}(A) = \bar{P}(A)$ a framework of lower and upper probabilities degenerates to a single probability $P(A)$. Complete lack of knowledge about likelihood of A is modeled by $\underline{P}(A)=0$ and $\overline{P}(A)=1$. This means that when likelihood of an event is absolutely unknown, they suppose that probability of this event may take any value from [0,1] (from impossibility to occur up to certain occurrence).

Constraints on probabilities imply existence of a set of probability distributions, that is, multiple priors, which are an alternative approach to handle incomplete information on probabilities. Under the certain consistency requirements the use of multiple priors is equivalent to the use of lower and upper probabilities. Approaches in which imprecise probabilities are handled in form of intervals $[p_1, p_2]$. (Such approaches are unified under the name *interval probabilities*.

An alternative way to handle incomplete information on probabilities is the use of non-additive probabilities, typical cases of which are lower probabilities and upper probabilities and their convex combinations. However, multiple priors are more general and intuitive approach to handle incomplete probability information than non-additive probabilities.

The most fundamental axiomatization of imprecise probabilities was suggested by Peter Walley who suggested the term *imprecise probabi-lities.* The behavioral interpretation of Walley's axiomatization is based on buying and selling prices for gambles. Walley's axiomatization is more general than Kolmogorov's axiomatization of the standard probability theory. The central concept in Walley's theory is the lower prevision concept which generalizes standard (additive) probability, lower and upper probabilities and non-additive measures. However, in terms of generality, the concept of lower prevision is inferior to multiple priors. Another disadvantage of lower prevision theory is its high complexity that limits its practical use.

Alternative axiomatizations of imprecise probabilities were suggested by Kuznetsov [3] and Weichselberger [4] for the framework of interval probabilities. Weichselberger generalizes Kolmogorov's axioms to the case of interval probabilities but, as compared to Walley, does not suggest a behavioral interpretation. However, his theory of interval probability is more tractable in practical sense.

What is the main common disadvantage of the existing imprecise probability theories? This disadvantage is missing the intrinsic feature of probability-related information which was pointed out by L. Savage even before emergence of the existing imprecise probability theories:

Savage wrote [5]: "…there seem to be some probability relations about which we feel relatively 'sure' as compared with others…. The notion of 'sure' and 'unsure' introduced here is vague, and my complaint is precisely that neither the theory of personal probability as it is developed in this book, nor any other device known to me renders the notion less vague". Indeed, in real-world situations we don't have sufficient information to be definitely sure or unsure in whether that or another value of probability is true. Very often, our sureness stays at some level and does not become complete being hampered by a lack of knowledge and information. That is, sureness is a matter of a strength, or in other words, of a degree. Therefore, 'sure' is a loose concept, a vague concept. In our opinion, the issue is that in most real-world decision-making problems, relevant information perceived by DMs involves possibilistic uncertainty. Fuzzy probabilities are the tools for resolving this issue to a large extent because they represent a degree of truth of a considered numeric probability.

Fuzzy probabilities are superior from the point of view of human reasoning and available information in real-world problems than interval probabilities which are rather the first departs from precise probabilities frameworks. Indeed, interval probabilities only show that probabilities are imprecise and no more. In real-world, the bounds of an interval for probability are subjectively 'estimated' but not calculated or actually known as they are in Ellsberg experiment. Subjective assignments of probability bounds will likely inconsistent with human choices in real-world problems as well as subjective probabilities do in Ellsberg experiment. Reflecting imperfect nature of real-world information, probabilities are naturally soft-constrained.

As opposed to second-order probabilities which are also used to differentiate probability values in terms of their relevance to available information, fuzzy probabilities are more relaxed constructs. Second-order probabilities are too exigent to available information and more suitable for designed experiments.

Fuzzy probability is formally a fuzzy number defined over [0,1] scale to represent an imprecise linguistic evaluation of a probability value. Representing likelihoods of mutually exclusive and exhaustive events, fuzzy probabilities are tied together by their basic elements summing up to one. Fuzzy probabilities define a fuzzy set $\tilde{P}^{\rho}$ of probability distributions ρ which is an adequate representation of imprecise probabilistic information related to objective conditions especially when the latter are vague. As compared to the use of second-order probabilities, the use of possibility distribution over probability distributions [6,1] is appropriate and easier for describing DM's (or experts') confidence. This approach does not require from a DM to assign beliefs over priors directly. Possibility distribution can be constructed computationally from fuzzy probabilities assigned to states of nature [7,8]. This means that a DM or experts only need to assign linguistic evaluations of probabilities to states of nature as they usually do. For each linguistic evaluation a fuzzy probability can then be defined by construction of a membership function. After this possibility distribution can be obtained computationally [7,8] without involving a DM.

We can conclude that fuzzy probabilities [9,10,11,12,13] are a successful interpretation of imprecise probabilities which come from human expertise and perceptions being linguistically described. For example, in comparison to multiple priors consideration, for majority of cases, a DM has some linguistic additional information coming from his experience or even naturally present which reflects unequal levels of belief or possibility for one probability distribution or another. This means, that it is more adequate to consider sets of probability distributions as fuzzy sets which allow taking into account various degrees of belief or possibility for various probability distributions. Really, for many cases, some probability distributions are more relevant, some probability distributions are less relevant to the considered situation and also it is difficult to sharply differentiate probabilities that are relevant from those that are irrelevant. This type of consideration involves second-order uncertainty, namely, probability-possibility modeling of decision-relevant information.

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THE DECISION OF A TASK OF SYNTHESIS OF AN INTERVAL REGULATOR ENSURING STABILITY OF MECHANICAL TWO-MASS SYSTEM

E.E. Esanov, X.S. Sodikov, S.D. Murodova, M.R. Ishmamatov

Navoi state mining institute

Abstract*: In the given work the task of synthesis of an interval regulator ensuring stability of mechanical two-mass system, finding the application in a robotics, designing of protective-vibration systems is decided (solved).*

In practice of designing of systems of automatic control (SAC) rather often there is a situation, when the real meanings (importance) of separate parameters of object of management are unknown and there is no their any statistical description. Uncertainty in parameters can appear owing to the various reasons: uses at account of a control system of the simplified models, approximately real physical process, and presence of non-stationary factors in the equations of mathematical model of object. Besides the object of management can be influenced, for example, by(with) such technology factors, as defects of the equipment, vibration, non-uniformity of a course, change of modes of operations, error of measuring tools, discrepancy of scales. The operational features also can result in a deviation (rejection) of real testimonials from of rating values. In all listed cases character of variations of unknown parameters SAC consider (count) uncertain, as their changes are subordinated only a priory to restrictions. The researches carry out such SAC within the framework of the theory of management in conditions of uncertainty. For the decision of tasks of management of objects with uncertain parameters usually involve (attract) of a minimax method and theory of games, theories of stochastic management, theory of invariance, theory of sensitivity, theory compensation. Use of this or that approach depends on a kind is not determined and requirements showed to structure and quality SAC. The advantage of the given approach is, that for accounts it is enough to know the bottom and top borders of ranges of change of uncertain parameters, which are usually known in practice.

Last years in designing robust SAC has appeared new one direction, which distinctive feature is the description of uncertain parameters with the help of numerical intervals and use at synthesis of the special mathematical device - interval analysis [1]. In a basis last the concept of interval number representing two-parametrical set, consisting from the material numbers which are taking place between given borders on a numerical axis is necessary.

The task of stabilization of mechanical system arises in many areas of modern engineering connected to management of manipulators, robots, with protective-vibration of objects from sources of fluctuations. The task of stabilization of system consists in synthesis of such regulator, which would reduce fluctuations of object called by forces arising in communications (connections), connecting object with a source of fluctuations.

In the given work the task of synthesis of an interval regulator ensuring stability of mechanical two-mass system, finding the application in a robotics, designing protective-vibration of systems is decided (solved).

The a little bit simplified mechanical system consisting of two weights and two springs (see a fig. 1) and having of uncertainty in the task of some parameters let is given [2]. It is required to synthesize a regulator ensuring stabilization of system for a short interval of time at the following assumptions: the force of weight and force of an attraction between objects is not taken into account, the fluctuations of cargoes occur in weightlessness, the spring ideal (losses of energy no).

The object of management is described by the following equations:

$$\begin{cases} m_1 \cdot \dfrac{d^2}{dt^2} x_1 = U_1 + k_2 \cdot (x_2 - x_1) - k_1 \cdot x_1; \\ m_2 \cdot \dfrac{d^2}{dt^2} x_2 = U_2 + k_2 \cdot (x_2 - x_1), \end{cases}$$

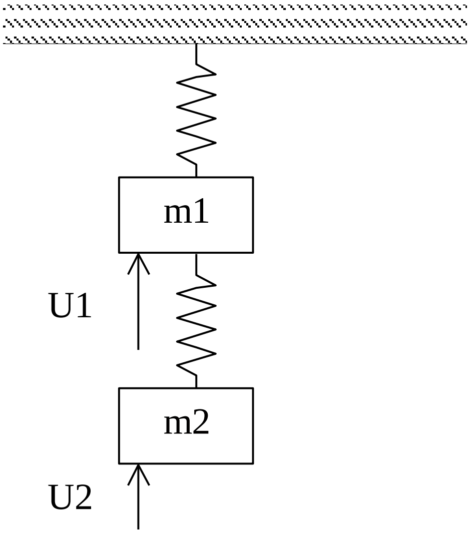

Fig. 1. ***The circuit of mechanical two-mass system.***

Where, k_1, k_2- factors of compression of springs; m_1, m_2 - weight of cargoes; U_1, U_2- forces working on cargoes; x_1, x_2 - size of vertical displacement of cargoes.

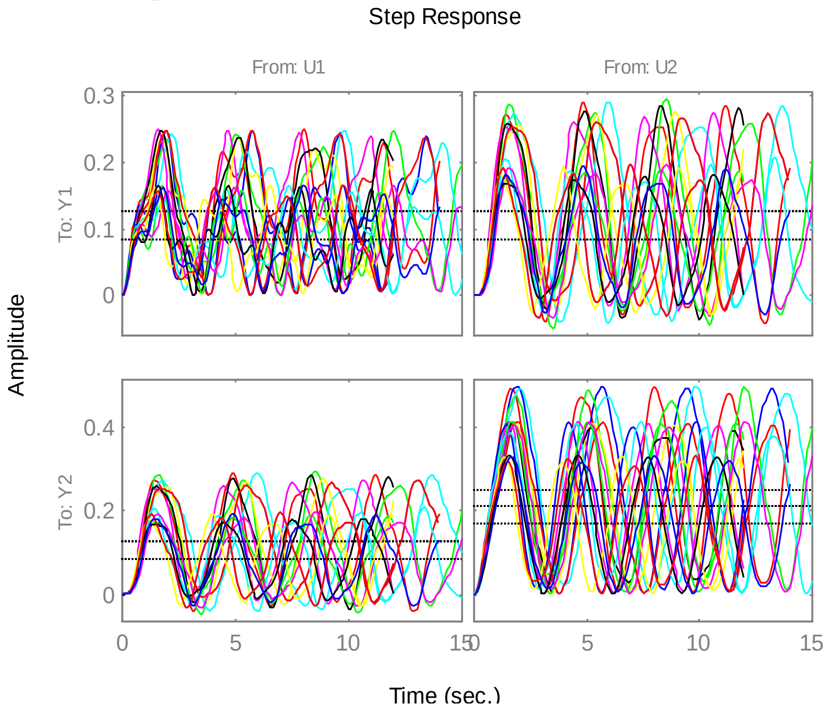

Fig. 2. ***Transients of object.***

After some transformations we shall receive the description of object in space of condition

$$A = \begin{bmatrix} 0 & -(k_2 + k_1)/m_1 & 0 & k_2/m_1 \\ 1 & 0 & 0 & 0 \\ 0 & k_2/m_2 & 0 & -k_2/m_2 \\ 0 & 0 & 1 & 0 \end{bmatrix}; \; B = \begin{bmatrix} 1/m_1 & 0 \\ 0 & 0 \\ 0 & 1/m_2 \\ 0 & 0 \end{bmatrix}; \; C = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

The parameters of object have uncertainty and are given as $k_1 = [8;12]; k_2 = [8;12]; m_1 = [0.8;1.2]; m_2 = [0.8;1.2]$. The transients of object are submitted in a fig. 2.

It is required for the given object to synthesize a regulator as it is possible of the smaller order ensuring stability of system, transients of the minimal duration and condition $\max_i \mathrm{Re}(\lambda_i) < -0.4$.

After some transformations with use of rules of interval mathematics we have interval matrix transfer function of object

$$W_p(s)=\begin{bmatrix} \dfrac{[0.8333;1.25]s^2+[5.556;18.75]}{s^4+[20;40]s^2+[40;225]} & \dfrac{[5.556;31.25]}{s^4+[20;40]s^2+[40;225]} \\ \dfrac{[5.556;18.75]}{s^4+[20;40]s^2+[40;225]} & \dfrac{[0.833;1.25]s^2+[11.11;37.5]}{s^4+[20;40]s^2+[40;225]} \end{bmatrix}$$

At the first stage we shall choose structure a regulator of the first order of a kind

$$W_c(s)=\begin{bmatrix} \dfrac{n_{c0}^{11}}{s+d_{c0}^{11}} & \dfrac{n_{c0}^{12}}{s+d_{c0}^{12}} \\ \dfrac{n_{c0}^{21}}{s+d_{c0}^{21}} & \dfrac{n_{c0}^{22}}{s+d_{c0}^{22}} \end{bmatrix}.$$

For maintenance of stability interval characteristic polynomial of the closed system about $n=6$ it is necessary to ensure (supply) stability four polynom of Xaritonov's [3]. After action optimum of procedure with function [4]

$$f(\Lambda)=\mu, \qquad \mu=\begin{cases} 0, \textit{если } \lambda\in D; \\ \rho(\lambda,D), \textit{если } \lambda\notin D, \end{cases}$$

Where D - given area of an arrangement of poles of the closed system in space $\boldsymbol{R}^n$; n - quantity(amount) of poles of system; $\lambda=(\lambda_1,\lambda_2,\ldots,\lambda_n)$ - point in space $\boldsymbol{R}^n$ with coordinates connected to meanings(importance) of roots; $\rho(\lambda, D)$ - distance from a point with coordinates $(\lambda_1,\lambda_2,\ldots,\lambda_n)$ up to the given area D.

$$\rho(\lambda_i,D)=\sqrt[p]{|\rho(\lambda_1,D)|^p+|\rho(\lambda_2,D)|^p+\ldots|\rho(\lambda_n,D)|^p},$$

Where $\rho(\lambda_i,D)$ - distance on coordinate λ_i up to the nearest point D, we receive a regulator

$$W_c(s)=\begin{bmatrix} \dfrac{-1.746}{s+3.007} & \dfrac{-2.608}{s+0.4322} \\ \dfrac{4.287}{s+0.8041} & \dfrac{-10.73}{s+2.842} \end{bmatrix} \tag{1}$$

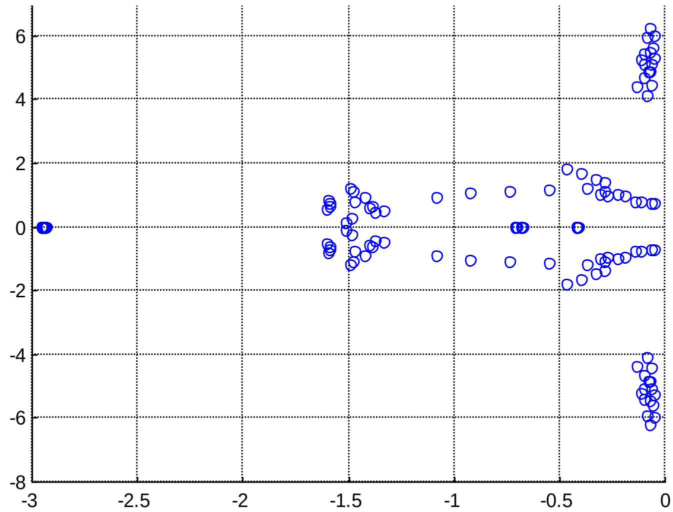

Fig. 3. ***An arrangement of poles of system with a regulator (1).***

Having poles of the closed system in area submitted on Having poles of the closed system in area submitted in a fig. 3 and transients, represented on a fig. 4.

As is seen from figures the required quality of transients is not achieved. Let's increase the order of numerator of matrix transfer function

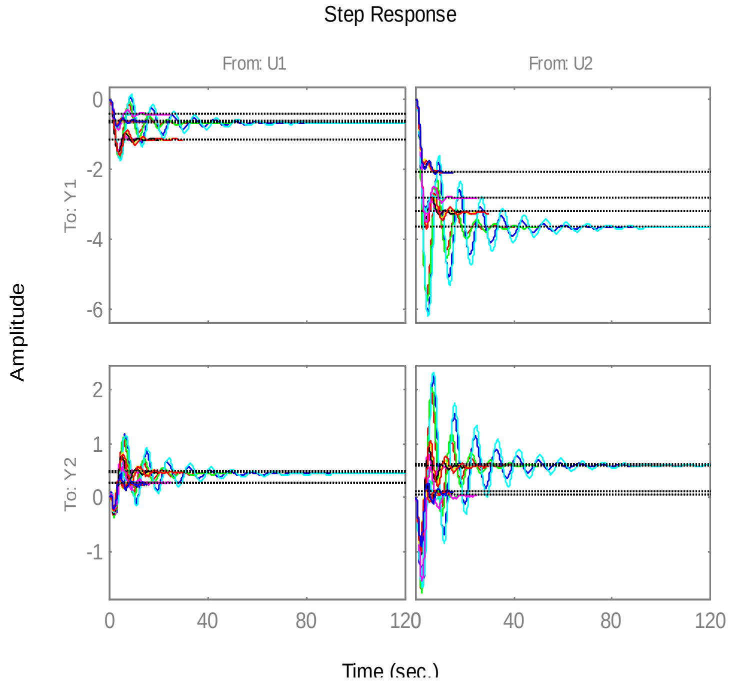

Fig. 4. ***Transients in system with a regulator (1).***

Regulator on unit also we shall accept

$$W_c(s) = \begin{bmatrix} \dfrac{n_{c1}^{11}s + n_{c0}^{11}}{d_{c1}^{11}s+1} & \dfrac{n_{c1}^{12}s + n_{c0}^{12}}{d_{c1}^{12}s+1} \\ \dfrac{n_{c1}^{21}s + n_{c0}^{21}}{d_{c1}^{21}s+1} & \dfrac{n_{c1}^{22}s + n_{c0}^{22}}{d_{c1}^{22}s+1} \end{bmatrix}$$

From empirical reasons we shall choose factors

$$d_{c1}^{11} = 0.5; \quad d_{c1}^{12} = 0.5; \quad d_{c1}^{21} = 0.5; \quad d_{c1}^{22} = 0.5.$$

After action optimization procedure we have

$$W_c(s) = \begin{bmatrix} \dfrac{68.3286s - 36.3521}{0.5s+1} & \dfrac{-24.7311s - 72.4166}{0.5s+1} \\ \dfrac{-14.3616s + 29.3918}{0.5s+1} & \dfrac{46.2679s + 29.7378}{0.5s+1} \end{bmatrix}. \qquad (2)$$

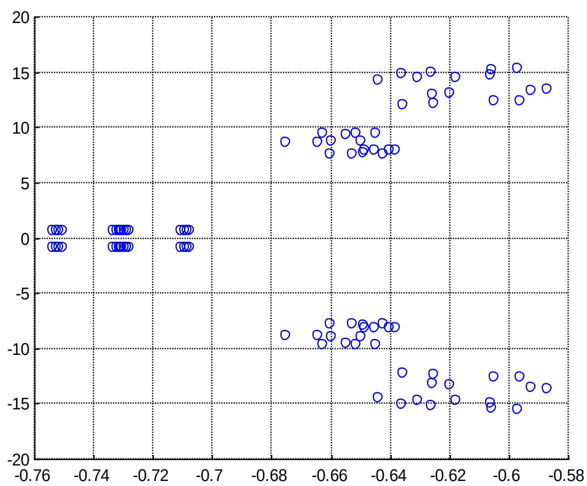

Fig. 5. ***An arrangement of poles of system with a regulator (2).***

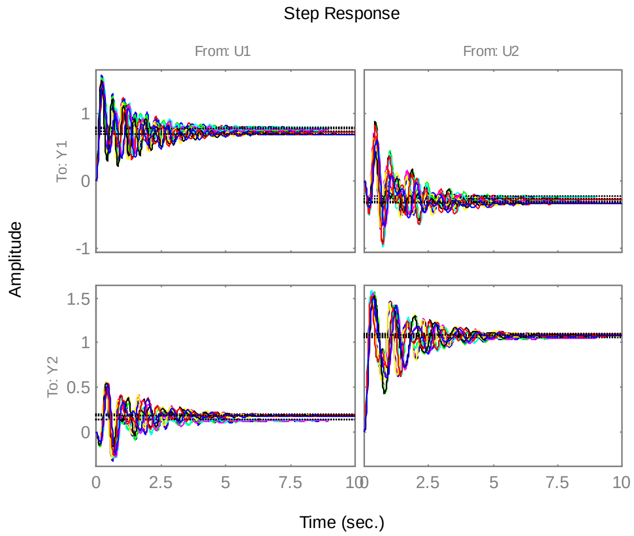

Fig. 6. ***Transients in system with a regulator (2).***

The received regulator provides an arrangement of poles of system and transients represented in a fig. 5, 6 accordingly. As it is visible from figures the put requirements are executed. The further increase about a regulator does not result in essential improvement of quality of transients, therefore iterative procedure on it will stop.2)

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MODELING OF A DECISION MAKER UNDER Z-INFORMATION

Lala M. Zeinalova

Department of Computer-Aided Control Systems, Azerbaijan State Oil Academy, Azerbaijan, Baku, Azadlyg ave. 20, AZ1010, e-mail: Zeynalova-69@mail.ru.

Abstract*: The impact of the DM features on decision making sometimes contradicts with the traditional theories. Decision making is a behavioral process highly conditioned by the primary motives beliefs of a DM. L. Zadeh suggested a concept of a Z-number to describe a reliability of given information. In this study we suggest a Z-number valued multiple regression analysis to describe a dependence of the personal quality of a DM on a fairness and an emotion of a DM. We provide an experiment showing application of the suggested analysis.*

Keywords*: Behavioral modeling, Decision making, Z-number, multiple regression.*

I. Introduction

Under the decision making we understand a selection of an action from the set of alternatives. We solve a problem of decision making to investigate preferences of a DM and to construct a decision making model. How does a DM make choices? He/she seeks to maximize the value of earnings. Of particular importance for decision making is that not every DM maximizes his/her value of earnings, but also care about others' earnings. A decision making model is primarily a behavioral model. Different DMs make different choices depending on their own features in the same situations. During the development of the decision theories scientists try to take into account the features of human nature in decision making models to make the latter closer to human decision activity. The behavioral models most often cited in the literature are those modeling risk issues in decisions. People are risk averse for gains and risk seeking for losses. Risk measures are used to model risk aversion of a DM in order to rationalize the decision process with respect to different (financial) positions [1]. The other important issue is uncertainty aversion. People mostly prefer events with known probabilities to those with unknown probabilities. Such choice behavior is commonly referred to as ambiguity aversion [2]. At the same time DMs have different risk attitudes towards events with known probabilities (risk) and unknown probabilities (uncertainty). A number of theoretical models have also been proposed to account for ambiguity aversion, including Choquet expected utility [3], maxmin expected utility (MMEU) [4], α-maxmin [5], cumulative prospect theory [6] [2]. A new stream of works is devoted to trust, inequity aversion and reciprocity that are identified as primary motives underlying human decision making [7,8,9].

In [10] author considers the appropriateness of fuzzy sets and fuzzy “if-then” rules for representing human centered cognitive concepts. It is noted that human behavioral modeling requires an ability to formally represent sophisticated cognitive concepts that are often at best described in imprecise linguistic terms. It is shown in [10] how probabilistic uncertainty can be included into the output of a fuzzy rule in by using Dempster-Shafer paradigm. The methodology that combines fuzzy and probabilistic uncertainty provides a framework for construction of models that can include both the complex concepts and unpredictability needed to model human behavior.

In a modern behavioral modeling in many cases it becomes impossible to solve a problem of decision making without of taking into account the beliefs of a DM. In all the existing classical decision making theories the probability measures are regarded to be described in a precise manner, which, in many real-world cases could be impossible to achieve. In real-world decision making problems, especially those encountered in economics, such probabilities are subjective and usually imprecise. There are a lot of approaches for describing imprecision of probability relevant information. One of the approaches is the use of hierarchical imprecise models. These models capture the second-order uncertainty inherent in real problems. According to this approach, an expert opinion on the imprecise probability assessments is usually also imprecise [11,12,13].

In [14] Zadeh introduced the concept of Z-numbers to describe the uncertain information in a generalized form. A Z-number is an ordered pair of fuzzy numbers $(\tilde{A},\tilde{B})$. Here $\tilde{A}$ is a value of some variable and $\tilde{B}$ represents an idea of certainty or other closely related concept such as sureness, confidence, reliability, strength of truth, or probability [15]. It should be noted that in everyday decision making most decisions are in the form of Z-numbers. Zadeh suggests some operations for computation with Z-numbers, using the extension principle. This theme was extended in [15]. It was shown how to use these Z-numbers to provide information about an uncertain variable in the form of Z-valuations, assuming that this uncertain variable is random. In [16] author offers an illustration of a Z-valuation, showing how to make decisions and answer questions. Also an alternative formulation is used for the information contained in the Z-valuations in terms of a Dempster-Shafer belief structure that made use of type-2 fuzzy sets. Simplified version of Z-valuation of decision relevant information is considered in [16]. In [17] authors considered multi-criteria decision making problems with Z-numbers. For purpose of decision making, Z-numbers are converted into classical fuzzy numbers and a priority weight of each alternative is determined.

In this study we suggest a Z-number valued multiple regression analysis to be applied for behavioral modeling. Previously suggested models are based on precise information or use imprecise information. For example, in [18] a fuzzy regression analysis based on genetic algorithms is suggested. Fuzzy regression analysis is very effective for modeling of complex systems. The Z-number valued regression analysis is important for modeling of human behavior. It helps to understand the primary motives underlying human decision making. Unfortunately, there is no Z-number valued regression analysis model cited in the literature. In this work as example we analyze a DM’s choices depending on his features.

The paper is organized as follows. In Section II we present required prerequisite material. In Section III we formulate a statement of the problem. In Section IV we suggest an experiment showing application of the suggested approach. Concluding comments are included in Section V.

II. Preliminaries

Definition 1. *Fuzzy sets* [19].

Let X be a classical set of objects, called the universe, whose generic elements are denoted x. Membership in a classical subset A of X is often viewed as a characteristic function μ_A from X to $\{0,1\}$ such that

$$\mu_A(x) = \begin{cases} 1 \ iff \ x \in A \\ 0 \ iff \ x \notin A \end{cases}$$

where $\{0,1\}$ is called a valuation set; 1 indicates membership while 0 – non membership.

If the valuation set is allowed to be in the real interval $[0,1]$, then A is called a fuzzy set, μ_A is the grade of membership of x in A: $\mu_A(x): X \to [0,1]$.

Let E^n be a space of all fuzzy subsets of R^n, satisfying the conditions of normality, convexity, and are upper semicontinuous with compact support. Then, let's denote by $E^1_{[a,b]}$ the corresponding space of fuzzy numbers defined over $[a,b] \subset R$.

Definition 2. *A Z-number* [14].

A Z-number is an ordered pair of fuzzy numbers, $(\tilde{A}, \tilde{R})$. $\tilde{A}$-is a fuzzy restriction on the values which a real-valued uncertain variable is allowed to take. $\tilde{R}$ is a measure of reliability of the first component.

Definition 3. *The Hamming distance* [20].

The Hamming distance is a useful technique for calculating the differences between two elements, two sets, etc. For two sets A and B it can be defined as follows.

The Hamming distance of dimension n is a mapping $d: R^n \times R^n \to R$ such that:

$$d(A,B) = \sum_{i=1}^{n} |a_i - b_i|$$

where a_i and b_i are the ith arguments of the sets $A = \{a_1, a_2, ..., a_n\}$ and $B = \{b_1, b_2, ..., b_n\}$, respectively.

III. Problem statement

Let we are given M Z-number valued multiple input-single output system. As inputs we choose such features of a DM as fairness and emotion to estimate his personal quality. The Z-number valued multiple regression analysis is used to link the inputs of the model to its output. Let the Z-number valued output be $W = (\tilde{Z}_{W_1}, \tilde{Z}_{W_2}, ..., \tilde{Z}_{W_m})$,describing a personal quality of a DM, $X = (\tilde{Z}_{X_1}, \tilde{Z}_{X_2}, ..., \tilde{Z}_{X_m}) \subset E^n$ be a space of the first Z-number valued input describing fairness of a DM and $Y = (\tilde{Z}_{Y_1}, \tilde{Z}_{Y_2}, ..., \tilde{Z}_{Y_m}) \subset E^n$ be a space of the second Z-number valued input describing the emotion of the DM. Then we call $\Omega = X \times Y$ a space "fairness-emotion", elements of which are combined Z-number valued multiple regression inputs $\tilde{Z}_{\varpi} = (\tilde{Z}_X, \tilde{Z}_Y)$, where $\tilde{Z}_X \in X$, $\tilde{Z}_Y \in Y$. The regression coefficients are also the Z-numbers:

$$A_0 = (\tilde{Z}_{A_{01}}, \tilde{Z}_{A_{02}}, ..., \tilde{Z}_{A_{0n}}), A_1 = (\tilde{Z}_{A_{11}}, \tilde{Z}_{A_{12}}, ..., \tilde{Z}_{A_{1n}}) \ A_2 = (\tilde{Z}_{A_{21}}, \tilde{Z}_{A_{22}}, ..., \tilde{Z}_{A_{2n}}).$$

Our goal is to define multiple regression model for fitting Z-number valued type of data. We consider the following regression model:

$$\tilde{Z}_W^{Model}(\tilde{Z}_{X_1,X_2,\dots,X_M},\tilde{Z}_{Y_1,Y_2,\dots,Y_M}) = \\ = \tilde{Z}_{A_{0j}} + \sum_{i=1}^{M}\sum_{j=1}^{N}\tilde{Z}_{A_{1j}}\times\tilde{Z}_{X_i} + \sum_{i=1}^{M}\sum_{j=1}^{N}\tilde{Z}_{A_{2j}}\times\tilde{Z}_{Y_i} \tag{1}$$

We have to determine the Z-number valued coefficients $\tilde{Z}_{A_{0j}},\tilde{Z}_{A_{1j}},\tilde{Z}_{A_{2j}},\ j=\overline{1,N}$ so that a Z-valued Hamming distance $\tilde{Z}_D=(\tilde{Z}_{D_1},\tilde{Z}_{D_2},\dots,\tilde{Z}_{D_n})$ between the Z-number valued inputs and the corresponding Z-number valued output will be minimal:

$$\tilde{Z}_D(\tilde{Z}_W^{Model},\tilde{Z}_W)=\sum_{i=1}^{M}\left|\tilde{Z}_{W_i}-\tilde{Z}_{W_i}^{Model}\right|\to\min \tag{2}$$

IV. Problem solving

In this study the Z-number valued output, inputs and the regression coefficients are represented by Z-numbers composed of triangular fuzzy numbers of restrictions and confidences.

$\tilde{Z}_W=(W,A_W,B_W)$, $\tilde{Z}_X=(X,A_X,B_X)$, $\tilde{Z}_Y=(Y,A_Y,B_Y)$,

$\tilde{Z}_{A_0}=(A_0,A_{A_0},B_{A_0})$, $\tilde{Z}_{A_1}=(A_1,A_{A_1},B_{A_1})$, $\tilde{Z}_{A_2}=(A_2,A_{A_2},B_{A_2})$,

where A_W, A_X, A_Y, A_{A_0},A_{A_1},A_{A_2} are the restrictions on the values that variables W, X, Y, A_0, A_1, A_2 are allowed to take; B_W, B_X, B_Y, B_{A_0}, B_{A_1}, B_{A_2} are the measures of the reliability of the first components [14]. For example, Z-valuation (X,A_X,B_X) is defined as $\mathrm{Pr}ob(X\ is\ A_X)\ is\ B_X$.

The effective way of exploiting the imprecision of restriction A and confidence B involves approximation of the membership function of restriction by an interval-valued membership function, $A^{Bandwith}$ [14]. As here we consider an interval of A then we can write

$$(A_1^{Bandwith},B_1)*(A_2^{Bandwith},B_2)=(A_1^{Bandwith}*A_2^{Bandwith},B_1\times B_2) \tag{3}$$

where $*$ is a binary operation and $B_1\times B_2$ is the product of the fuzzy numbers B_1 and B_2 [14].

So, we can write the following, using (1) and (3)

$$\tilde{Z}_{\tilde{Z}_{A_{1j}}\times\tilde{Z}_{X_i}}=\sum_{i=1}^{M}\sum_{j=1}^{N}((A_{1_j}^{Bandwith}\times A_{X_i}^{Bandwith}),(B_{A_{1j}}\times B_{X_i})),$$

$$\tilde{Z}_{\tilde{Z}_{A_{2j}}\times\tilde{Z}_{Y_i}}=\sum_{i=1}^{M}\sum_{j=1}^{N}((A_{2_j}^{Bandwith}\times A_{Y_i}^{Bandwith}),(B_{A_{2j}}\times B_{Y_i})),$$

$$\tilde{Z}_{\tilde{Z}_{A_{1j}}\times\tilde{Z}_{X_i}}+\tilde{Z}_{\tilde{Z}_{A_{2j}}\times\tilde{Z}_{Y_i}}=\sum_{i=1}^{M}\sum_{j=1}^{N}((A_{1_j}^{Bandwith}\times A_{X_i}^{Bandwith})++(A_{2_j}^{Bandwith}\times A_{Y_i}^{Bandwith})),((B_{A_{1j}}\times B_{X_i})\times \\ (B_{A_{2j}}\times B_{Y_i})),$$

$$\tilde{Z}_{W_j}^{Model}=\tilde{Z}_{\tilde{Z}_{A_{0j}}}+\tilde{Z}_{\tilde{Z}_{A_{1j}}\times\tilde{Z}_{X_i}}+\tilde{Z}_{\tilde{Z}_{A_{2j}}\times\tilde{Z}_{Y_i}}=\sum_{i=1}^{M}\sum_{j=1}^{N}(A_{0_j}^{Bandwith}+(A_{1_j}^{Bandwith}\times A_{X_i}^{Bandwith})\times \\ \times(A_{2_j}^{Bandwith}\times A_{Y_i}^{Bandwith})),(B_{A_{0j}}\times(B_{A_{1j}}\times B_{X_i})\times(B_{A_{2j}}\times B_{Y_i})) \tag{4}$$

After these computations we determine the minimal aggregated Z-number valued Hamming distance $\tilde{Z}_{D_h}(\tilde{Z}_{W_j}^{Model},\tilde{Z}_{W_j})$. It should be noted that a use of least squares and gradient based methods for solving the problem (2) is not feasible as the value of the Hamming distance in (2) is non-differentiable [18] and we will use genetic algorithms as optimization techniques.

V. An experiment.

Let the first input of the regression "Fairness" be represented by Z-valuation and be defined as $\tilde{Z}_X=(X,A_X,B_X)$ (Table 1).

Table 1

Z-valuation of the regression input "Fairness"

N	X	A_X	B_X
1	Fairness	Highest	Very sure
2	Fairness	Almost high	Almost sure
3	Fairness	Low	Very likely
4	Fairness	Better than high	Likely
5	Fairness	High	Almost not sure
6	Fairness	Better than average	Usually
7	Fairness	Almost average	Not sure
8	Fairness	Average	Almost usually
9	Fairness	Almost low	Not usually
10	Fairness	Better than low	Almost unlikely
11	Fairness	Very low	Unlikely

The second input of the regression "Emotion" is defined as $\tilde{Z}_Y = (Y, A_Y, B_Y)$ (Table 2).

Table 2

Z-valuation of the regression input "Emotion"

N	Y	A_Y	B_Y
1	Emotion	Better than average	Almost usually
2	Emotion	Highest	Almost unlikely
3	Emotion	Better than low	Usually
4	Emotion	Better than high	Not usually
5	Emotion	Almost average	Likely
6	Emotion	Average	Very sure
7	Emotion	High	Unlikely
8	Emotion	Almost high	Very likely
9	Emotion	Very low	Almost sure
10	Emotion	Low	Not sure
11	Emotion	Almost low	Almost not sure

The output of the regression "Personal quality" is defined as $\tilde{Z}_W = (W, A_W, B_W)$ (Table 3).

Table 3

Z-valuation of the regression output "Personal quality"

N	W	A_W	B_W
1	Personal quality	Very low	Unlikely
2	Personal quality	Almost low	Almost unlikely
3	Personal quality	Low	Not usually
4	Personal quality	Better than low	Almost usually
5	Personal quality	Almost average	Usually
6	Personal quality	Average	Not sure
7	Personal quality	Better than average	Almost not sure
8	Personal quality	Almost high	Likely
9	Personal quality	High	Very likely
10	Personal quality	Better than high	Almost sure
11	Personal quality	Highest	Very sure

The restriction values A_i as triangular fuzzy numbers is defined in Table 4

Table 4

The values of A_i

N	A linguistic description	A_i
1	"Very low"= A_1	(0.05, 0.1, 0.15)
2	"Almost low"= A_2	(0.09, 0.15, 0.19)
3	"Low"= A_3	(0.13, 0.18, 0.23)
4	"Better than low"= A_4	(0.17, 0.23, 0.27)
5	"Almost average"= A_5	(0.21, 0.26, 0.31)
6	"Average"= A_6	(0.29, 0.35, 0.39)
7	"Better than average"= A_7	(0.36, 0.42, 0.46)
8	"Almost high"= A_8	(0.44, 0.48, 0.54)
9	"High"= A_9	(0.55, 0.61, 0.65)
10	"Better than high"= A_{10}	(0.63, 0.68, 0.73)
11	"Highest"= A_{11}	(0.7, 0.77, 0.87)

The measure of the reliability B_i as a triangle fuzzy number is defined in Table 5.

Table 5

The values of B_i

N	A linguistic description	B_i
1	"Unlikely"= B_1	(0.08, 0.12, 0.18)
2	"Almost unlikely"= B_2	(0.16, 0.21, 0.26)
3	"Not usually"= B_3	(0.23, 0.29, 0.33)
4	"Almost usually"= B_4	(0.31, 0.36, 0.41)
5	"Usually"= B_5	(0.41, 0.45, 0.51)
6	"Not sure"= B_6	(0.48, 0.53, 0.58)
7	"Almost not sure"= B_7	(0.57, 0.61, 0.67)
8	"Likely"= B_8	(0.66, 0.71, 0.76)
9	"Very likely"= B_9	(0.75, 0.8, 0.85)
10	"Almost sure"= B_{10}	(0.81, 0.86, 0.91)
11	"Very sure"= B_{11}	(0.87, 0.92, 0.97)

We determine an interval-valued membership function $A^{Bandwith}$ (for α-cut equal to 0.5).

$A_1^{Bandwith}$=[0.075, 0.125], $A_2^{Bandwith}$=[0.12, 0.17],

$A_3^{Bandwith}$=[0.155, 0.205], $A_4^{Bandwith}$=[0.195, 0.25],

$A_5^{Bandwith}$ =[0.235, 0.285], $A_6^{Bandwith}$=[0.32, 0.37],

$A_7^{Bandwith}$ =[0.39, 0.44], $A_8^{Bandwith}$ =[0.46, 0.51],

$A_9^{Bandwith}$ =[0.58, 0.63], $A_{10}^{Bandwith}$=[0.655, 0.705],

$A_{11}^{Bandwith}$ =[0.735, 0.82].

Let us determine the Z-number valued Hamming distance for the sample data set given the following random Z-number values for the regression coefficients:

$\tilde{Z}_{A_0} = (A_0, A_{A_0}, B_{A_0})$ = (A_0 , (0.61, 0.66, 0.72;1), (0.75, 0.82, 0.88;1)),

$\tilde{Z}_{A_1} = (A_1, A_{A_1}, B_{A_1}) = (A_1$,(0.21, 0.25, 0.27;1), (0.25, 0.31, 0.35;1)),

$\tilde{Z}_{A_2} = (A_2, A_{A_2}, B_{A_2}) = (A_2$,(0.55, 0.61, 0.65;1), (0.2, 0.26, 0.3;1)).

First, we determine an interval-valued membership functions:

$A_{A_0}{}^{Bandwith}$=[0.35, 0.69], $A_{A_1}{}^{Bandwith}$=[0.23, 0.26], $A_{A_2}{}^{Bandwith}$ =[0.58, 0.63].

For the first string of the sample data set we have the following values:

X_1=(Fairness,highest,very sure)=(Fairness,(0.7,0.77,0.87;1),(0.87,0.92, 0.97;1)),

$A_{X_1}{}^{Bandwith} = A_{11}{}^{Bandwith}$ =[0.805, 0.82],

Y_1=(Emotion, better than average, almost usually)=
=(Emotion,(0.36,0.42,0.46;1),(0.31,0.36, 0.41;1)),

$A_{Y_1}{}^{Bandwith} = A_7{}^{Bandwith}$ =[0.39, 0.44].

W_1^{Table}=(Personal quality, very low, unlikely)=(Personal quality, (0.05,0.1, 0.15;1), (0.08, 0.12, 0.18;1)),

$A_{W_1}{}^{Table,Bandwith} = A_1{}^{Bandwith}$ =[0.075, 0.125].

Now we can determine the output value of the model

$\tilde{Z}_{W_1^{Model}}$= ([0.35, 0.69], (0.75, 0.82, 0.88; 1)) + ([0.23, 0.26], (0.25, 0.31, 0.35; 1))× ([0.805, 0.82], (0.87, 0.92, 0.97;1)) + ([0.58, 0.63], (0.2, 0.26, 0.3; 1)) × ([0.39, 0.44], (0.31, 0.36, 0.41;1))= ([0.8404, 1.10135], (0.006503, 0.02189, 0.033913)).

The absolute value of the difference of the Z-number values of the table and model outputs is determined:

$\left|\tilde{Z}_{W_1}{}^{Table} - \tilde{Z}_{W_1}{}^{Model}\right|$=|([0.075, 0.125], (0.08, 0.12, 0.18;1)) - ([0.8404, 1.10135], (0.006503, 0.02189, 0.033913))|=|([0.9654, 1.17635], (-9.5E-05, 0.002627, 0.05383;1))|=([0.9654, 1.17635], (0/0+0.11/0.000207444+0.22/0.000509889+
0.33/0.000812333+0.44/0.00111478+0.55/0.00141722+0.66/0.00171967+
0.77/0.00202211+0.88/0.00232456+1/0.002627+0.88/0.00831622+
+0.77/0.0140054+0.66/0.0196947+0.55/0.0253839+0.44/0.0310731+
+0.33/0.0367623+0.22/0.0424516+0.11/0.0481408+0/0.05383)).

The absolute value plot for the fuzzy number $\left|B_{W_1}{}^{Table} - B_{W_1}{}^{Model}\right|$, describing the difference between the measures of the reliability of the table and the model outputs is shown on the Figure1.

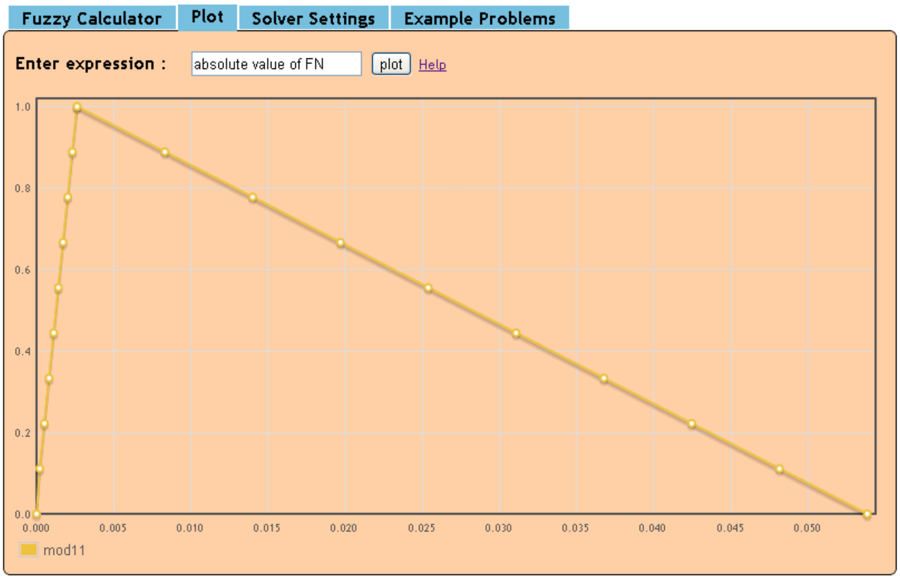

Figure 1.

An absolute value of the fuzzy number $\left|B_{W_1}{}^{Table} - B_{W_1}{}^{Model}\right|$

Analogously, we determine the absolute values of the differences of the Z-number values of the table and model outputs for all the strings of the sample data set:

$\left|\tilde{Z}_{W_2}{}^{Table} - \tilde{Z}_{W_2}{}^{Model}\right|$=([1.1692,1.3421],(0/0+0.11/0.000180778+0.22/0.000471556+0.33/0.000762333+0.44/0.00105311+0.55/0.00134389+0.66/0.00163467+0.77/0.00192544+0.88/0.00221622++1/0.002507+0.88/0.00275489+
+0.77/0.0300278+0.66/0.00324067+0.55/0.00349856+0.44/0.00374644+
+0.33/0.00399433+0.22/0.00424222+0.11/0.00449011+0/0.004738)),

$\left|\tilde{Z}_{W_3}{}^{Table} - \tilde{Z}_{W_3}{}^{Model}\right|$=([1.1249,1.30695],(0/0.00091+0.11/0.00157644+
+0.22/0.00224189+0.33/0.00290733+0.44/0.00357278+0.55/0.00423822+
+0.66/0.00490367+0.77/0.00556911+0.88/0.00623456+1/0.0069+
+0.88/0.00742889+0.77/0.00795778+0.66/0.00848667+0.55/0.00901556+
+0.44/0.00954444+0.33/0.0100733+0.22/0.0106022+0.11/0.0111311+
+0/0.01166)),

$\left|\tilde{Z}_{W_4}{}^{Table} - \tilde{Z}_{W_4}{}^{Model}\right|$=([1.22745,1.41555],(0/0.000363+0.11/0.000867+
+0.22/0.001371+0.33/0.001875+0.44/0.002379++0.55/0.002883+
+0.66/0.003387+0.77/0.003891+0.88/0.004395+1/0.004899+0.88/0.00528178+
+0.77/0.00566456+0.66/0.00604733+0.55/0.00643011+0.44/0.00681289+
+0.33/0.00719567+0.22/0.00757844+0.11/0.00796122+0/0.008344)),

$\left|\tilde{Z}_{W_5}{}^{Table} - \tilde{Z}_{W_5}{}^{Model}\right|$=([0.97835,1.1947],(0/0.003419+0.11/0.00447033+
+0.22/0.00552167+0.33/0.006573+0.44/0.00762433+0.55/0.00867567+
+0.66/0.009727+0.77/0.0107783+0.88/0.0118297+1/0.012881+0.88/0.013823+
+0.77/0.014765+0.66/0.015707+0.55/0.016649+0.44/0.017591+0.33/0.018533++0.22/0.019475+0.11/0.020417+0/0.021359)),

$\left|\tilde{Z}_{W_6}{}^{Table} - \tilde{Z}_{W_6}{}^{Model}\right|$=([1.0675,1.2853],(0/0.001777+0.11/0.00250778+
+0.22/0.00323856+0.33/0.00396933+0.44/0.00470011+0.55/0.00543089+
+0.66/0.00616167+0.77/0.00689244+0.88/0.00762322+1/0.008354+
+0.88/0.00898344+0.77/0.00961289+0.66/0.0102423+0.55/0.0108718+
+0.44/0.0115012+0.33/0.0121307+0.22/0.0127601+0.11/0.0133896+0/014019)),

$\left|\tilde{Z}_{W_7}{}^{Table} - \tilde{Z}_{W_7}{}^{Model}\right|$=([1.261,1.47045],(0/0+0.11/0.000278222+
+0.22/0.000563944+0.33/0.000849667+0.44/0.00113539+0.55/0.00142111+
+0.66/0.00170683+0.77/0.00199256+0.88/0.00227828+1/002564+
+0.88/0/0.00286278+0.77/0.00316156+0.66/0.00346033+0.55/0.00375911+
+0.44/0.00405789++0.33/0.00435667+0.22/0.00465544+0.11/0.00495422+
+0/0.005253)),

$\left|\tilde{Z}_{W_8}{}^{Table} - \tilde{Z}_{W_8}{}^{Model}\right|$=([1.2775,1.4904],(0/0.002953+0.11/0.00412644+
+0.22/0.00529989+0.33/0.00647333+0.44/0.00764678+0.55/0.00882022+
+0.66/0.00999367+0.77/0.0111671+0.88/0.0123406+1/0.013514+
+0.88/0.0144569+0.77/0.0153998+0.66/0.0163427+0.55/0.0172856+
+0.44/0.0182284+0.33/0.0191713+0.22/0.0201142+0.11/0.0210571+0.022)),

$\left|\tilde{Z}_{W_9}{}^{Table} - \tilde{Z}_{W_9}{}^{Model}\right|$=([1.10295,1.3411],(0/0.0002147+0.11/0.00337367+
+0.22/0.00460033+0.33/0.005827+0.44/0.00705367+0.55/0.00828033+

+0.66/0.009507+0.77/0.0107337+0.88/0.0119603+1/0.013187+0.88/0.0140875++0.77/0.0149879+ 0.66/0.0158884+0.55/0.0167889+0.44/0.0176893+
+0.33/0.0185898+0.22/0.0194903+0.11/0.0203907+0/0.021912)), $\left|\tilde{Z}_{W_{10}}{}^{Table}-\tilde{Z}_{W_{10}}{}^{Model}\right|$=([1.24915, 1.47975],(0/0.000631+0.11/0.00126378+
+0.22/0.00189656+0.33/0.00252933+0.44/0.00316211+0.55/0.00379489+
+0.66/0.00442767+0.77/0.00506044+0.88/0.00569322+1/0.006326+
+0.88/0.00685078+0.77/0.00737556+0.66/0.00790033+0.55/0.00843511+
+0.44/0.00894989+0.33/0.00947467+0.22/0.00999944+0.11/0.0105242+
+0/0.011049)),
$\left|\tilde{Z}_{W_{11}}{}^{Table}-\tilde{Z}_{W_{11}}{}^{Model}\right|$=([1.3096,1.51185],(0/0.000165+0.11/0.000641222+
+0.22/0.00111744+0.33/0.00159367+0.44/0.00206989+0.55/0.00254611+
+0.66/0.00302233+0.77/0.00349856+0.88/0.00397478+1//0.004451+
+0.88/0.00494989+0.77/0.00544878+0.66/0.00594767+0.55/0.00644656+
+0.44/0.00694544+0.33/0.00744433+0.22/0.00794322+0.11/0.00844211+
+0/0.008941)).

Now we determine the total sum of the absolute values of the differences of the Z-number values of the table and model outputs for all the strings of the sample data set:

$\sum_{i=1}^{11}\left|\tilde{Z}_{W_i}{}^{Table}-\tilde{Z}_{W_i}{}^{Model}\right|$=([12.733,14.7795],(0/0+0.11/1.80353e-33+
+0.22/3.850093e-31+0.33/1.13784e-29+0.44/1.43329e-28+0.55/1.0996e-27+
+0.66/6.07244e-27+0.77/2.65024e-26+0.88/9.68689e-26+1/3.08212e-25+
+0.88/2.20704e-24+0.77/7.89071e-24+0.66/2.23166e-23+0.55/5.52128e-23+
+0.44/1.24566e-22+0.33/2.62055e-22+0.22/5.21256e-22+0.11/9,8968e-22+
+0/1.80605e-21)).

We solve the optimization problem and determine the minimal absolute value of the restriction $\sum_{j=1}^{N}\left|A_W{}^{Table}-A_W{}^{Model}\right|$ and the corresponding maximal value of the confidence $\sum_{j=1}^{N}\left|B_W{}^{Table}-B_W{}^{Model}\right|$, simultaneously satisfying the constraints of the optimization problem, the corresponding random given Z-number valued coefficients of the regression. We solve the maximization problem for the measures of the reliability to be sure in the conclusions. Finally we transform the interval valued membership function of the restriction into triangular fuzzy number.

Applying the described methodology we determine the following optimal Z-number valued coefficients of the multiple regression and the optimal Hamming distance:

$\tilde{Z}_{A_0}=(A_0, A_{A_0}, B_{A_0})=(A_0$, (0.61, 0.66, 0.72;1), (0.75, 0.82, 0.88;1)),

$\tilde{Z}_{A_1}=(A_1, A_{A_1}, B_{A_1})=(A_1$,(0.21, 0.25, 0.27;1), (0.25, 0.31, 0.35;1)),

$\tilde{Z}_{A_2}=(A_2, A_{A_2}, B_{A_2})=(A_2$,(0.55, 0.61, 0.65;1), (0.2, 0.26, 0.3;1)).

$\min\sum_{j=1}^{N}\left|\tilde{Z}_W^{Table}-\tilde{Z}_W^{Model}\right|$==([7.745493,8.170431),(0/0.002027+0.11/0.004304+
+0.22/0.006581+0.33/0.008858+0.44/0.011135+0.55/0.013412+0.66/0.015689++0.77/0.017966+0. 88/0.020243+1/0.02252+0.88/0.0248037+0.77/0.0270873+
+0.66/0.029371+0.55/0.0316547+0.44/0.0339383+0.33/0.036222+
+0.22/0.0385057+0.33/0.036222+0.22/0.0385057+0.11/0.0407893+0/0.43073)).

It should be noted that our final regression coefficients are the optimal links between such features of the DM as “fairness” and “emotion”, that have a great impact on our knowledge about his/her personal quality.

VI. **Conclusions**

An important qualitative attribute of information on which decisions are based is its reliability. We cannot estimate the features of the DM trustfully if we do not take into account reliability of this information. Unfortunately, in almost all the existing decision theories reliability of decision relevant information is missing. In this study, we suggest a Z-number valued multiple regression analysis.. The outlined approach to decision-making brings forward a much more general framework that coincides with human-oriented assessment of imperfect information. We applied the suggested theory and methodology to an experiment describing the impact of the DM’s features on his/her decision The obtained results proved validity of the suggested approach.

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RECURRENT INTERVAL ALGORITHMS HAVING ESTIMATED PARAMETERS OF MATHEMATICAL MODELS OF DYNAMIC OBJECTS

N.R. Kul'muratov, O.I. Iskandarov, S.S. Turaev

Navoi state mining institute, Uzbekistan

Abstract*: In the given article the interval dynamic recurrent of algorithms to be estimated of parameters of mathematical models of linear objects are offered in view of an interval variants of the data for object.*

The construction of models on realizations of entrance and target signals is most typical by a return task and means reception of the information by means of measurement of entrance and target signals. Thus in most cases process of measurement of signals carries the approached character. This approximate can be expressed by an accessory(belonging) of true meanings(importance) of physical sizes to some intervals, which can be considered(examined) as result of the appropriate measurements. The failure (refusal) of the account of a similar sort of discrepancies as a result of measurements can result that the quality of functioning of the designed system can considerably differ from required. Thus, the construction of adequate mathematical models of objects is one of prime tasks of the theory of management. The interval character of results of measurement results in expediency of use of the device of the interval analysis [1-3]

Usually on object the set of the external factors works, therefore arises to noise of the data. The application probably of methods for processing to noise of meanings (importance) is frequently complicated in connection with continuous functioning of object and changes as measurements of sizes an input - exit, and parameters of the object in time.

Application of the device of the interval analysis [1-3] allows representing in the simple form of measurement of various physical sizes and parameters of technical objects. The interval representation enables to take into account various sources of uncertainty and thus, it is enough to know only boundary meanings (importance) of sizes determining intervals possible (probable), or allowable meanings (importance).

The representation of measurements as intervals is most natural, as the measuring equipment enables to estimate real meaning(importance) of size only with some accuracy (depending on a class of accuracy of used devices) and besides, the application of intervals does not assume knowledge of the laws of distribution. On the other hand, at normal functioning of many technical objects the changes itself measure of size in some limits are admitted(allowable), and such deviations(rejections) do not result in occurrence of emergencies; that is processes are not determined.

Thus, the representation of measurements as intervals is derivate by various mechanisms: by an error of measurements, nature of the process, ways of removal and processing of the measured information etc.

In the given job the interval analogues recurrent of algorithms to estimate of parameters of mathematical models of linear objects are offered in view of an interval type of the data for object. The attraction of the device of the interval analysis enables to receive interval estimations of parameters of model of object, and their width is defined(determined) as accuracy of initial interval measurements, and interval representation of mathematical model.

Usually, for the decision of a task of parametrical identification usually use methods of an estimation of parameters of object based on processing of results of measurements on complete sample (retrospective estimate) [4,5]. However essential lacks of these methods is that for their application it is necessary to have at once all results of measurements, that requires (demands), first, operative computer memory of large volume, and secondly, does not allow a message of calculation in real time, i.e. to process results of measurements in process of their receipt, probably, "overlooking"("forgetting") thus the previous measurements.

These lacks are deprived so-called recurrent algorithms [6]. The essence of these algorithms consists in the following. We admit (allow), that on the moment of time on meanings (importance) of an input (entrance) of an output (exit) at object the estimations of parameters of object are received. At receipt of measurement the vector of estimations of parameters of object on the moment of time is under construction, and for its construction not all sequence of measurements, but only measurement (one-dot algorithm) or last measurements (multimode algorithm is used, thus The meaning (importance) l is less of total of measurements made to the moment of time), and estimation of parameters of object received on the moment of time.

From the engineering point of view these differences have the important meaning (importance). Number of operations and required memory influence a choice of means, for realization of algorithm estimate. The availability of results of intermediate calculations to some applications can be essential, if, for example, the new measurements act which are necessary are too used in real time for specification of estimations with observation; such intermediate results are important, in particular, for the purposes of management.

Recurrent one-dot algorithms. The given algorithms concerns with to the following to a type of methods estimate, i.e., the specification of estimations of parameters of object occurs simultaneously to arrival of the appropriate measurements entrance and target (day off) variable.

Some one-dot algorithms and their properties are considered in jobs [4,5].

Let's result here interval variant only one of them - optimum one-dot algorithm, which is analytically represented following(next) recurrent by the formula:

$$\alpha_t = (\alpha_{t-1} + \frac{(\mathbf{y}_t - (\mathbf{x}_t, \alpha_{t-1}))}{(\mathbf{x}_t, \mathbf{x}_t)} \cdot \mathbf{x}_t) \cap \alpha_{t-1}, \qquad t = 1,2,3,..... \tag{1}$$

Where a $\cap$ - crossing of crossing of intervals, α_{t-1} - interval vector of estimations of parameters of object calculated on previous $t-1$- step estimation; α_t- new interval vector of estimations calculated on $t-u$ the current step of management; $\mathbf{x}_t$-n-мерный a vector of the measured meanings(importance) of entrance influences at the moment of time, t, a $\mathbf{y}_t$-the measured interval meaning(importance) of an output(exit) of object in this the moment of time.

Let's result some remarks concerning convergence of optimum one-dot algorithm (1).

Let's enter a vector of a mistake of definition of interval parameters of object $\theta_t^T = \alpha - \mathbf{a}_t$, with components

$$\theta_t^T = (\theta_{1t}, \theta_{2t}, ..., \theta_{nt}),$$

Where

$$\theta_{it} = \alpha_i - \mathbf{a}_{it}.$$

Let's calculate meaning(importance) of scalar product $\theta_t^T = (\mathbf{x}_t)$. At first, using that fact, that the vector instead of changes from a step to a step, we shall copy (1) in designations, convenient for us:

$$\theta_t = (\theta_{t-1} - \frac{(\theta_{t-1}^T, \mathbf{x}_t)}{(\mathbf{x}_t^T, \mathbf{x}_t)} \mathbf{x}) \cap_t \theta_{t-1}. \tag{2}$$

Multiplying the right and left part of this equality скалярно is received:

$$(\theta_t^T, \mathbf{x}_t) = (\theta_{t-1}^T, \mathbf{x}_t) - \frac{(\theta_{t-1}^T, \mathbf{x}_t)(\mathbf{x}_t^T, \mathbf{x}_t)}{(\mathbf{x}_t^T, \mathbf{x}_t)} = 0.$$

It is clear, that at the described way of construction of estimations distance from a "interval" point of parameters of object, and up to a "interval" point of estimations cannot be increased, and at change of a vector of entrance influences can only decrease. It is necessary also to note, that the mistake of definition of each separate parameter decreases, generally speaking, not monotonously. A total mistake monotonously decreases only, and the mistake of definition of separate parameter can accept any meaning (importance) within the limits of a total mistake.

From above mentioned reasonings as follows, that if the vectors $\mathbf{x}_t$ and $\mathbf{x}_{t+1}$ coincide on a direction, that, obviously, the specification of estimations of parameters of object in $t+1$-м a step will not take place. But the reuse of identical vectors of entrance influences together with others, undoubtedly, is meaningful.

Let's erect in a square both parts of equality (2) and having simplified them, we shall receive:

$$(\theta_t^T,\theta_t) = (\theta_{t-1}^T,\theta_{t-1})\left\{1-\frac{[\theta_{t-1}^T,\mathbf{x}_t]^2}{(\theta_{t-1}^T,\theta_{t-1})(\mathbf{x}_t^T,\mathbf{x}_t)}\right\}.$$

The basic properties of optimum one-dot algorithm are the following:

1) The given algorithm is simple enough in the computing attitude(relation). The labour input of calculations which are carried out according to the given algorithm on one step of specification of estimation α_t, is characterized by the following parities(ratio):

$$N_c = 3\cdot n;\ N_y = 3\cdot n;\ N_д = 1;\ N_в = 1, \tag{3}$$

Where N_c, N_y, $N_ä$, $N_â$- number of operations of addition, multiplication, division and subtraction of material numbers; - quantity (amount) of estimated parameters;

2) requires (demands) small operative memory at its realization with by the help of the Computer;

3) allows tracing changes of variable parameters of object;

4) is recurrent, i.e. allows a message of calculation in real time scale in process of receipt of results of supervision, that rather Essentially at management of non-stationary objects;

5) allows precisely enough to define (determine) parameters of object at any initial estimation of the given parameters;

6) there is a lot of opportunities of increase it noise stabilities and these opportunities is hardware and programs easily are realized.

The listed advantages enable for practical application of the given algorithm at automation of industrial objects.

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COMPUTATIONS WITH Z-NUMBERS

Akif V. Alizadeh, Rashad R. Aliev, Rafig R. Aliyev

[1] Department of Mathematics and Informatics, Azerbaijan University, Baku, Azerbaijan,
Azerbaijan Association of "Zadeh's Legacy", Baku, Azerbaijan, akifoder@au.edu.az, akifoder@yahoo.com
2 Eastern Mediterranean University, Department of Mathematics, Gazimagusa,
Turkish Republic of Northern Cyprus, Via Mersin-10, Turkey
3 Eastern Mediterranean College, Gazimagusa, Northern Cyprus

Abstract. *In real-world decision making takes place under information which is imprecise, incomplete and partially reliable. Moreover, such information is usually described in natural language and, therefore, cannot be adequately described by precise constraints. The concept of Z-numbers, suggested by L.A. Zadeh, is the most general and adequate of the existing representations of information. Z-number represents NL-based information as a fuzzy value of a variable of interest with the associated imprecise partial reliability formally described as a fuzzy probability. In the present paper we suggest operational approach for application of Expected Utility to solving decision problems with Z-information. The suggested approach is applied to solving decision making problem in business area.*

Keywords: *Z-number, fuzzy set, Expected Utility, Decision making.*

1. Introduction

Zadeh suggested the concept of a Z-number as the most general representation for real information and emphasized necessity of its use in decision making and other important areas of human activity. A Z-number is defined as an ordered pair of fuzzy numbers (A, B). A is considered as a fuzzy subset of the domain of the variable of interest U and B is considered as a fuzzy subset of the unit interval[1]. The interpretation is that A is an imprecise evaluation of a value of a variable of interest and B serves as an imprecise degree of reliability of A. More precisely, is considered as a possibilistic restriction on a probability measure of A. Z-information, that is, information represented by Z-numbers supports taking into account reliability of information and, moreover, is adequate to imperfect information of real world which is commonly described in natural language [8].

In [1] some operations for computation over Z-numbers are suggested as based on the Zadeh's extension principle. In [2] it is shown how to use Z-numbers for the purpose of reasoning. An alternative formulation Z-information in terms of a Dempster-Shafer belief structure is also suggested. In [3] they suggest an approach to use Z-numbers for making decisions and answering questions. In [4] authors suggest solving multi-criteria decision making problem with Z-numbers. In [3] and [4] the Z-numbers are converted into classical fuzzy numbers over which computation are made. However this leads to loss and distortion of information. In the present paper we suggest an operational approach to solving decision problem with Z-information by using Expected Utility. This approach is based on computation over 'original' Z-numbers (without conversion to fuzzy numbers) according to operations in [1]. We provide an example of application of the suggested approach to solving a business decision making problem.

The paper is organized as follows. In Section 2 we present required preliminaries and cover some prerequisite material. In Section 3 we formulate Z-valuations of random variables. In Section 4 we cover application of the suggested method to a real-life business problem. Concluding comments are included in Section 5.

2. Preliminaries

Definition 1 [5,7]. A fuzzy set A is defined on a universe U may be given as:

$$A = \{(u, \mu_A(u)) \mid u \in U\}$$

where $\mu_A : U \to [0,1]$ is the membership function. A membership value $\mu_A(u)$ describes the degree of belongingness of $u \in U$ in A.

Definition 2. A trapezoidal fuzzy number A is a fuzzy number with piecewise linear membership function

$$\mu_A(u) = trapmf(u,[a_1,a_{2,},a_3,a_4]) = \max(\min((u-a_1)/(b_1-a_1),(d_1-u)/(d_1-c_1),1),0) = = \begin{cases} \frac{u-a_1}{a_2-a_1}, & a_1 \le u \le a_2 \\ 1, & a_2 \le u \le a_3 \\ \frac{a_3-u}{a_3-a_2}, & a_3 \le u \le a_4 \\ 0, & otherwise \end{cases}$$

which can denoted as (a_1,a_2,a_3,a_4) [2].

Definition 3[11]. For a trapezoidal fuzzy number A, the generalized mean value $gmv(A)$ is

$$gmv(A) = mean[a_1,a_2,a_3,a_4] = \frac{a_1+a_2+a_3+a_4}{4}.$$

Definition 4. Z-number [1]. A Z-number is an ordered pair of fuzzy numbers, (A,B). For simplicity, A and B are assumed to be trapezoidal fuzzy numbers. A Z-number is associated with a real-valued uncertain variable, U, with the first component, A, playing the role of a fuzzy restriction, $R(U)$, on the values which U can take, written as U *is* A, where A is a fuzzy set.

The restriction $R(U): U\ is\ A$, is referred to as a possibilistic restriction (constraint), where A plays the role of the possibility distribution of U:

$$R(U): U\ is\ A \ \to Poss(U \equiv A)\ \equiv \mu_A(u),$$

where μ_A is the membership function of A, $u \in U$. μ_A is viewed as a constraint associated with $R(U)$ with $\mu_A\ u$ being the degree to which u satisfies the constraint.

Definition 5 [1]**.** Z^+-number. Basically, a Z^+-number, Z^+, is a combination of a fuzzy number, A, and a random number, R, written as an ordered pair $Z^+ \equiv (A;R)$. In this pair, A plays the same role as it does in a Z-number, and R is the probability distribution of a random number.

R may be viewed as the probability distribution of U in the Z-valuation (U,A,B)[1]. A Z^+-number may be expressed as (A,p_U) or, equivalently, (μ_A,p_X), where μ_A is the membership function of A. Then a Z^+-valuation is expressed as (U,A,p_U) (or as (U,μ_A,p_X), where p_U is the probability density over U. A Z^+-number is associated with a bimodal distribution as a combination the possibility and probability distributions over U. Then compatibility of these distributions should be considered which in [1] is understood as

$$\int_R u p_U(u)du = \frac{\int_R u\mu_A(u)du}{\int_R \mu_A(u)du}.$$

An adequate in some cases and an effective from computational point assumption is to consider p_U as a parametric distribution, for example, normal distributions with parameters m_U and σ_U. In this case, given $\mu_A = trapmf(u,[a_1,a_{2,},a_3,a_4])$ and $p_U = normpdf(u,m,\sigma)$, compatibility conditions requires [1] $gmv(A) = m$.

The probability measure P_A of A is a scalar product of μ_A and p_U, $\mu_A \cdot p_U$:

$$\mu_A \cdot p_U = P_A = \int_R \mu_A(u)p_U(u)du \cdot$$

This connects the concepts of a Z-number a Z^+-number as follows:

$$Z(A,B) = Z^+(A,\mu_A \cdot p_X \ \text{ is }\ B).$$

Definition 6. Expected utility [6]. Let $P: S \to R$ be any probability measure on a set of states S such that $P(s) > 0$ for all $s \in S$. For each $s \in S$ define $v_s: Z \to R$. Then

$$U(f)=\sum_{s\in S}P(s)v_s(f(s))$$

where f is an act, $z=f(s)$ is an outcome, $v_s(f(s))$ is a utility in state s and $U(f)$ is the expected value of utility.

3. Z-valuations of random variables

Z -number (A,B) can be interpreted as $\text{Prob}(U\ is\ A)\ is\ B$.

This expresses that we do not know the true probability density over U, but have a constraint in form of a fuzzy subset P of the space $\mathbf{P}$ of all probability densities over U. This restriction induces a fuzzy probability B. Let p *be* density function over U. The probability $\text{Prob}_p(U\ is\ A)$ (probability that $U\ is\ A$) is determined on the base of the definition of the probability of a fuzzy subset suggested by Zadeh [9] as

$$\text{Prob}_\text{p}(U\ is\ A)=\int_{-\infty}^{+\infty}\mu_A(u)p_U(u)du\,.$$

Then the degree to which p satisfies the Z -valuation $\text{Prob}_p(U\ is\ A)\ is\ B$ is

$$\mu_P(p)=\mu_B(\text{Prob}_p(U\ is\ A))=\mu_B(\int_{-\infty}^{+\infty}\mu_A(u)p_U(u)du)\,.$$

When p is taken as some a parametric distribution, e.g. a normal distribution, the operations over Z-numbers given in [1] will be sufficiently simplified. The density function of a normal distribution is

$$p_U(u)=normpdf(u,m,\sigma))=\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(u-m)^2}{2\sigma^2}\right).$$

In this situation, for any m, σ we have

$$\text{Prob}_{m,\sigma}(U\ is\ A)=\int_{-\infty}^{+\infty}\mu_A(u)p_{m,\sigma}(u)du=\int_{-\infty}^{+\infty}\mu_A(u)\frac{1}{\sigma\sqrt{2\pi}}\exp\left(\frac{(u-m)^2}{2\sigma^2}\right)du=$$

$$=quad(trapmf(u,[a_1,a_{2,},a_3,a_4])*normpdf(u,m,\sigma),-\inf,+\inf)$$

Then the space $\mathbf{P}$ of probability distributions will be the class of all normal distributions each uniquely defined by its parameters m,σ.

Let $U=(A_U,B_U)$ and $V=(A_V,B_V)$ be two independent Z-numbers. Consider determination of $W=U+V$. First, we need compute A_U+A_V using Zadeh's extension principle:

$$\mu_{(A_U+A_V)}(w)=\sup_u(\mu_{A_U}(u)\wedge\mu_{A_V}(w-u)),\quad \wedge=\min\,.$$

As the sum of random variables involves the convolution of the respective density functions [10] we can construct $\tilde{P}_W$, the fuzzy subset of $\mathbf{P}$, associated with the random variable W. Recall that the convolution of density functions p_1 and p_2 is defined as the density function

$$p=p_1\oplus p_2$$

such that

$$p(w)=\int_{-\infty}^{+\infty}p_1(u)p_2(w-u)du=\int_{-\infty}^{+\infty}p_1(w-u)p_2(u)du$$

One can then find the fuzzy subset $\tilde{P}_W$. For any $p_W\in\mathbf{P}$, one obtains

$$\mu_{P_W}(p_W)=\max_{p_U,p_V}[\mu_{P_U}(p_U)\wedge\mu_{P_V}(p_V)],$$

subject to

$$p_W=p_U\oplus p_V\text{, that is, }p_W(w)=\int_{-\infty}^{+\infty}p_\text{U}(u)p_\text{V}(w-u)du=\int_{-\infty}^{+\infty}p_\text{U}(w-u)p_\text{V}(u)du\,.$$

Given $\mu_{P_U}(p_U)=\mu_{P_U}(m_U,\sigma_U)$ and $\mu_{P_V}(p_V)=\mu_{P_V}(m_V,\sigma_V)$ as

$$\mu_{P_U}(m_U,\sigma_U)=\mu_{B_U}(\int_{-\infty}^{+\infty}\mu_{A_U}(u)\frac{1}{\sigma_U\sqrt{2\pi}}\exp\left(\frac{(u-m_U)^2}{2\sigma_U{}^2}\right)du,$$

$$\mu_{P_V}(m_V,\sigma_V)=\mu_{B_V}(\int_{-\infty}^{+\infty}\mu_{A_V}(u)\frac{1}{\sigma_V\sqrt{2\pi}}\exp\left(\frac{(u-m_V)^2}{2\sigma_V{}^2}\right)du$$

one can define $\tilde{P}_W$ as follows

$$p_W=p_{m_U,\sigma_U}\oplus p_{m_V,\sigma_V},$$

$$p_W(w)=p_{m_W,\sigma_W}=normpdf[w,m_W,\sigma_W]=$$

$$=quad(normpdf(u,m_U,\sigma_U)*normpdf(w-u,m_V,\sigma_V),-\text{inf},+\text{inf})=$$

$$=\int_{-\infty}^{+\infty}\frac{1}{\sigma_U\sqrt{2\pi}}\exp\left(\frac{(u-m_U)^2}{2\sigma_U{}^2}\right)\frac{1}{\sigma_V\sqrt{2\pi}}\exp\left(\frac{(w-u-m_V)^2}{2\sigma_V{}^2}\right)du$$

where

$$m_W=m_U+m_V \text{ and } \sigma_W=\sqrt{\sigma_U^2+\sigma_V^2},$$

$$\mu_{P_W}(p_W)=\sup(\mu_{P_U}(p_U)\wedge\mu_{P_V}(p_V))$$

subject to

$$p_W=p_{m_U,\sigma_U}\oplus p_{m_V,\sigma_V}$$

B_W is found as follows.

$$\mu_{B_W}(b_W)=\sup(\mu_{\tilde{P}_W}(p_W))$$

subject to

$$b_W=\int_{-\infty}^{+\infty}p_W(w)\mu_{A_W}(w)dw$$

Let us now consider determination of $W=U\cdot V$.

$A_U\cdot A_V$ is defined by:

$$\mu_{(A_U\cdot A_V)}(w)=\sup_u(\mu_{A_U}(u)\wedge\mu_{A_V}(\frac{w}{u})),\quad \wedge=\min.$$

the probability density p_W associated with W is obtained as

$$p_W=p_{m_U,\sigma_U}\otimes p_{m_V,\sigma_V},$$

$$p_W(w)=p_{m_W,\sigma_W}=\int_{-\infty}^{+\infty}\frac{1}{\sigma_U\sqrt{2\pi}}\exp\left(\frac{(u-m_U)^2}{2\sigma_U{}^2}\right)\frac{1}{\sigma_V\sqrt{2\pi}}\exp\left(\frac{(\frac{w}{u}-m_V)^2}{2\sigma_V{}^2}\right)du,$$

where

$$m_W=\frac{m_U m_V}{\sigma_U\sigma_V}+r, \text{ and } \sigma_W=\frac{\sqrt{m_U^2\sigma_V^2+m_V^2\sigma_U^2+2m_U m_V\sigma_U\sigma_V r+\sigma_U^2\sigma_V^2+\sigma_U^2\sigma_V^2 r^2}}{\sigma_U\sigma_V}.$$

Where r is correlation coefficient.

If U and V are two independent random variables, then

$$m_W=\frac{m_U m_V}{\sigma_U\sigma_V}, \text{ and } \sigma_W=\frac{\sqrt{m_U^2\sigma_V^2+m_V^2\sigma_U^2+\sigma_U^2\sigma_V^2}}{\sigma_U\sigma_V}.$$

If take into account compatibility conditions $\sigma_U\sigma_V=1$.

The other steps are analogous to those of determination of $W=U+V$.

4. An application to business problem

Let us consider problem of decision making Z-information in business area. A management of a hotel should make a decision concerning a construction of an additional wing. The alternatives are buildings with 30 **(** f_1**)**, 40 **(** f_2 **)** and 50 **(** f_3 **)** rooms. The results of each decision depend on a combination of local government legislation and competition in the field. With respect to this, three states of nature are considered: positive legislation and low competition (s_1), positive legislation and strong competition (s_2), no legislation and low competition (s_3). The outcomes (results) of each decision are values of anticipated payoffs (in percentage) described by Z-numbers. The problem is to find how many rooms to build in order to maximize the return on investment.

Z -information for the utilities of the each act taken at various states of nature and probabilities on states on states of nature are provided in Table 1, Table 2, respectively.

Table 1

The utility values of actions under various states

	s_1	s_2	s_3
f_1	(high; likely)	(below than high; likely)	(medium; likely)
f_2	(below than high; likely)	(low; likely)	(below than high; likely)
f_3	(below than high; likely)	(high; likely)	(medium; likely)

Table 2

The values of probabilities of states of nature

$P(s_1)$ =(medium; quite sure)	$P(s_2)$ =(more than medium; quite sure)	$P(s_2)$ =(low; quite sure)

Here $\tilde{Z}_{v_{s_j}(f_i(s_j))} = (\tilde{v}_{s_j}(f_i(s_j)), \tilde{R}_1)$, where the outcomes and corresponding reliability are the trapezoidal fuzzy numbers:

$$Z_{11} = (A_{11}, B_{11}) = \tilde{Z}_{v_{s1}(f_1(s_1))} = (\tilde{v}_{s_1}(f_1(s_1)), \tilde{R}_1) = \{\text{high; likely}\} =$$
$$=[(0.0, 0.8, 0.9, 1.0), (0.0, 0.7, 0.7, 0.8)],$$
$$Z_{12} = (A_{12}, B_{12}) = \tilde{Z}_{v_{s2}(f_1(s_2))} = (\tilde{v}_{s_2}(f_1(s_2)), \tilde{R}_1) = \{\text{below than high; likely}\} =$$
$$=[(0.0, 0.7, 0.8, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{13} = (A_{13}, B_{13}) = \tilde{Z}_{v_{s3}(f_1(s_3))} = (\tilde{v}_{s_3}(f_1(s_3)), \tilde{R}_1) = \{\text{medium; likely}\} =$$
$$=[(0.0, 0.5, 0.6, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{21} = (A_{21}, B_{21}) = \tilde{Z}_{v_{s1}(f_2(s_1))} = (\tilde{v}_{s_1}(f_2(s_1)), \tilde{R}_1) = \{\text{below than high; likely}\} =$$
$$=[(0.6, 0.7, 0.8, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{22} = (A_{22}, B_{22}) = \tilde{Z}_{v_{s2}(f_2(s_2))} = (\tilde{v}_{s_2}(f_2(s_2)), \tilde{R}_1) = \{\text{low; likely}\} =$$
$$=[(0.0, 0.4, 0.5, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{23} = (A_{23}, B_{23}) = \tilde{Z}_{v_{s3}(f_2(s_3))} = (\tilde{v}_{s_3}(f_2(s_3)), \tilde{R}_1) = \{\text{below than high; likely}\} =$$
$$=[(0.0, 0.7, 0.8, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{31} = (A_{31}, B_{31}) = \tilde{Z}_{v_{s1}(f_3(s_1))} = (\tilde{v}_{s_1}(f_3(s_1)), \tilde{R}_1) = \{\text{below than high; likely}\} =$$
$$=[(0., 0.7, 0.8, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{32} = (A_{32}, B_{32}) = \tilde{Z}_{v_{s2}(f_3(s_2))} = (\tilde{v}_{s_2}(f_3(s_2)), \tilde{R}_1) = \{\text{high; likely}\} =$$
$$=[(0.0, 0.8, 0.9, 1.0), (0.0, 0.7, 0.7, 1.0)],$$
$$Z_{33} = (A_{33}, B_{33}) = \tilde{Z}_{v_{s3}(f_3(s_3))} = (\tilde{v}_{s_3}(f_3(s_3)), \tilde{R}_1) = \{\text{medium; likely}\} =$$
$$=[(0.0, 0.5, 0.6, 1.0), (0.0, 0.7, 0.7, 1.0)].$$

Let the probabilities for s_1 and s_2 be Z-numbers $\tilde{Z}_{P(s_j)} = (\tilde{P}(s_j)), \tilde{R}_2)$, where the probabilities and the corresponding reliability are the triangular fuzzy numbers:

$$Z_{41} = (A_{41}, B_{41}) = \tilde{Z}_{P(s_1)} = (\tilde{P}(s_1)), \tilde{R}_2) = \text{(medium; quite sure)} =$$
$$=[(0.0,\ 0.3,\ 0.3,\ 1.0),\ (0.0,\ 0.9,\ 0.9,\ 1.0)].$$
$$Z_{42} = (A_{42}, B_{42}) = \tilde{Z}_{P(s_2)} = (\tilde{P}(s_2)), \tilde{R}_2) = \text{(more than medium quite sure)} =$$
$$=[(0.0,\ 0.4,\ 0.4,\ 1.0),\ (0.0,\ 0.9,\ 0.9,\ 1.0)].$$

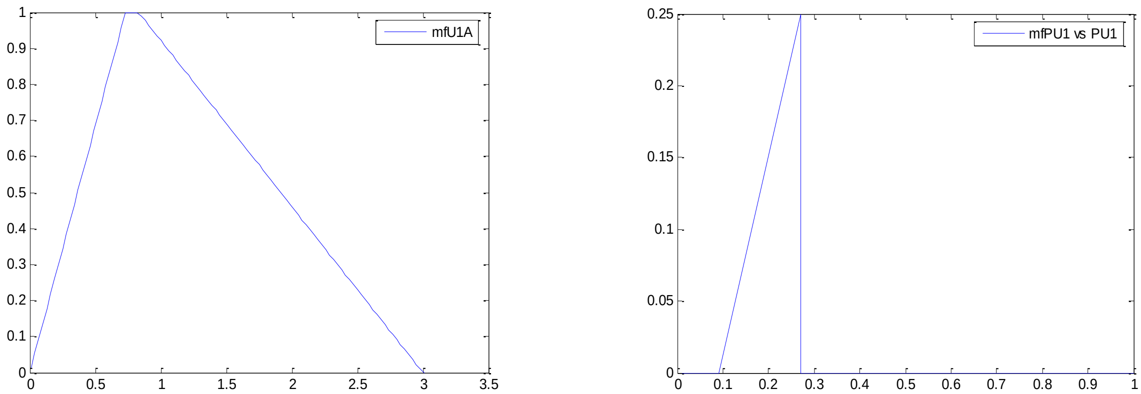

Fig. 1. ***Membership function of*** A_{U_1} ***and*** B_{U_1} **.**

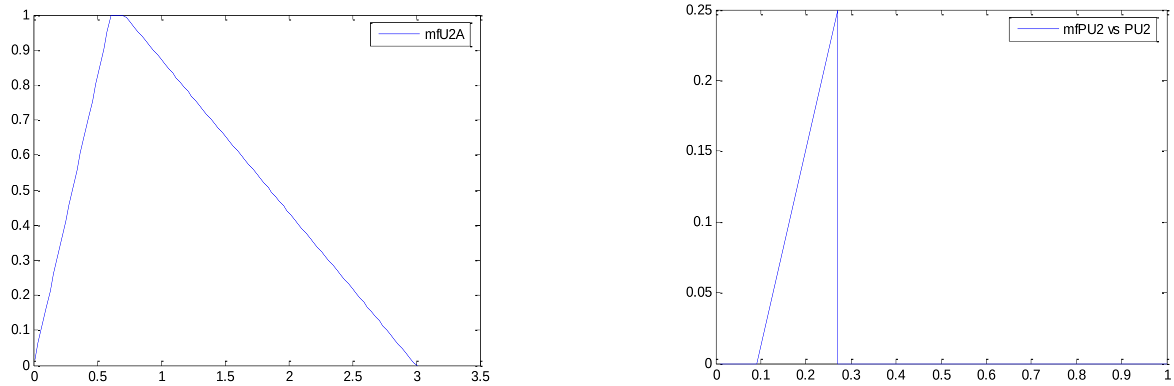

Fig. 2. ***Membership function of*** A_{U_2} ***and*** B_{U_2} **.**

In accordance with [11] we have calculated probability for s_3:

$$Z_{43} = (A_{43}, B_{43}) = \tilde{Z}_{P(s_3)} = (\tilde{P}(s_3)), \tilde{R}_2) = \text{(low; quite sure)} =$$
$$=[(0.0,\ 0.3,\ 0.3,\ 1.0),\ (0.0,\ 0.9,\ 0.9,\ 1)].$$

Given these data and following the proposed decision making method, we get the expected values of utility for acts f_1, f_2, f_3:

$$Z(A_{U_1}, B_{U_1}) = \tilde{Z}_{U(f_1)} = \tilde{Z}_{v_{s_1}(f_1(s_1))} \text{ x } \tilde{Z}_{P(s_1)} + \tilde{Z}_{v_{s_2}(f_1(s_2))} \text{ x } \tilde{Z}_{P(s_2)} + \tilde{Z}_{v_{s_3}(f_1(s_3))} \text{ x } \tilde{Z}_{P(s_3)},$$
$$Z(A_{U_2}, B_{U_2}) = \tilde{Z}_{U(f_2)} = \tilde{Z}_{v_{s_1}(f_2(s_1))} \text{ x } \tilde{Z}_{P(s_1)} + \tilde{Z}_{v_{s_2}(f_2(s_2))} \text{ x } \tilde{Z}_{P(s_2)} + \tilde{Z}_{v_{s_3}(f_2(s_3))} \text{ x } \tilde{Z}_{P(s_3)},$$
$$Z(A_{U_3}, B_{U_3}) = \tilde{Z}_{U(f_3)} = \tilde{Z}_{v_{s_1}(f_3(s_1))} \text{ x } \tilde{Z}_{P(s_1)} + \tilde{Z}_{v_{s_2}(f_3(s_2))} \text{ x } \tilde{Z}_{P(s_2)} + \tilde{Z}_{v_{s_3}(f_3(s_3))} \text{ x } \tilde{Z}_{P(s_3)}.$$

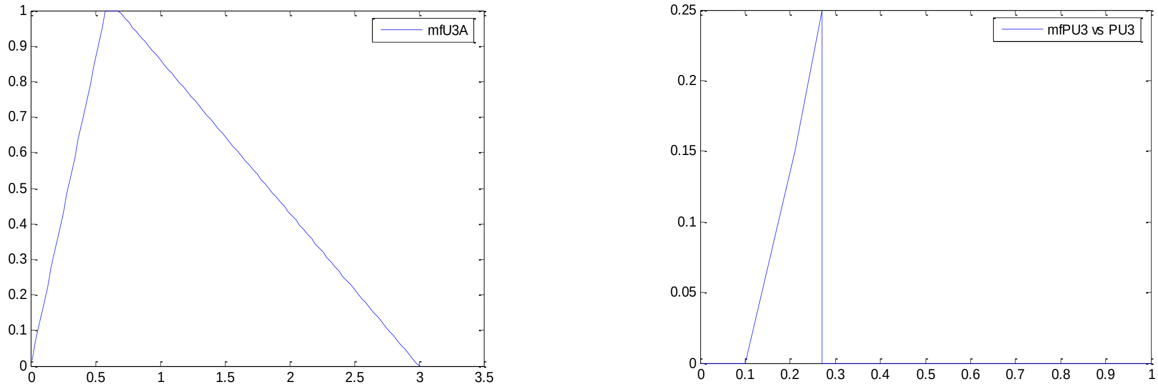

Fig. 3. ***Membership function of*** A_{U_3} ***and*** B_{U_3}

Ranking of fuzzy values of utilities gives a preference to the first alternative, i.e. $f_1 \succ f_3 \succ f_2$.

5. Conclusion

Reliability is one of the most important qualitative attributes of decision-relevant information. However, in most the existing decision theories reliability of decision-relevant information is missing. In this study, we consider decision making under Z-information as information represented by Z-numbers. Z-number is an adequate formalization of real-world information which almost always should be considered in light of its reliability. Moreover, Z-number represents the fact that real information and real reliability are commonly described in a natural language due to imperfect knowledge. We developed an approach to decision making which generalize the existing Expected Utility approach to the case of Z-information. This approach, as opposed to the other works on a decision making under Z-information, is based on direct computation over Z-numbers without conversion of them to fuzzy numbers. Direct computation over Z-numbers rules out loss of information related to a conversion. The approach is applied to solving a real-world business problem. The obtained results showed validity of the suggested approach.

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PROBLEM OF SYNTHESIS OF AN INTERVAL REGULATOR ENSURING STABILITY TO DYNAMIC SYSTEM

L.O. Otakulov, K.Z. Aslonov, D.X. Bazarova, R.Z. Yarashev

Navoi state mining institute, Uzbekistan

***Abstract**: The problem of synthesis of a proportional regulator ensuring asymptotic stability to dynamic system is considered which parameters vary in the given ranges. At a conclusion of the law of control the device of interval mathematics is used.*

1. Introduction

At designing control systems often there is a necessity of maintenance of stability in view of possible deviations of parameters of object from the given rating values. Fluctuations and drift of parameters can be caused by imperfection of a method of measurements, aging of elements and other reasons. Sometimes it is required to switch on in a contour of control a regulator, which could serve some close modes of operations without re customizing factors of amplification [1]. For such objects usually use complex adaptive algorithms of control, though in some cases the system with uncertain parameters can be made steady, applying more simple law of controls for example proportional, which guarantees preservation in the closed system of required properties at any allowable changes of parameters.

In the present work the method of account of factors of amplification of a rough regulator stabilizing a control system is offered submitted in space of condition by the linear differential equations with interval factors [2]. At synthesis of the law of control the specialized device - interval analysis is used [2-4]. An offered method, as against existing, we apply for system both with one, and with several inputs and is convenient for numerical realization on the computer.

2. Basic terms and concepts

Let's designate: $\mathbf{a}=[\underline{a},\overline{a}]$, $\mathbf{a}_{ij}=[\underline{a}_{ij},\overline{a}_{ij}]$ - interval number and element of an interval matrix $\mathbf{A}$ with left $\underline{a},\underline{a}_{ij}$ and right $\overline{a},\overline{a}_{ij}$ numerical endpoints; $b\in\mathbf{a}$ - the number b belongs to an interval $\mathbf{a}$; $(\underline{a}\le b\le\overline{a})$; $B\in\mathbf{A}$ a numerical matrix B belongs to an interval matrix $\mathbf{A}$; $\mathbf{b}\subseteq\mathbf{a}$ - interval $\mathbf{b}$ contains in an interval $\mathbf{a}$, for endpoints of intervals it is fair $\underline{a}\le\underline{b}\le\overline{b}\le\overline{a}$; the interval $\mathbf{a}=\mathbf{b}$; - $\mathbf{a}$ is equal to an interval $\mathbf{b}$, if $\underline{a}=\underline{b}$, $\overline{a}=\overline{b}$; $wid(\mathbf{a})=\overline{a}-\underline{a}$, $mid(\mathbf{a})=(\underline{a}+\overline{a})/2$ - width and midpoint of an interval $\mathbf{a}$; $wid(\mathbf{A})$, $mid(\mathbf{A})$ matrixes consisting of width and the midpoints of elements of an interval matrix $\mathbf{A}$.

3. Problem statement

Let's consider object of control, which behavior in space of condition is described by system of the linear differential equations

$$\dot{x}=\mathbf{A}x+\mathbf{B}u, \tag{1}$$

where $x-n-$ vector of a condition, $u-r-$ vector of inputs $A=\|a_{ij}\|$, $B=\|b_{ik}\|-(n\times n)-$ and $(n\times r)$ matrix, which elements are unknown and can be any numbers from intervals

$$a_{ij}\in[\underline{a}_{ij},\overline{a}_{ij}],\ \ b_{ik}\in[\underline{b}_{ik},\overline{b}_{ik}],\ \ i,\ j=\overline{1,n}.\ \ k=\overline{1,r}. \tag{2}$$

In (2) $\underline{a}_{ij}$, $\underline{b}_{ik}$, $\overline{a}_{ij}$, $\overline{b}_{ik}$ - given left and right endpoints.

One of ways of the description of object with uncertain parameters is its symbolical record as linear system

$$\dot{x}=\mathbf{A}x+\mathbf{B}u. \tag{3}$$

With interval matrixes $\mathbf{A}$ and $\mathbf{B}$. Elements of matrixes $\mathbf{A}$ and $\mathbf{B}$ essence interval numbers, which endpoints satisfy to conditions (2).

Definition 1. By interval dynamic system (3) [6] the set of linear stationary systems is called

$$(\dot{x}=\mathbf{A}x+\mathbf{B}u,\ A\in\mathbf{A},\ B\in\mathbf{B}). \tag{4}$$

Definition 2. The interval dynamic system (3) is steady, if steady each system from set (4) is.

Definition 3. The interval dynamic system (3) is controlled, if any system from set (4) has property of controllability.

Definition 4. Interval polynom is called asymptotic steady, if any multimember with numerical factors $d_i \in \mathbf{d}_i$, $i = \overline{0,\ n-1}$ from set (5) asymptotic is steady.

$$\begin{gathered} \mathbf{D}(s) = s^n + \mathbf{d}_{n-1}s^{n-1} + ... + \mathbf{d}_1 s + \mathbf{d}_0 = \\ \{D(s) = s^n + d_{n-1}s^{n-1} + ... + d_1 s + d_0,\ d_i \in \mathbf{d}_i,\ i = \overline{0,\ n-1}\} \end{gathered} \tag{5}$$

We shall consider a problem of stabilization of object (1) in conditions of uncertainty of parameters, using its interval representation (3).

$$u = Kx, \tag{6}$$

The statement of a problem can be formulated as follows. For interval controlled system (3) is required to find law of control as linear feedback on condition with numerical $(n \times r)$ - matrix to ensuring accommodation of factors characteristic polynomial of an interval matrix of the closed system

$$\dot{x} = (\mathbf{A} + \mathbf{B}K)x. \tag{7}$$

Inside the given ranges $\mathbf{d}_i = [\underline{d}_i,\ \overline{d}_i],\ i = \overline{0,\ n-1}$ - factors asymptotic steady interval polynomial (5).

4. Main result

Let's lead (carry out) at first synthesis of control for system with one input. Shall copy equation (3) at $r = 1$ as.

$$\dot{x} = \mathbf{A}x + bv, \tag{8}$$

where v - scalar input, $\mathbf{b} - n -$ a vector with interval components.

We shall consider conditions controlled of system (8). System

$$\dot{x} = Ax + bv \tag{9}$$

With numerical matrixes A and b is controlled in only case when, when $(n \times n)$ the matrix controllability $Y = (b, Ab, ..., A^{n-1}b)$ has a complete rank: $rankY = n$ [6]. Last condition is equivalent to the following:

$$\det Y \neq 0, \tag{10}$$

Let's construct interval expansion [2] matrixes controlled Y:

$$\mathbf{Y} = (\mathbf{b},\ \mathbf{Ab}, ..., \mathbf{A}^{n-1}\mathbf{b}) \tag{11}$$

Let for any matrix controllability $Y \in \mathbf{Y}$, calculated on the basis of matrixes $A \in \mathbf{A}$, $b \in \mathbf{b}$, the condition (10) is fair. Then for system (8) it is possible to formulate the following sufficient attribute controllability [5].

The statement 1. If zero does not belong to an interval $\det \mathbf{Y}$ - determinant of an interval matrix $\mathbf{Y}$, the interval system (8) is controlled.

We shall consider further, that for system (8) the statement 1 is carried out. Let's define the linear law of control as a feedback on a condition

$$v = kx \tag{12}$$

About a vector $k = [k_1, k_2, ..., k_n]$ - line of the unknown numerical parameters ensuring accommodation of factors characteristic polynomial of a matrix of closed system

$$\dot{x} = (\mathbf{A} + \mathbf{b}k)x \tag{13}$$

In the given factors asymptotic steady polynomial (5). It is known [6], that for object (9) with numerical parameters such vector – line k guaranteeing to closed system $\dot{x} = (A + bk)x$ given characteristic polynomial

$$D(s) = s^n + d_{n-1}s^{n-1} + ... + d_1 s + d_0 , \tag{14}$$

Is defined as the decision of the equation

$$l = kP, \tag{15}$$

where $n-$ a vector $l-$ line and $(1 \times n)-$ matrix P look like

$$l = (a_0 - d_0 \, , \, a_1 - d_1 \, , ..., a_{n-1} - d_{n-1}) \tag{16}$$

$$P = Y \begin{bmatrix} a_1 & a_2 & ... & a_{n-1} & 1 \\ a_2 & a_3 & ... & 1 & 0 \\ ... & ... & ... & ... & ... \\ a_{n-1} & 1 & ... & 0 & 0 \\ 1 & 0 & ... & 0 & 0 \end{bmatrix}, \tag{17}$$

a Y - a matrix controllability of pair (A, b) the factors $d_i , \; i = \overline{0, n-1}$ get out of conditions asymptotic of stability polynomial, and $D(s)$ (14), a $a_i , \, i = \overline{0, n-1}$ are factors characteristic polynomial of a matrix $A : \varphi_A (s) = s^n + a_{n-1}s^{n-1} + ... + a_1 s + a_0$.

The stated method was taken for a basis at the solution of a problem of stabilization of interval system (8). Let vector - line is calculated under the formulas

$$k\mathbf{P} \subseteq \mathbf{l}, \tag{18}$$

$$\mathbf{l} = (\mathbf{l}_1, ..., \mathbf{l}_n), \mathbf{l}_{i+1} = [\underline{a}_i - \overline{d}_i \, , \, \overline{a}_i - \underline{d}_i \,], i = \overline{0, n-1}, \tag{19}$$

$$P = Y \begin{bmatrix} \mathbf{a}_1 & \mathbf{a}_2 & ... & \mathbf{a}_{n-1} & [1,1] \\ \mathbf{a}_2 & \mathbf{a}_3 & ... & [1,1] & [0,0] \\ ... & ... & ... & ... & ... \\ \mathbf{a}_{n-1} & [1,1] & ... & [0,0] & [0,0] \\ [1,1] & [0,0] & ... & [0,0] & [0,0] \end{bmatrix}, \tag{20}$$

Where $\mathbf{a}_i = [\underline{a}_i , \overline{a}_i \,] \, i = \overline{0, \, n-1} -$ factors characteristic polynomial of an interval matrix $\mathbf{A}$, $\mathbf{Y} -$ interval expansion of a matrix controlled (11), [0,0], [1,1] - degenerate interval numbers [2]. Then the following theorem is fair.

The theorem k vector-line of factors of amplification of a regulator (12), calculated on the formulas (18) - (20), guarantees asymptotically stability to the closed system (13).

Problem of synthesis of a regulator (12) for system (8) solution able, if interval equation (18) solution rather k as

$$k = m\mathbf{l} \, (m\mathbf{P})^{-1} , \tag{21}$$

where $m\mathbf{P} -$ no degenerate a matrix having inverse $(m\mathbf{P})^{-1}$. Last takes place, if for k calculated is satisfied condition

$$|k| \omega \mathbf{P} \leq \omega \mathbf{l}. \tag{22}$$

In an inequality (22) $|k| = (|k_1|, |k_2|, ..., |k_n|)$ where $|k_i|$ - module k_i, $\omega\mathbf{P}$, $\omega\mathbf{l}$ matrixes consisting of lengths of interval elements of matrixes $\mathbf{P}$ and $\mathbf{l}$ accordingly.

We will address now to synthesis of control for system with multidimensional by an input $(m \geq 2)$ We shall enter a number of definitions.

Definition 5. The numerical system (1) supposes scalar control [7], if there is $r-$ a vector q, such, that pair is (A, Bq) completely controlled and $rank(Bq, ABq, ..., A^{n-1}Bq) = n$.

Definition 6. The interval system (3) supposes scalar control, if any system from set (4) has the specified property.

Definition 7. If any matrix $A \in \mathbf{A}$ simple, we shall name by $\mathbf{A}$ an interval simple matrix. Let in (3) interval matrixes simple.

Let in (3) interval matrixes $\mathbf{A}$ simple. By virtue of definitions 6, 7 such systems are supposed with scalar control. Then, using the received above results the stabilizing regulator (6) for interval system (3) is calculated as follows.

The numerical vector q, such is set, that was satisfied condition

$$0 \notin \left(\mathbf{Bq}, \mathbf{ABq}, \ldots, \mathbf{A}^{n-1}\mathbf{Bq}\right) \tag{23}$$

The input and systems (3) is represented as: $\mathbf{u} = \mathbf{q}v$, where v - scalar control. Substituting $\mathbf{u} = \mathbf{q}v$ in (3), we shall receive system (8) with a scalar input and $(n \times 1)$- matrix of entrance influences

$$\mathbf{b} = B\mathbf{q}. \tag{24}$$

For system (8), (24) the proportional regulator (12) can be calculated under the formulas (18) - (20). The matrix of factors of transfer of a regulator (6), stabilizing system (3), is defined by substitution (12), (24) in (8), whence follows $K = \mathbf{q}k$.

Remark. If the interval system (3) does not suppose scalar control, by introduction of a special feedback on a condition it is possible to receive system with an interval simple matrix of dynamics $\mathbf{A}$ [5].

5. Example

Let's calculate the regulator ensuring maintenance of the given characteristics of technological process cutting of the machine MRB-100 [1]. Dynamics of initial object in space of a condition $x = (x_1, x_2, x_3)^T$ and vector of an input (entrance) $\mathbf{u} = (u_1, u_2)^T$. The matrixes $\mathbf{A}$ and $\mathbf{B}$ also look like

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & 0 \\ a_{31} & 0 & 0 \end{pmatrix}, \quad B = \begin{pmatrix} 0 & 0 \\ 0 & b_{22} \\ b_{31} & 0 \end{pmatrix}, \tag{25}$$

And the separate elements are constant numbers: $a_{12} = -38545$, $a_{13} = -38495$, $a_{31} = -0.0073256$, $b_{31} = -0.014878$.

Other elements change in the following ranges:

$$\begin{aligned} &a_{11} \in [-3.6106, -2.41], \; a_{21} \in [0.0036233,\, 0.0037481], \\ &a_{22} \in [0.063918,\, 0.068379], \; b_{22} \in [-0.01353, -0.01286]. \end{aligned} \tag{26}$$

As the opened system is unstable [1] there is a problem of synthesis of the regulator providing (12) stability closed to system at any values of uncertain elements of matrixes A and B from ranges (26). We will set a steady interval polynomial [1]:

$$\mathbf{D}(s) = s^3 + [1.8365,\, 4.2287]s^2 + [358.77,\, 484.77]s + [15.403,\, 21.89].$$

At $q = (0.8,\, 0.9)^T$ it is possible, using parities (18) - (22), to calculate

$$K = qk = \begin{pmatrix} -0.00032358 & 2.814 & 3.1363 \\ -0.00026537 & 3.1668 & 3.5283 \end{pmatrix}.$$

Stability of the closed system proves to be true modeling of transients.

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INDUSTRIAL ROBOTIC INTELLIGENT ROBUST CONTROL SYSTEM: APPLICATION OF QUANTUM SOFT COMPUTING TECHNOLOGIES IN UNPREDICTED CONTROL SITUATIONS

S.V. Ulyanov, A.V. Nikolaeva, S.P. Petrov, N.Y. Nefedov, A.G. Reshetnikov

Dubna International University for Nature, Society, and Man,
Institute of Systems Analysis and Control
e-mail: ulyanovsv@mail.ru; nikolaevaav@lenta.ru

Abstract: *A new quality control method of dynamically unstable object based on quantum soft computing is described. This method enables to control object in unpredicted situations with incomplete (imperfect) information about the structure of the control object and external environments. The efficiency over other methods of intelligent control is shown on the benchmark with partial unstable generalized coordinates as stroboscopic industrial manipulator and redundant robotic manipulator.*

Keywords*: quantum fuzzy inference, intelligent control in unpredicted situations, robustness, quantum algorithms, industrial robot*

Introduction

One of the intelligent control systems application areas is the development of autonomous robots that are able operated under condition of the information uncertainty and unpredicted control situations. Application area of robots ranging from household and business sectors to solutions of special problems of military-industrial complexes and aerospace is mainly associated with monotonous or dangerous work. In 2011 for the accident at the Fukushima nuclear power plant have been used mobile robots on tracks with established U.S. company *iRobot* manipulators and also Monirobot machines designed by Japan's Nuclear Safety Technology Center in 1999 after an accident at a nuclear plant Tokaimura.

The principal feature in the construction of multilink robotic manipulator is modularity which provides adaptability and reconfigurability of the dynamic structure in accordance with the problem to be solved.

The possibility of unstable industrial robots control has considered for a long time. But practical importance controlling such objects has appeared relatively recent. The fact is unstable control objects (CO) have a lot of useful qualities (e.g. high-speed performance); it is possible if this objects properly controlled. But in case of failure of control of unstable object can represent a significant threat. In this kind of situations can apply the technology of computational intelligence, such as soft computing (including neural networks, genetic algorithms, fuzzy logic, and etc.). The advantage of intelligent control system is a possibility to achieve the control goal in the presence of incomplete information about CO functional. The basis of any intelligent control system (ICS) is knowledge base (including parameters of membership functions and set of fuzzy rules), therefore the main problem of designing ICS is building optimal robust KB, which guarantee high control quality in the presence of the abovementioned control difficulties in any complex dynamic systems.

Development of FC is one of the most perspective areas of fuzzy systems. For CO developers, fuzzy systems are so attractive because of the fact that they are universal "approximator" systems with poorly known dynamics and structure. In addition, they allow you to control dynamic object without expert. Experts for creation KB ICS are sometimes used, and this design methodology able to achieve control goals, but not always. Even experienced expert have difficulties to find an optimal KB (Optimal base is called base this optimal parameters of membership functions and numbers of rule, according to approximation with required accuracy of the optimal control signal) of fuzzy controller (FC) in situations of controlling nonlinear CO with stochastic noises.

In this report intelligent control system (ICS) for stroboscopic robot and 3 degrees of freedom (DoF) redundant planar manipulator is developed by sequential increasing of intelligence. Configuration redundancy provides many solutions of inverse problem of dynamic which allows operate the control object (CO) in a changing environment.

1. Design technology knowledge bases on soft computing

Application of Fuzzy Neural Networks cannot guarantee to achieve the required accuracy of approximation of the teaching signal (TS), received by genetic algorithm (GA). As a result, an essential change in external conditions is a loss of accuracy to achieve the control goal. However decision of this problem can solve by new developed tool *Soft Computing Optimizer* (SCO) [1, 2].

Using the design technology by SCO and previously received TS, describing the specific situation of control, it is possible to design a robust KB for control complex dynamic CO. The benchmarks of variety CO and control systems based on this approach can be found in [3].

The designed (in the general form for random conditions) robust FC for dynamic CO based on the KB optimizer with the use of soft computing technology (stage 1 of the information design technology - IDT) can operate efficiently only for fixed (or weakly varying) descriptions of the external environment. This is caused by possible loss of the robustness property under a sharp change of the functioning conditions of CO's: the internal structure of CO's, control actions (reference signal), the presence of a time delay in the measurement and control channels, under variation of conditions of functioning in the external environment, and the introduction of other weakly formalized factors in the control strategy. To control dynamical object in different situations one has to consider all of them, i.e. design the required number of KB, the use of which will be achieved the required level of robustness control.

But how can you determine what KB has to be used in the current time?

A particular solution of a given problem is obtained by introducing a generalization of strategies in models of fuzzy inference on a finite set of FC's designed in advance in the form of new *quantum fuzzy inference* (QFI) [4].

2. ICS model based on quantum fuzzy inference

From computer science viewpoint the QA structure of QFI model (as a particular case of the general quantum control algorithm of self-organization) must includes following necessary QA features: *superposition* preparation; *selection of quantum correlation* types; *quantum oracle* (black box model) application and *transportation* of extracted information (dynamic evolution of "*intelligent control state*" with minimum entropy); a *quantum correlation* over a classical correlation as power source of computing; applications of an *interference* operator for the answer extraction; *quantum parallel massive* computation; *amplitude amplification* of searching solution; effective quantum solution of classical *algorithmically unsolved* problems.

In this section we will show that we can use ideas of mathematical formalism of quantum mechanics for discovery new control algorithms that can be calculated on classical computers.

We will use a mathematical model of CO described in Matlab/Simulink. The kernel of the abovementioned FC design tools is a so-called SC Optimizer (SCO) implementing advanced soft computing ideas.

The quantum algorithm for QFI the following actions are realized [5]:

- The results of fuzzy inference are processed for each independent FC;
- Based on the methods of quantum information theory, valuable quantum information hidden in independent (individual) knowledge bases is extracted;
- In on-line, the generalized output robust control signal is designed in all sets of knowledge bases of the fuzzy controller.
- In this case, the output signal of QFI in on-line is an optimal signal of control of the variation of the gains of the PID controller, which involves the necessary (best) qualitative characteristics of the output control signals of each of the fuzzy controllers, thus implementing the self-organization principle.

Therefore, the domain of efficient functioning of the structure of the intelligent control system can be essentially extended by including robustness, which is a very important characteristic of control quality. The robustness of the control signal is the background for maintaining the reliability and accuracy of control under uncertainty conditions of information or a weakly formalized description of functioning conditions and/or control goals.

QFI model based on physical laws of quantum information theory, for computing use unitary invertible (quantum) operators and they have the following names: *superposition*, *quantum correlation* (entangled operators), and *interference*. The forth operator, measurement of result quantum computation is irreversible.

In the general form, the model of quantum computing comprises the following five stages:

- preparation of the initial (classical or quantum) state $|\psi_{out}\rangle$;
- execution of the Hadamard transform for the initial state in order to prepare the superposition state;

- application of the entangled operator or the quantum correlation operator (quantum oracle) to the superposition state;
- application of the interference operator;
- application of the measurement operator to the result of quantum computing $|\psi_{out}\rangle$.

On Fig.1 is shown the functional structure of QFI.

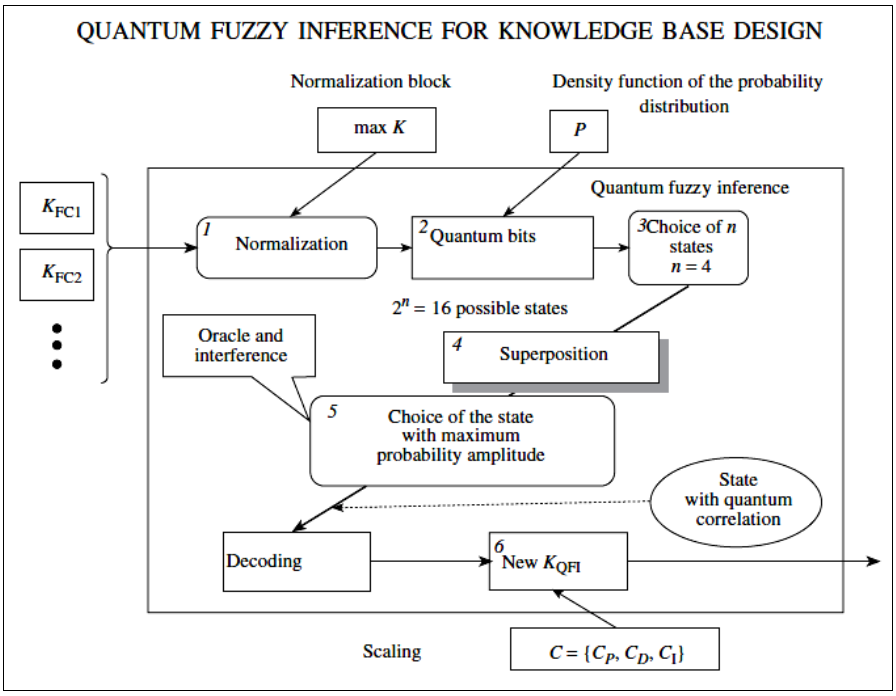


*Fig. 1. **The functional structure of QFI in on-line.***

This QFI model solves the problem robust control essentially-nonlinear unstable CO in unpredicted control situations, by extracting additional information from designed individual KB FC, created for different control situations, based on different optimization criteria.

Thus, the quantum algorithm in the model of quantum fuzzy inference is a physical prototype of production rules, implements a virtual robust knowledge base for a fuzzy PID controller in a program way (for the current unpredicted control situation), and is a problem-independent toolkit. On Fig. 2 is shown intelligent robust control system of essentially nonlinear CO's.

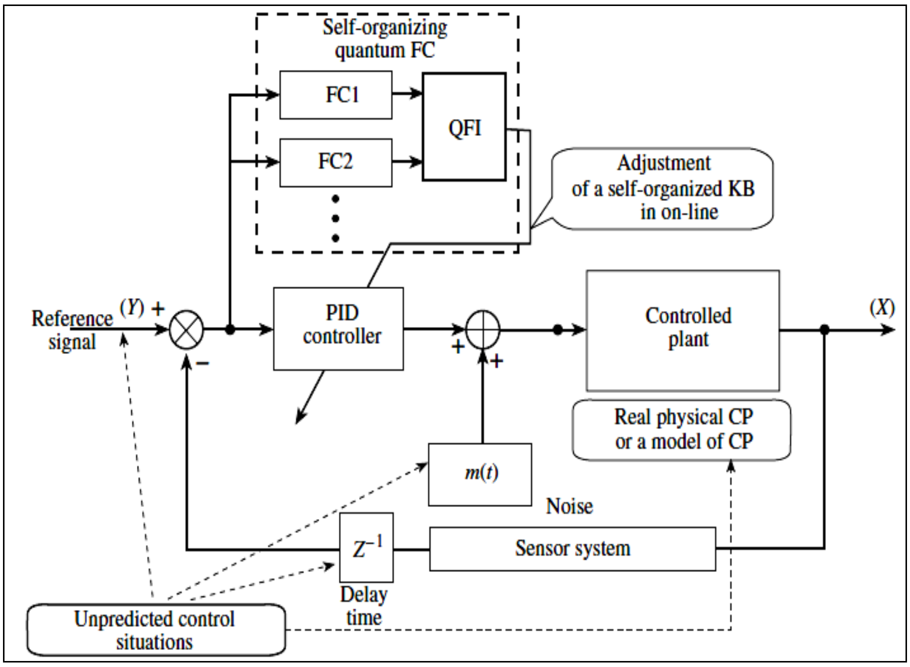


*Fig. 2. **Principle structure of a self-organizing ICS in unpredicted control situations.***

In next stage this work will be described benchmark by using developed design technology ICS.

3. Simulation of control object with partial unstable general coordinates

Control object model As Benchmark example we are choice the popular "*Swing"* dynamic system. Dynamic peculiarity of this system is consisted in following: one generalized coordinate is local unstable (angle) and another coordinate is global unstable (length).

Model of "*swing*" dynamic system (as dynamic system with globally and locally unstable behavior) is shown on Fig. 3.

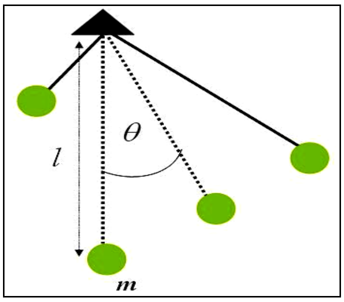


*Fig. 3.**Swing dynamic system.***

Swing dynamic system behavior under control is described by second-order differential equations for calculating the force to be used for moving a pendulum:

$$\ddot{x} + (2\frac{\dot{y}}{y} + \frac{c}{my^2})\dot{x} + \frac{g}{y}\sin x = u_1 + \xi_1(t)$$

$$\ddot{y} + 2k\dot{y} - y\dot{x}^2 - g\cos x = \frac{1}{m}(u_2 + \xi_2(t)). \qquad (1)$$

Equations of entropy production rate are the following:

$$\frac{dS_\theta}{dt} = 2\frac{\dot{l}}{l}\dot{\theta}\cdot\dot{\theta}; \quad \frac{dS_l}{dt} = 2k\dot{l}\cdot\dot{l}. \qquad (2)$$

Swing motion, described by Eqs (1), (2), show that a swing system is the *globally unstable* along generalized coordinate *l* and *locally unstable* along generalized coordinate θ. Also model (1) has nonlinear essentially nonlinear cross links, affecting to local unstable by generalized coordinate *x*. In Eqs (1), (2) *x* and *y* — generalized coordinates; *g* — acceleration of gravity, *m* — pendulum weight, *l* — pendulum length, *k* — elastic force, *c* — friction coefficient, $\xi(t)$ — external stochastic noise, u_1 and u_2 — control forces.

Dynamic behavior of swing system (free motion and PID control) is demonstrated on Fig 4.

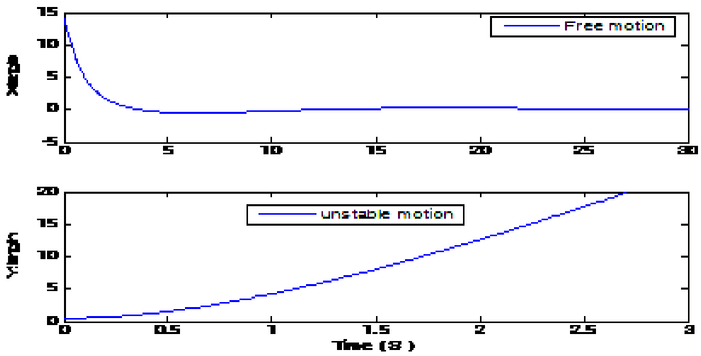


Fig. 4. ***Swing system free motion.***

Control problem: design a smart control system to move the swing system to the given angle (reference *x*) with the given length (reference *y*) in the presence of stochastic external noises and limitation on control force.

Swing system can be considered as a simple prototype of a *hybrid* system consisting of a few controllers where a problem of how to organize a coordination process between controllers is open (problem of *coordination* control).

Control task: Design robust knowledge base for fuzzy PID controllers capable to work in unpredicted control situations.

Consider excited motion of the given dynamic system under two fuzzy PID-control and design two knowledge bases for giving teaching situation (Table1).

Table1

Teaching control situation

Noise x: Gaussian (max amplitude = 1);
Noise y: Gaussian (max amplitude = 2);
*Sensor's delay time*_x = 0.001 s;
*Sensor's delay time*_y= 0.001s;
*Reference signal*_x = 0; Reference signal_y = 2;
Model parameters = (*kmc*)=(0.4 0.5 2);
Control force boundaries: $\lvert U_x \rvert \leq 10(N), \quad \lvert U_y \rvert \leq 10(N)$

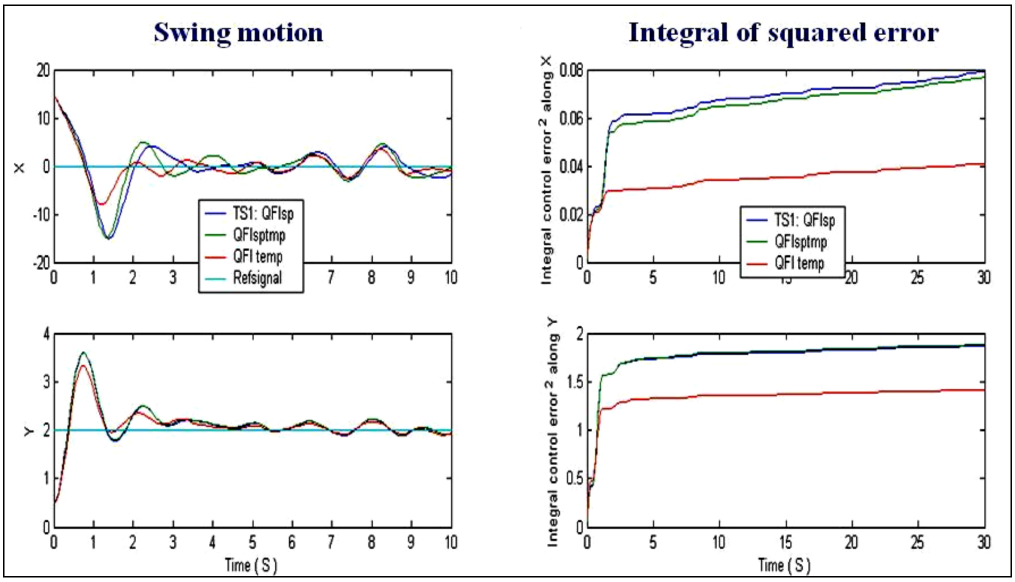


Fig. 5. ***Comparison of three types of quantum correlations.***

Investigate robustness of three types of spatial, temporal and spatiotemporal QFI correlations and choose best type of QFI for the given control object and given teaching conditions. On Figs 5 and 6 comparisons of three quantum fuzzy controllers (QFC) control performance based on three types of QFI (spatial, temporal and spatiotemporal QFI correlations) are shown for the teaching situation.

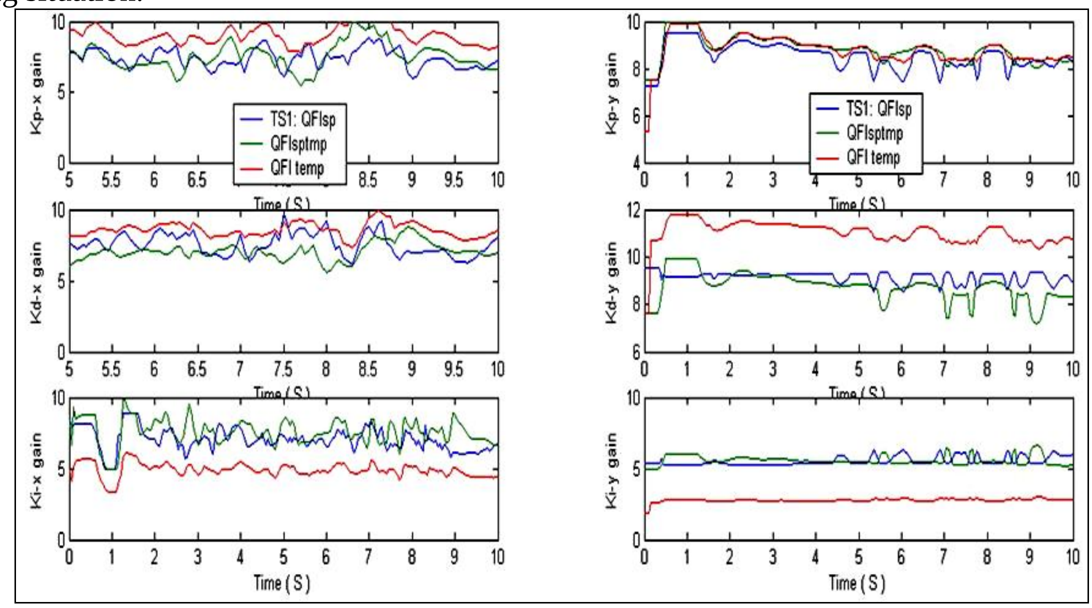


Fig. 6. ***Control laws comparison.***

Temporal QFI is better from minimum control error criterion. Choose temporal QFI for further investigations of robustness property of QFI process by using modelled unpredicted control situations.

Consider comparison of dynamic and thermodynamic behavior of our control object under different types of control: FC1, FC2, and QFC (temporal).

Comparison of FC1, FC2 and QFC performances is shown on Figs 7 and 8.

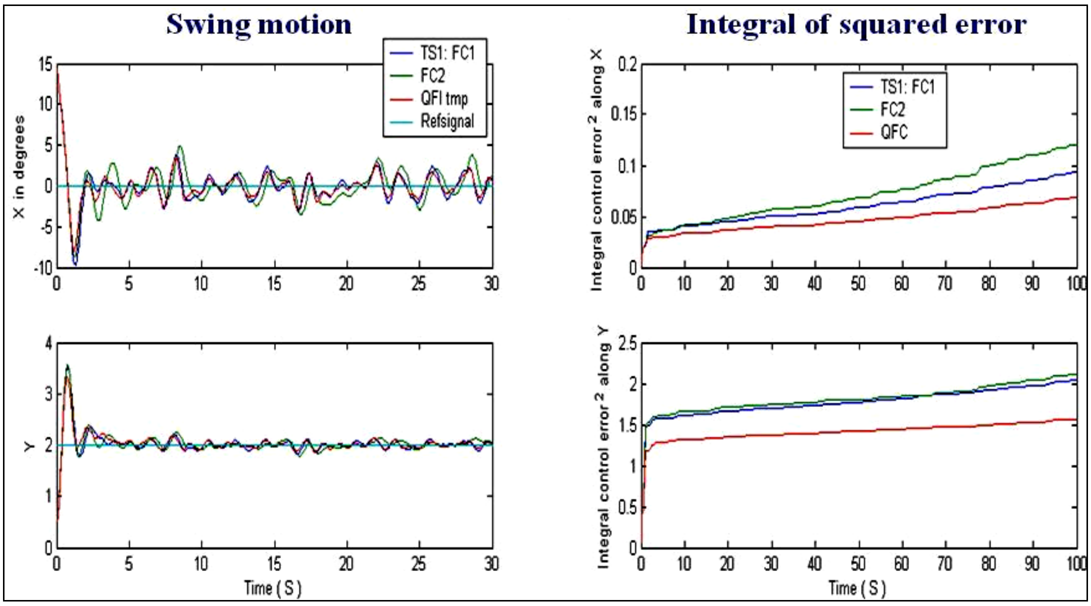


Fig. 7. ***Swing motion and integral control error comparison in TS situation.***

From the minimum control error criterion in teaching condition QFC has better performance than FC1, FC2.

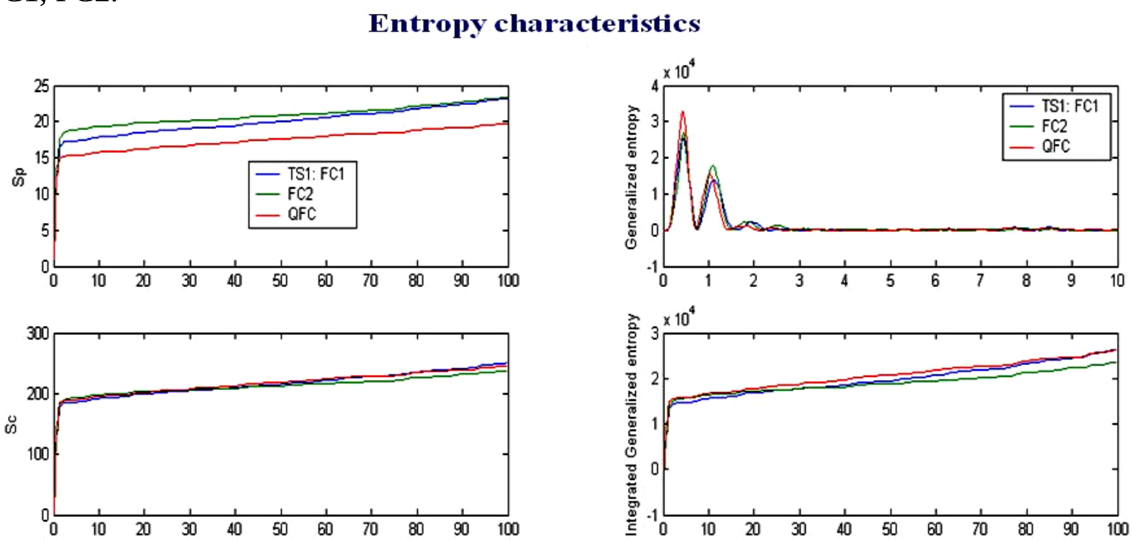


Fig. 8. ***Comparison of entropy production in control object (Sp) and in controllers (left) and comparison of generalized entropy production (right).***

Consider now behavior of our control object in unpredicted control situations and investigate robustness property of designed controllers (Table 2).

Unpredicted situation 1 Comparison of FC1, FC2 and QFC performances in situation 1 (see, Figs 9 – 11)

FC1 and FC2 controllers are failed in situation 1. QFC is *robust*.

Unpredicted situation 2 Comparison of FC1, FC2 and QFC performances in situation 2 (see, Figs 12– 14)

FC1 and FC2 controllers are failed in situation 2. QFC is *robust*.

Table 2

Unpredicted control situations

Unpredicted situation 1:	*Unpredicted situation* 2:
Noise *x*: Gaussian (max amplitude = 1); Noise *y*:Gaussian (max amplitude = 2); Sensor's delay time_x= 0.008 s; Sensor's delay time_y= 0.008s; Reference signal_x = 0; Reference signal_y = 2; Model parameters = (*kmc*)=(0.4 0.5 2) Control force boundaries: $\lvert U_x \rvert \le 10(N), \quad \lvert U_y \rvert \le 10(N)$	Noise *x*: Rayleigh(max amplitude = 1); Noise *y*: Rayleigh(max amplitude = 2); Sensor's delay time_x= 0.001 s; Sensor's delay time_y = 0.001s; Reference signal_x = 0; Reference signal_y= 2; Model parameters = (*kmc*)=(0.4 0.5 2) Control force boundaries: $\lvert U_x \rvert \le 10(N), \quad \lvert U_y \rvert \le 10(N)$

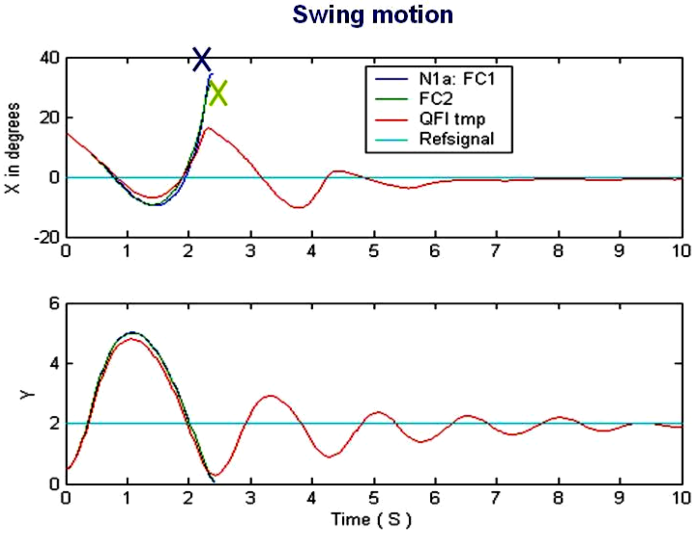


Fig. 9. ***Swing motion and integral control error comparison in unpredicted control situation 1.***

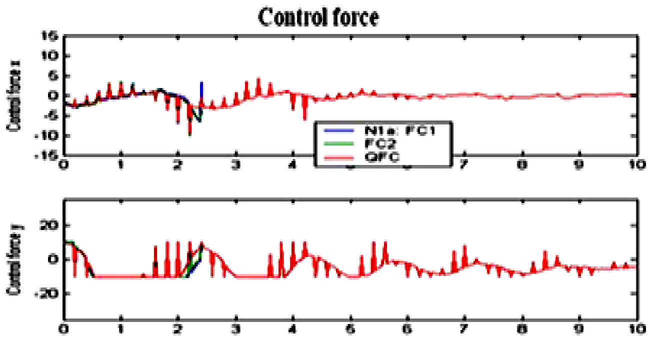


Fig. 10. ***Control forces comparison in unpredicted control situation 1.***

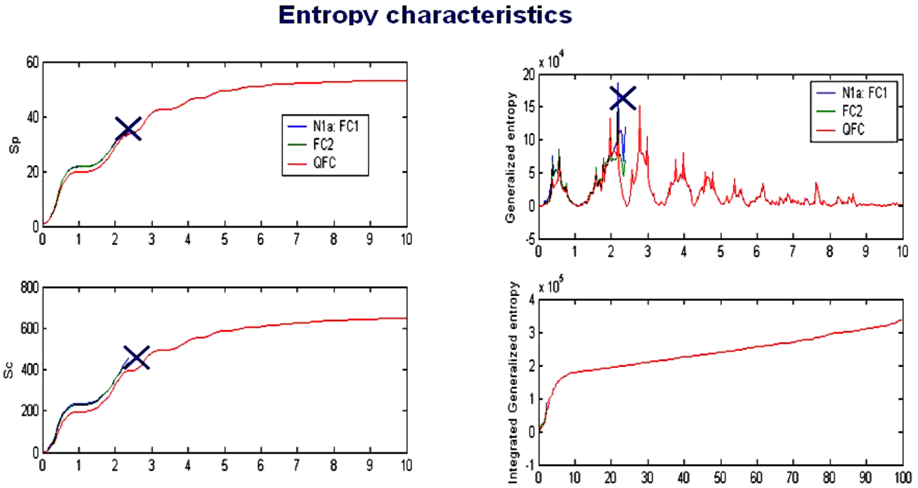


Fig. 11. ***Comparison of entropy production in control object (Sp) and in controllers (left) and comparison of generalized entropy production (right) in unpredicted control situation 1.***

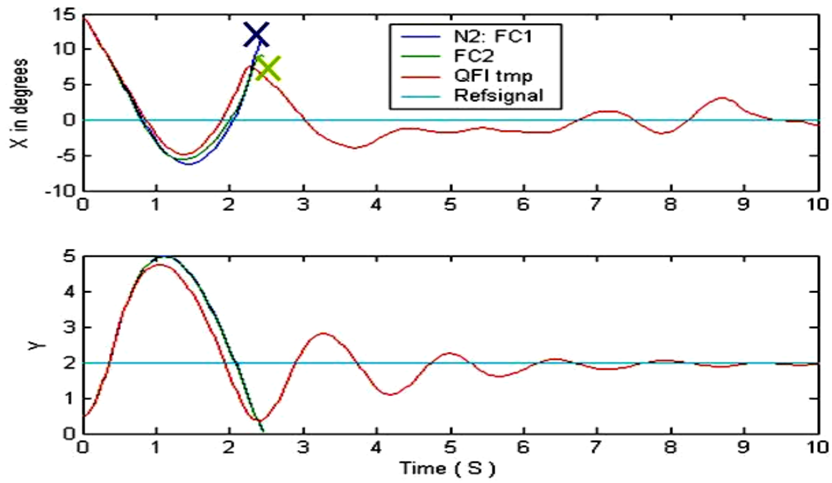


Fig.12. ***Swing motion and integral control error comparison in unpredicted control situation 2.***

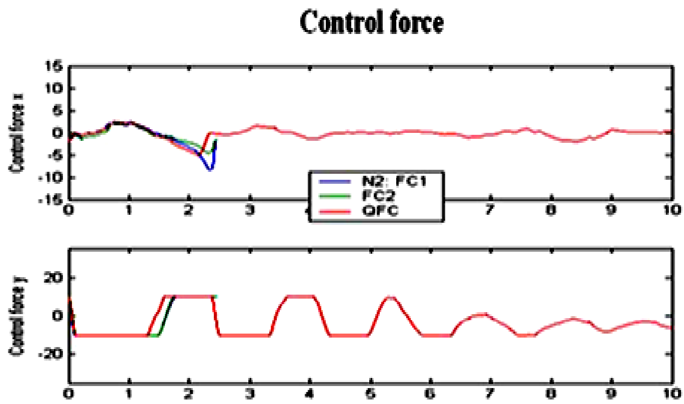


Fig. 13. ***Control forces comparison in unpredicted control situation 2.***

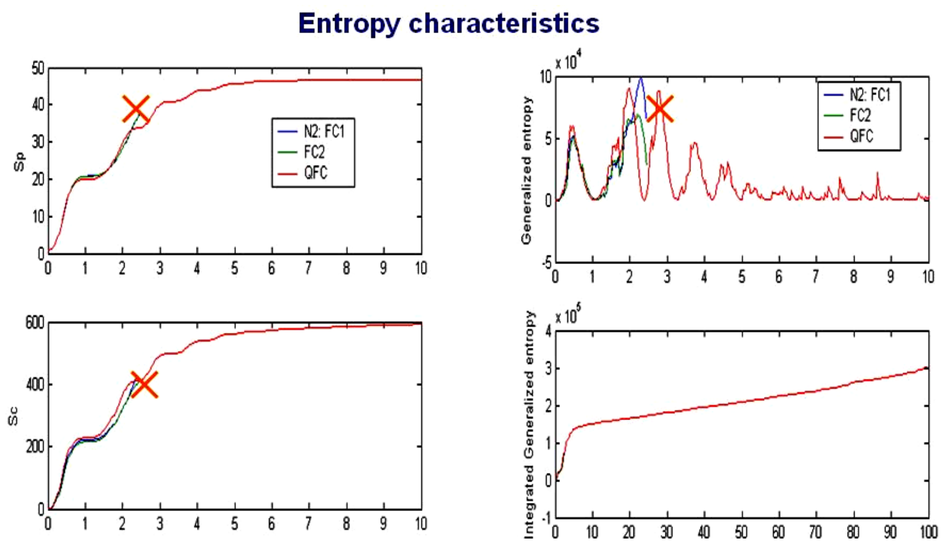


Fig. 14. ***Comparison of entropy production in control object (Sp) and in controllers (left) and comparison of generalized entropy production (right) in unpredicted control situation 2.***

General comparison of control quality of designed controllers Consider now general comparison of control quality of four designed controllers (FC1, FC2, QFC based on temporal QFI with 2 KB). We will use the control quality criteria of two types: dynamic behavior performance level and control performance level.

Control quality comparison is shown on Figs below15, 16.

Comparison based on integral of squared control error criterion

	TS	S1	S2
FC1	0,469	0	0
FC2	0,5171	0	0
QFC	0,3119	0,099	0,1115
Winner	QFC	QFC	QFC

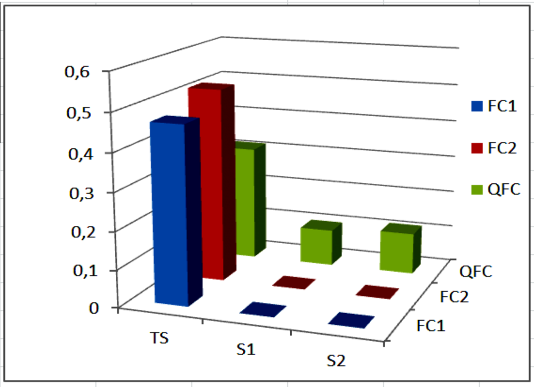


Fig.15. ***Comparison based on integral of squared control error criterion.***

Control force comparison

	TS	S1	S2
FC1	0,3153	0	0
FC2	0,3262	0,3161	0
QFC	0,3034	0,3187	0,1662
Winner	QFC	FC2	QFC

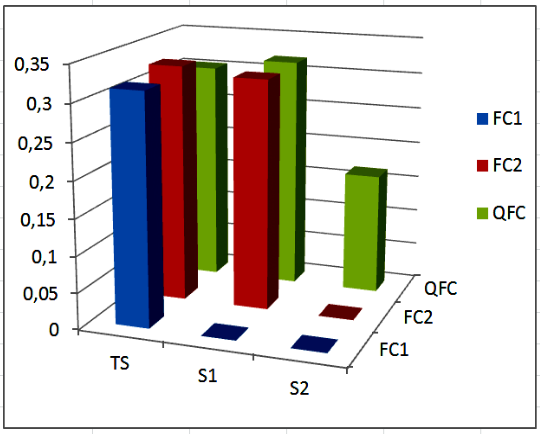


Fig.16. ***Comparison based on simplicity of control force.***

- QFC is robust in all situations;
- FC1 controller is not robust in**2, 3** situations;
- FC2 controller is not robust in **2, 3** situations.

Thus, ICS with QFI based on two KB and temporal correlation type has the highest robustness level (among designed controllers) and show the highest self-organization degree.

From simulation results follows an unexpected (for the classical logic and the methodology of ICS design) conclusion: with the help of QFI from two not robust (in unpredictable situation) controllers (FC1 and FC2) one can get robust FC online.

Let us consider intelligent control system (ICS) for 3 degrees of freedom (DoF) redundant planar manipulator that developed by sequential increasing of intelligence. Configuration redundancy provides many solutions of inverse problem of dynamic which allows operate the control object (CO) in a changing environment.

4. Three degrees of freedom manipulator

Behavior manipulator is a mechanism that performs motor functions, much like the movement of the human hand. However, the human hand has 27 degrees of freedom (DoF), while the majority of the manipulator is limited to 3–6 DoF, which are sufficient for a number of practical applications.

In this report, as CO, acts redundant 3 DoF planar manipulator.

Figure 17 shows schematic of CO, where q_1, q_2 and q_3 are position of manipulator links (index indicates the number of link from the base of the manipulator), (p_x, p_y) are coordinates of manipulator capture device respectively axes (X, Y).

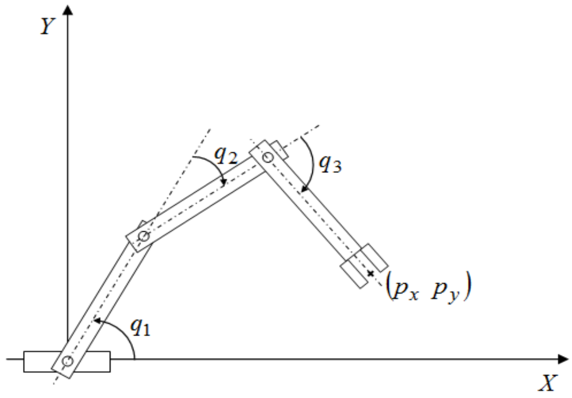


Fig. 17. ***Three degrees of freedom manipulator.***

The task of the robot arm with three degrees of freedom is the positioning of the capture device at a given point (p_x , p_y) by setting the position of the robot arm links angles — q_1, $q_2$and q_3 at a given level. The equation relating to the position of the links and the capture device point is described as following:

$$\begin{cases} p_x = l_1 \cos(q_1) + l_2 \cos(q_1 + q_2) + l_3 \cos(q_1 + q_2 + q_3) \\ p_y = l_1 \sin(q_1) + l_2 \sin(q_1 + q_2) + l_3 \sin(q_1 + q_2 + q_3) \end{cases} \qquad (1)$$

So as a reference signal of model is the value of the positions of the manipulator links — q_1, q_2 and q_3, in [6] was introduced the method of calculation of these positions under known Cartesian space coordinates (p_x , p_y), i.e. the solution method of the inverse problem of 3 DoF redundant manipulator dynamic.

Manipulator mathematical model is developed using *n* DoF manipulator dynamic equations [7]. The example of simplyfied 3 DoF redundant manipulator mathematical model was considered in [8]. Earlier in [6], *Matlab*-simulation based on genetic algorithms (GA) of ICS for redundant robot manipulator was described.

After preliminary research models of ICS 3 DoF manipulator module was designed (Fig. 18).

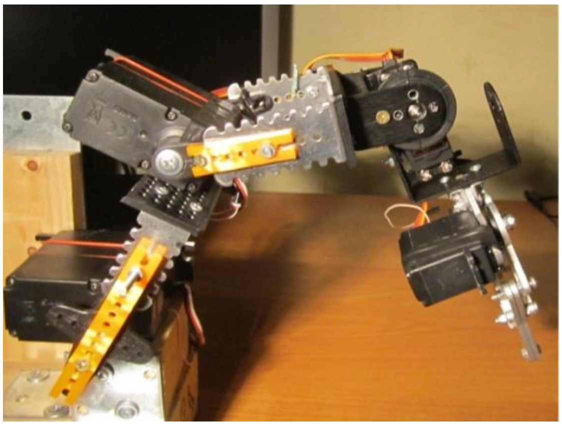


Fig. 18. ***Three DoF manipulator module.***

Given the limitations on the module models of ICS for real world CO was developed. These models (with their software and hardware implementation) are discussed further in this report.

The aim of this work is to design ICS for robot manipulator, which allows guaranteed control in unexpected (unpredicted) situations online due to application of the proposed control algorithms. Despite its importance the development of the design algorithm of robust ICS that can operate efficiently at risk refers to a complex and poorly studied area.

Earlier this objective is achieved by expert systems. To eliminate the subjectivity of knowledge soft computing technologies are applied [9]. They are the basis of computational intelligent tools named "Soft Computing Optimizer (SCO) of knowledge bases" [10].

4.1. *Development of model of ICS based on SCO of knowledge bases for 3 DoF redundant planar manipulator* Basis for the soft computing technology is fuzzy logic, which does not use the law of the excluded middle. Introduction to the theory of fuzzy systems subjective qualitative scale and display it in the form of linguistic approximation of the quantitative characteristics causes some logical difficulties, such as: the objective determination of the kind of membership function and its parameters in the production rules of knowledge base (KB), the definition of the optimal structure of fuzzy neural network at training tasks, the use of GA in multi-objective control, etc. The above problems have been tried and resolved by SCO of knowledge bases [11]. Computational intelligent design tools allows to robust KB design based on solution the one of the algorithmically intractable problems of the theory of artificial intelligence — extraction, processing and formation of objective knowledge without the use of expert estimations.

The main element of intelligent improvement of ICS based on SCO is fuzzy controller (FC), which in *online* mode performs adjustment of PID gains depending on current conditions.

Figure 19 demonstrates structure schematic of ICS based on SCO.

Knowledge base design process has described in [3].

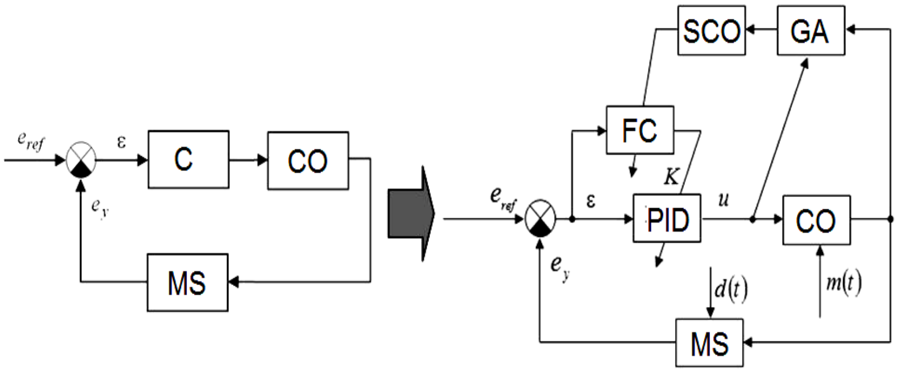


Fig. 19. ***Transition to ICS based on SCO of knowledge bases.***

To test the robustness of the developed ICS in the workspace of the manipulator has been selected a group of ten test points (Fig. 20).

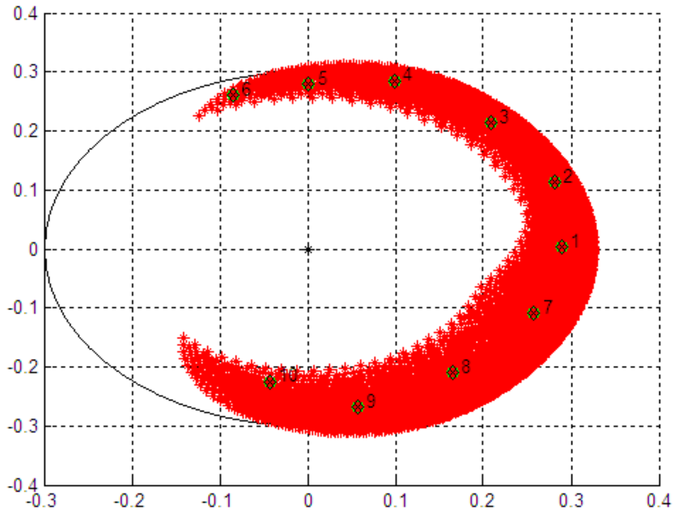


Fig. 20. ***Test space.***

Let us consider the following unpredicted control situations:

Situation 1 At the moment 0,2 second position of link 2 forced changes to the value q_2 = 67 deg

Situation 2 For ICS based on GA let's change initial condition: q_1 = 60 deg; q_2 = 57 deg; q_3 = - 43 deg.

Performance of ICS behavior is evaluated by following criteria:

1) the percentage of solution of positioning tasks for manipulator capture device (problem is considered solved if each of the three links is positioned with zero error within allowed time frame);

2) elapsed time to solve the positioning problem (limit — 10 sec. if for given time the problem is not solved, then the positioning time is specified with minimum error).

As the initial condition taken an upward manipulator position (q_1 = 60 deg; q_2 = 0 deg; q_3 = 0 deg). For demonstration ICS based on SCO performance the following KB of FC was created:

- GA model for teaching signal creation and three GA of SCO were described in [6];
- Sugeno 0 fuzzy inference model;
- Fuzzy AND operation is product;
- Number of input variables is 9;
- Number of output variables is 9;
- Optimization technique is back propagation algorithm.

Testing results of developed ICS based on SCO are represented in Tables 3 and 4.

Table 3

Experiment as results of ICS based on SCO for points 1-5

		Points of test space				
		1	2	3	4	5
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,26	0,28	0,32	0,24	0,42

Table 4

Experiment as results of ICS based on SCO for points 6-10

		Points of test space				
		6	7	8	9	10
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,34	0,36	0,4	0,6	0,64
Solution of positioning task (Table 8)		100 %				

Testing results can be concluded that ICS based on SCO copes with positioning task with given accuracy in all ten experiments. Moreover, if for ICS based on GA the average positioning task solution time is 5,082 s, than for ICS based on SCO this characteristic is 0,386 s. That is, the average positioning task solution time under ICS based on SCO is reduced in 13,17 times.

Consider the behavior of ICS based on SCO in above introduced uncertain situations.

Results of forced changing of link 2 position (Situation 1) for test point 1 are illustrated by Figs 21 and 22. Wherefrom can be seen that positioning task has solved during 0,88 s (the maximum time is 10 s).

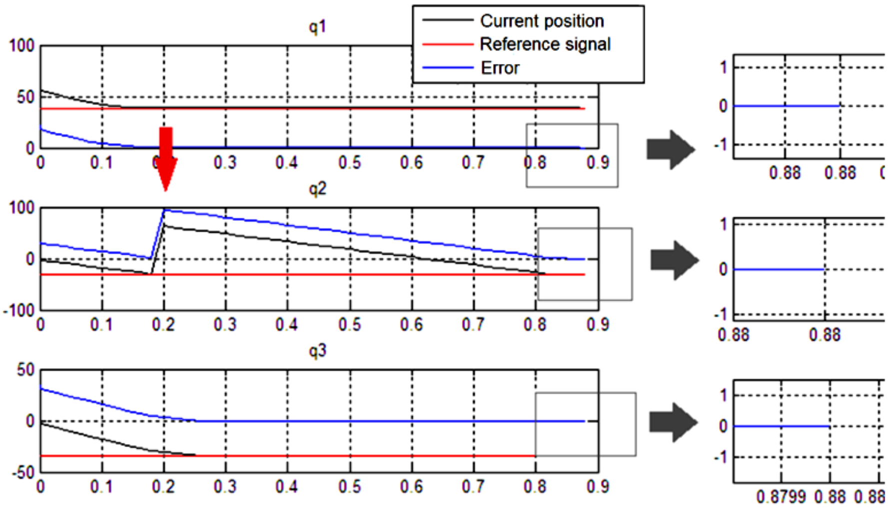


*Fig. 21 . **External influence reaction of ICS based on SCO.***

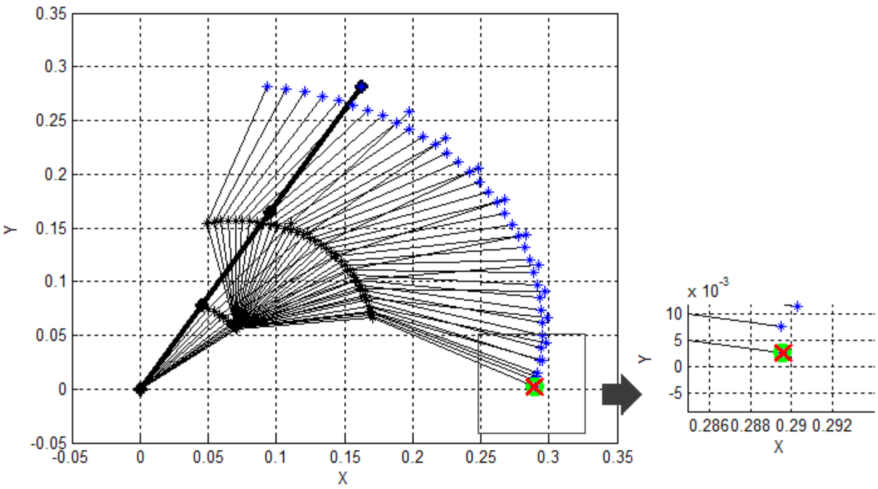


Fig. 22. ***Manipulator behavior motion trajectory.***

Let's change initial condition for test point 10 (Situation 2).

From Figs 23 and 24 can be seen that positioning task solved during 0,76 s.

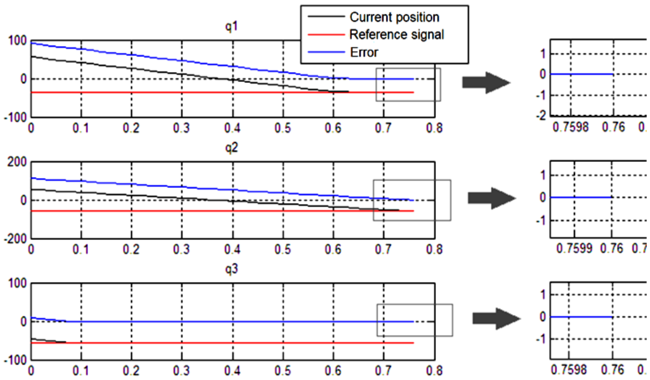


Fig. 23. ***Perturbation of initial condition changing.***

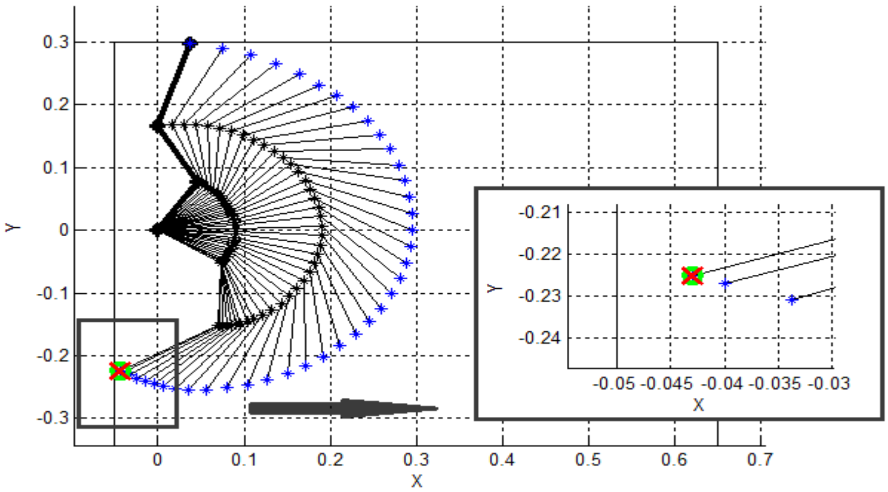


Fig. 24. ***Manipulator behavior motion trajectory.***

Obviously, in uncertain situations the positing time of manipulator capture device for ICS based on SCO is increased (in 3,38 times for Situation 1 and in 1,19 times for Situation 2), but its value does not exceed 0,9 s while for ICS based on GA the positioning task is not solved even during allotted time (10 s).

So, ICS based on SCO versus ICS based on GA besides reducing positioning time at known control situations on the average 13, 17 times, also ensures sustainable management in unforeseen situations by dynamically adjusting the control parameters.

Figure 25 depicts PID gains dynamic obtained online for last control example.

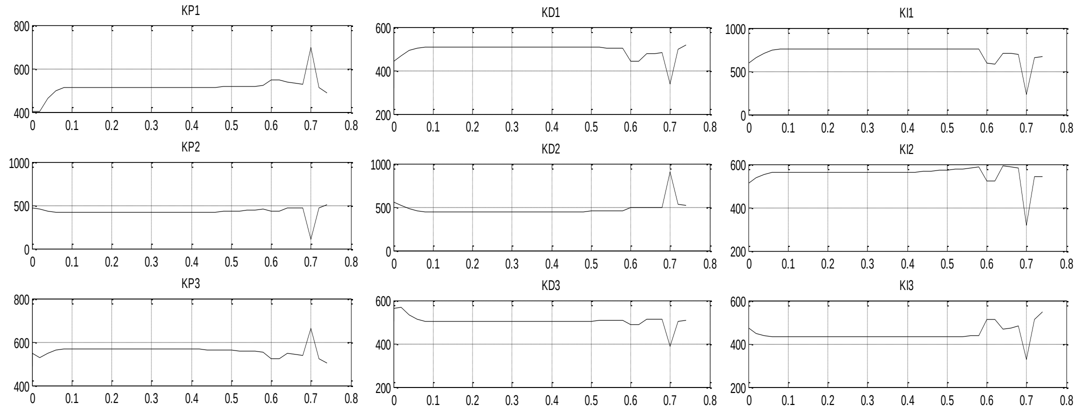


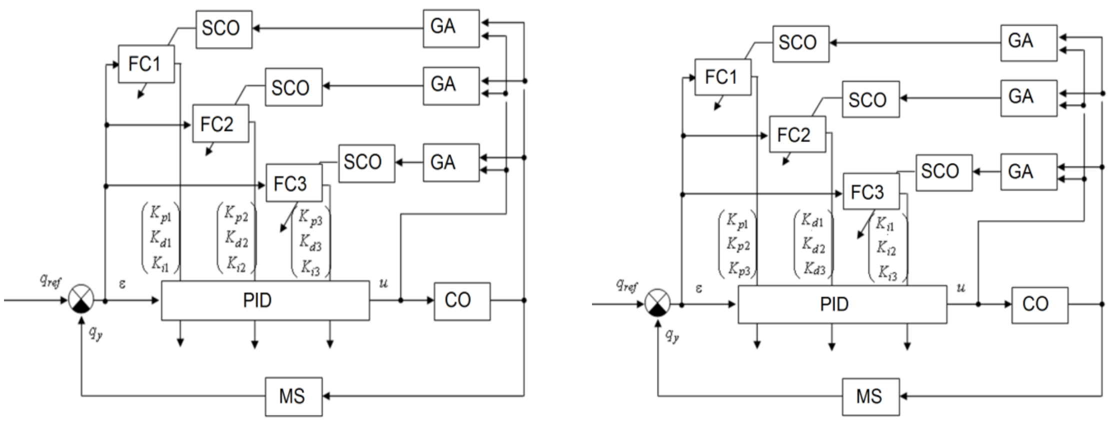
Fig. 25. ***PID gains.***

Remark. Often, the PID controller is implemented in software, and the problem of control is reduced to finding the coefficients of the PID controller K_P, K_I, K_D, which provide the desired character of the movement. Considered CO, 3 DoF planar manipulator, requires the control action vector $u = \left[u_1 \quad u_2 \quad u_3 \right]$, which dimension is equal to the number of DoF. When we select PID as regulator to identify each of the components of the vector u we need three terms K_P, K_I, K_D. Thus, to control the 3 DoF manipulator is necessary to determine the nine coefficients of the PID controller. Assume that the range of coefficients is determined by interval $K = \left[0..1000 \right]$ with up to 1 accuracy. Then the number of possible sets of coefficients of the PID controller is 1001^{3*n}, where n is the number of degrees of freedom of manipulator. For the case with 3 DoF manipulator it is 1009036084126126084036009001 variants. Using a genetic algorithm (GA) [6] with the size of the initial population of 200 individuals allows finding the solution that is close to the optimum in less than 20 iterations. However, when we need to increase the number of DoF each degree will increase the dimensionality of the search space up to three that will lead to an increase the time of the search algorithm execution and, as a result, may lead to the fact that the resources of the PC is not enough.

To reduce the dimensionality of the search space of control parameters of 3 DoF manipulator we have developed the control structure with split management based on three fuzzy controllers (FC) and knowledge bases (KB), obtained by the tools named “Soft Computing Optimizer” (SCO).

4.2. *Structures with split control* To control 3 DoF manipulator the logical solution would be to create the structure of intelligent control system (ICS) with three FC.

Depending on the control type the structures can be divided into individual links management systems (ICS structures for the three links, Fig. 26a), and the structures by error type management (ICS structures for proportional, integral and differential coefficients, Fig. 26b).



a. For three links

b. for proportional, integral and differential coefficients

Fig. 26. ***ICS structures.***

Depending on the method of obtaining KB for FC, one can distinguish parallel and cascade structures of ICS based on SCO.

Parallel structures of ICS perform independent management of FC. Obtaining KB for FC is in several stages:

1) obtaining parameters 1-3 (three outputs of first FC): parameters 4-9 are assumed constant;

2) obtaining parameters 4-6 (three outputs of second FC): parameters 1-3, 7-9 are assumed constant;

3) obtaining parameters 7-9 (three outputs of third FC): parameters 1-6 are assumed constant.

Thus, KB obtaining for each of three FC is independent of each other. Parallel structures are simple to implement and, importantly, the need to change KB of the one of FCs does not require changes in other KBs.

Cascade structures of ICS based on SCO perform sequentially-guided fuzzy control. Obtaining KB for FC is in several stages:

1) obtaining parameters 1-3 (three outputs of first FC): parameters 4-9 are assumed constant;

2) obtaining parameters 4-6 (three outputs of second FC): parameters 7-9 are assumed constant, parameters 1-3 are generated by first FC with KB get on the previous step;

3) obtaining parameters 7-9 (three outputs of third FC): parameters 1-6 are generated by first and second FCs with KBs get on the previous steps.

In the cascade structures each subsequent generated KB account previously obtained KBs. However, the need to change the KB of one of FC will require changes in the previous KBs. In addition, the procedure for determining of the parameters plays an important role.

As an example, let's consider the parallel structure of ICS for the three links based on SCO because it is simpler to implement and optimize.

4.3. *Development of the model of ICS based on SCO with split control* To check robustness of ICS model with split control on the example of the proposed parallel ICS structure based on SCO for three links we selected ten test points from the manipulator workspace.

Performance of ICS behavior is evaluated by following criteria:

1) the percentage of solution of positioning tasks for manipulator capture device (problem is considered solved if each of the three links is positioned with zero error within allowed time frame);

2) allowed time to solve the positioning problem (limit — 10 s, if for given time the problem is not solved, then the positioning time is specified with minimum error).

As the initial condition taken the following position: q_1 = 60 deg; q_2 = 0 deg; q_3 = 0 deg.

Results of ICS based on SCO for three links performance are shown in Tables 5 and 6.

Table 5

Experiment as results of ICS based on SCO with split control for points 1-5

		Points of test space				
		1	2	3	4	5
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		6,66	0,28	1,04	0,52	0,44

Table 6

Experiment as results of ICS based on SCO with split control for points 6-10

		Points of test space				
		6	7	8	9	10
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,36	8,44	0,38	0,58	0,64
Solution of position task (See Table 1)		100 %				

Form Tables 5 and 6 follows that ICS based on SCO with split control solved positioning task for all considered points. The average time of the positioning task solution is 1,934 s.

Continuing research on ICS based on SCO with split control let's consider a few unpredicted control situations.

Situation 1 At the moment 0,2 s position of link 2 forced changes to the value q_2 = 67 deg (Fig. 27).

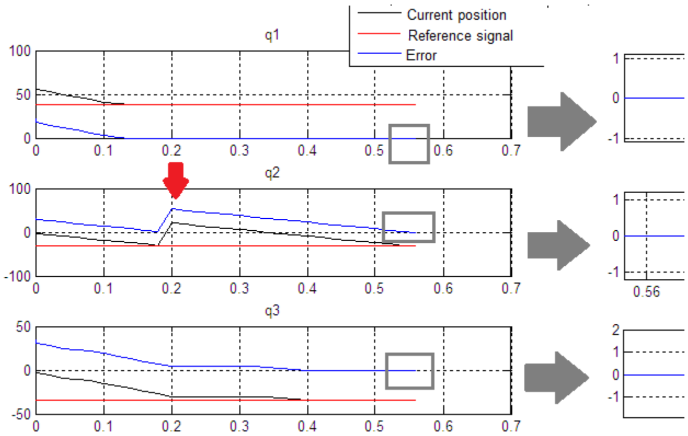


*Fig.27. **External influence and its perturbation.***

The result of this action (Fig. 27 based on an example of test point 1) is that the positioning task solved in 0,56 s. It should be noted that normally the task of positioning solved in 6,66 s (in 11,89 times slower), i.e. for this example, external influence "helped" — positioning time has significantly reduced.

Situation 2 Initial conditions changed respectively: q_1 = 60 deg; q_2 = 57 deg; q_3 = -43 deg (earlier q_1 = 60 deg, q_2 = 0 deg, q_3 = 0 deg were used).

As a result, changes in the initial conditions the positioning problem was not solved at all (Fig. 28).

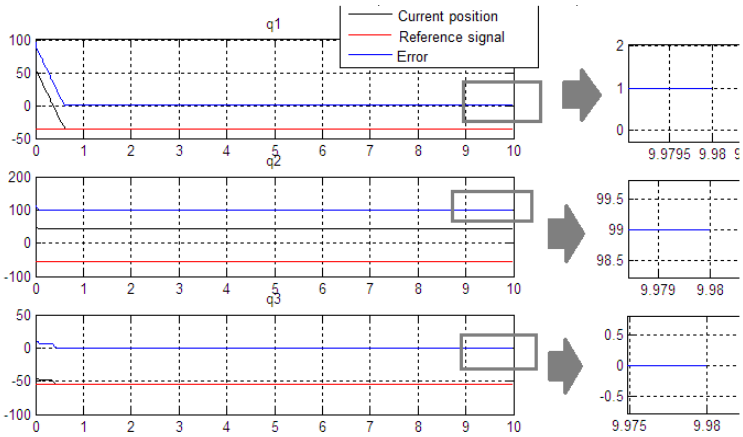


*Fig. 28. **The consequences of changes in the initial conditions.***

Situation 3 Initial conditions changed respectively: q_1 = 60 deg; q_2 = 57 deg; q_3 = -43 deg. Furthermore, at the moment 0,2 s position of link 2 forced changes to the value q_2 = 67 deg (Fig. 29).

As a result of such changes (in Fig. 29 as example was taken point 7 of manipulator workspace) the positioning problem was not solved.

Thus, under certain conditions, ICS based on SCO with split control is good enough to cope with the positioning task of the manipulator capture device. However, as demonstrated by *Situation* 2 and *Situation* 3, the proposed ICS becomes unable to perform certain tasks in unpredicted cases.

Solution the problem of CO management in unpredicted situations is possible using a strategy to improve the robustness of the designed FC through the use of new types of computations based on the methodology of quantum computing. Implementing the property of ICS — self organization of KB is achieved by introducing a generalization strategies in models of fuzzy inference in the form of a new, quantum fuzzy inference (QFI) [10].

QFI algorithm implemented in the intelligent tools named Quantum Computing Optimizer (QCO).

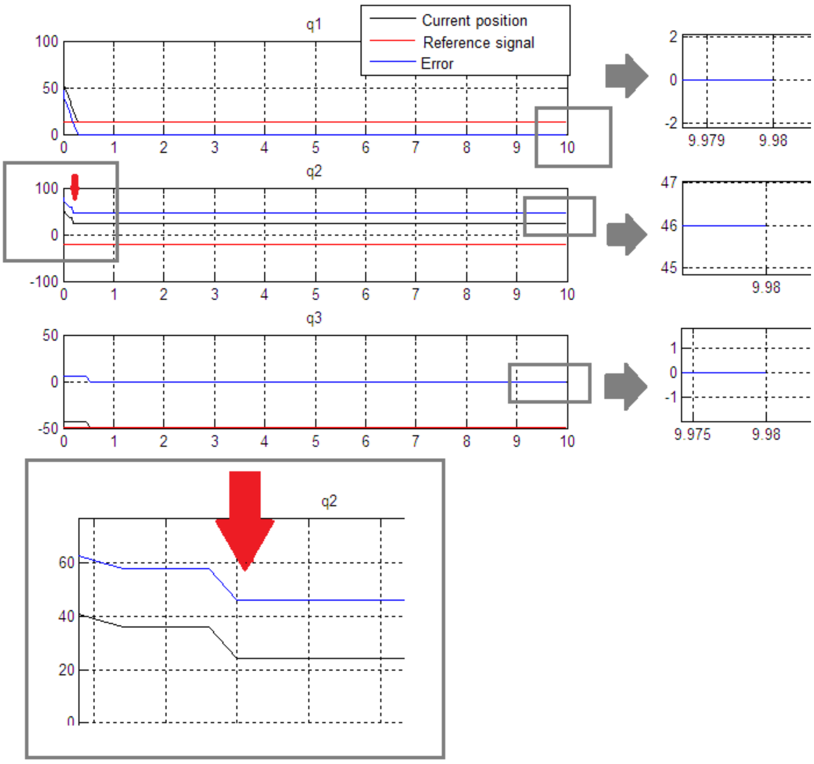


Fig. 29. ***The consequences of changes in the initial conditions and external influence.***

4.4 *Development of the model of ICS based on QCO* In [12, 13] given a generalized methodology for selection of the strategy to switch the flow of control signals from the output of the various knowledge bases of FC, designed for different control situations.

This methodology is illustrated in Fig. 30: designed in the first stage FCs for different control situations are generalized by QFI methodology in the second stage. As a result of "generalized" KB guaranties the management in all the control situations.

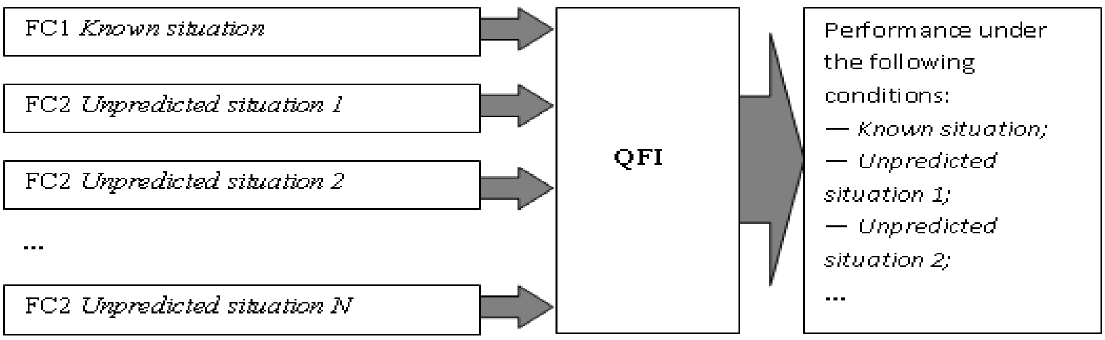


Fig. 30. ***Methodology for selection of a generalized strategy to switch the flow of control signals from the output of the various knowledge bases of FC designed for different control situations.***

The model of developed QFI is seen as a new kind of quantum search algorithm [14 - 16], acting on the generalized space of knowledge bases of FCs. QFI uses and implements processes of extraction of hidden quantum information contained in the individual classical KB of FC, based on physical laws of quantum information theory and quantum computing.

When applied to the developed ICS based on QCO to control 3 DoF manipulator we use the following methodology: extraction of hidden information from relationships of existing FCs (ICS structure with split control) for the three links of manipulator with KB obtained for known control situations (Fig. 31).

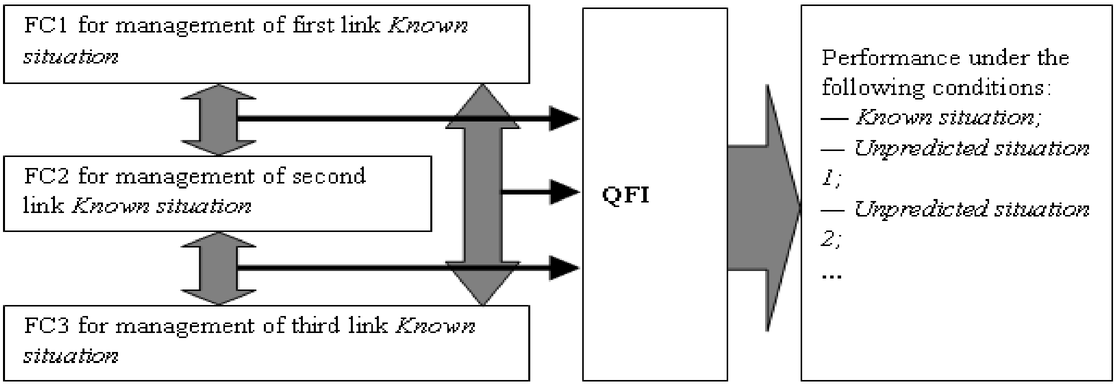


Fig. 32. ***The methodology of extraction of hidden information from relationships between KB, designed for known control situations.***

In accordance with this methodology the model of ICS based on QCO is designed. Further, the spatial, temporal and spatio-temporal correlation investigations are considered [12].

The results of ICS based on QCO performance in known situations control using spatial, temporal and spatio-temporal correlations are shown in Tables 7, 8, 9,10 and 11, 12 correspondingly.

Table 7

Experiment as results of ICS based on QCO with spatial correlation for points 1-5

		Points of test space				
		1	2	3	4	5
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,26	0,28	0,34	0,26	0,44

Table 8

Experiment as results of ICS based on QCO with spatial correlation for points 6-10

		Points of test space				
		6	7	8	9	10
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,36	0,36	0,4	0,58	0,64
Solution of position task (See Table 3)		100 %				

Table 9

Experiment as results of ICS based on QCO with spatiotemporal correlation for points 1-5

		Points of test space				
		1	2	3	4	5
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,24	0,28	0,34	0,24	0,44

Table 10

Experiment as results of ICS based on QCO with spatio- temporal correlation for points 6-10

		Points of test space				
		6	7	8	9	10
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,36	0,36	0,4	0,58	0,64
Solution of position task (See Table 5)		100 %				

Table 11

Experiment as results of ICS based on QCO with temporal correlation for points 1-5

		Points of test space				
		1	2	3	4	5
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,24	0,28	0,34	0,24	0,44

Table 12

Experiment as results of ICS based on QCO with temporal correlation for points 6-10

		Points of test space				
		6	7	8	9	10
Positioning error for a link, deg	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
Positioning task completion time, s		0,36	0,34	0,4	0,58	0,64
Solution of position task (See Table 7)		100 %				

From Tables 7 – 12 follows that in the case of ICS based on QCO in known control situations, when we select any of the three correlations, positioning tasks solved in 100% of cases, the average positioning time is:

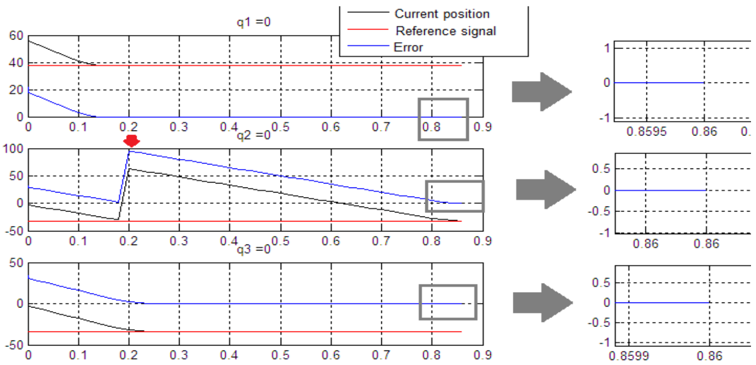
— 0,392 s for spatial correlation (on average, in 4,93 times faster than for ICS based on SCO with split control);

— 0,782 s for the spatio-temporal correlation (on average, in 2,47 times faster than for ICS based on SCO with split control);

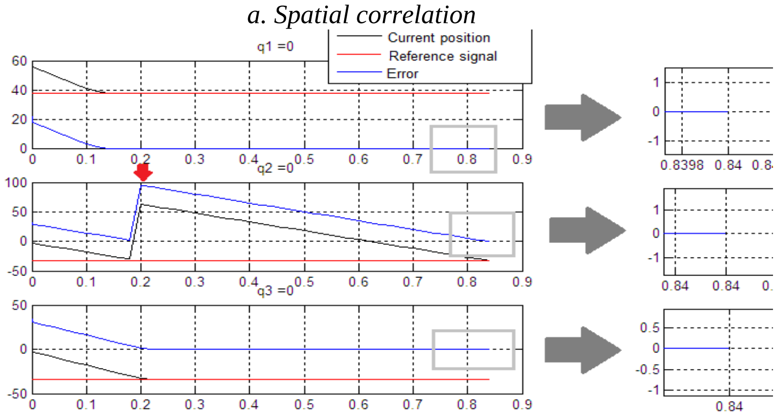
— 0,374 s for the temporal correlation (on average, in 5,17 times faster than for ICS based on SCO with split control).

Consider the behavior of ICS based on QCO in the above considered control situations.

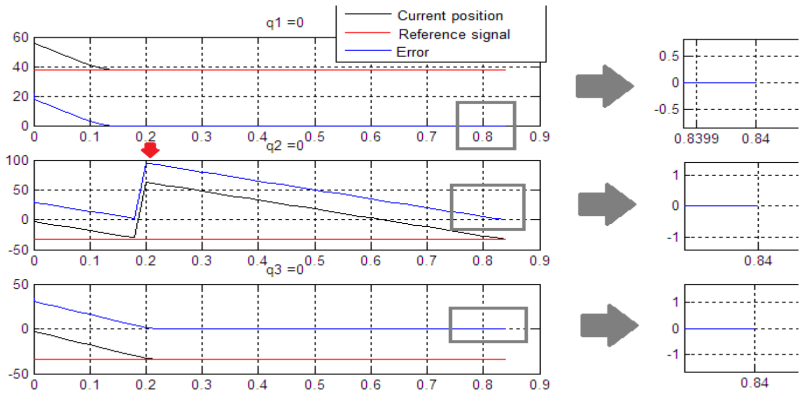
Situation 1: at the moment 0,2 s position of link 2 forced changes to the value q_2 = 67 deg (Fig. 33).



a. Spatial correlation



b. Spatio-temporal correlation



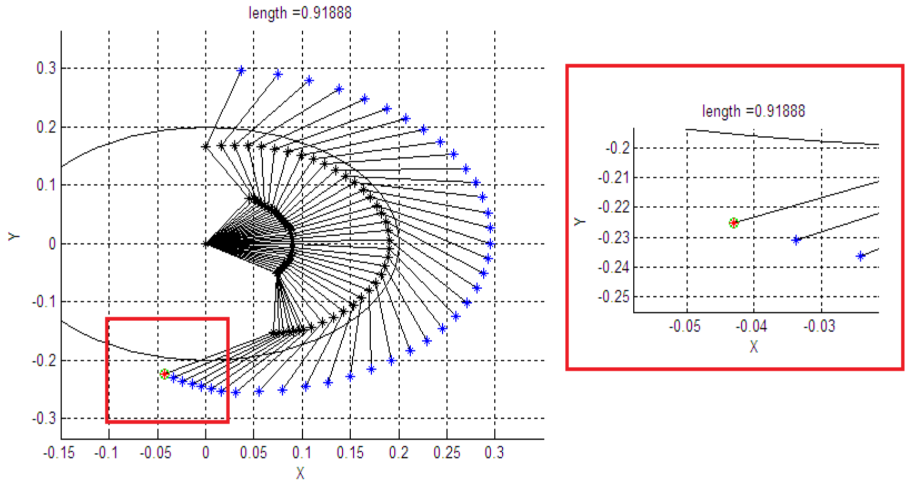
c. Temporal correlation

Fig. 33. ***External influence and its perturbation.***

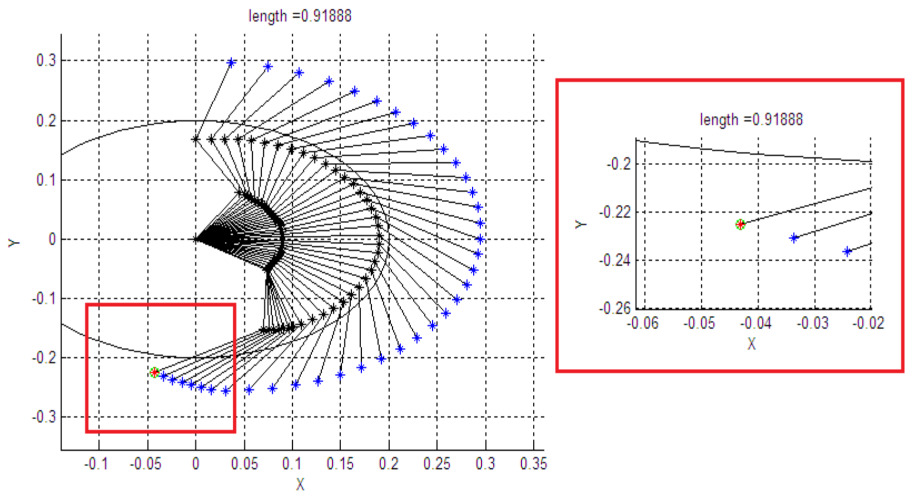
The result of this action (Fig. 33 based on an example of test point 1) is that the positioning task solved for different correlation in:

— 0,88 s (spatial correlation);
— 0,86 s (spatio-temporal);
— 0,86 s (temporal correlation).

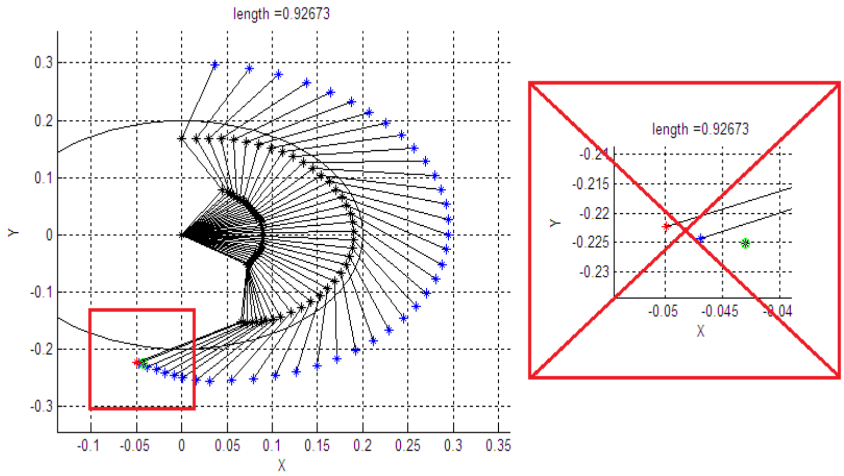
Situation 2: initial conditions changed respectively: q_1 = 60 deg; q_2 = 57 deg; q_3 = -43 deg (earlier, in known situation q_1 = 60 deg, q_2 = 0 deg, q_3 = 0 deg were used) (See Fig. 34).



a. Spatial correlation



b. Spatio-temporal correlation



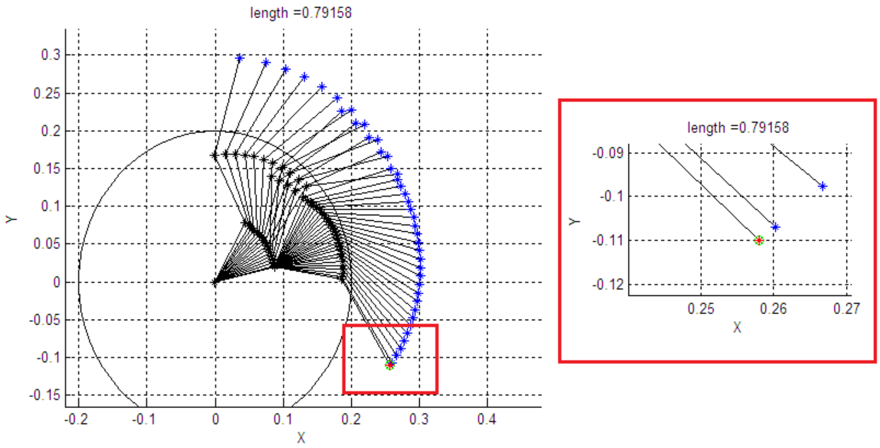
c. Temporal correlation

Fig. 34. ***The consequences of changes in the initial conditions.***

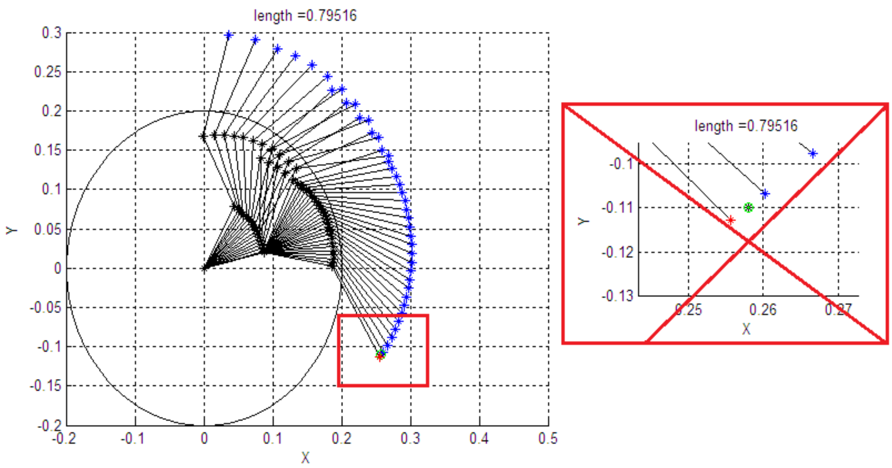
The result of this action (Fig. 34 based on an example of test point 10) is that the positioning task is not solved only for QFI based on temporal correlation.

*Situation 3***:** initial conditions changed respectively: q_1 = 60 deg; q_2 = 57 deg; q_3 = -43 deg. Furthermore, at the moment 0,2 s position of link 2 forced changes to the value q_2 = 67 deg (Fig. 35). The result of this action (Fig. 35 based on an example of test point 7) is that the positioning task is not solved for QFI based on temporal and spatio-temporal correlations. Thus, ICS based on QCO in known situations provides the successful solution of the positioning task, and allows in 2,47 times (as a minimum) to reduce the time of the transition.

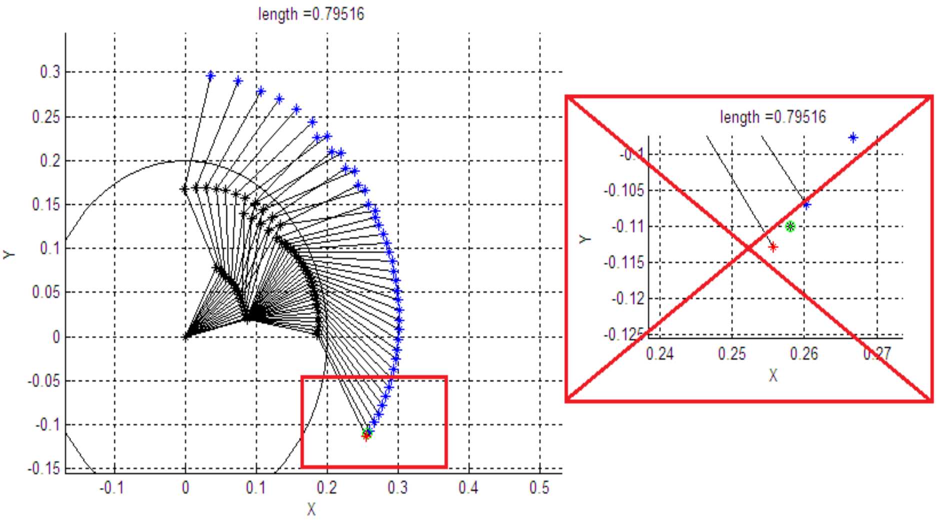
With proper selection of the type of correlation, ICS based on QCO provides a guaranteed control in unpredicted control situations (for considered *Situation* 1, *Situation* 2 and *Situation* 3 spatial correlation was used).



a. Spatial correlation



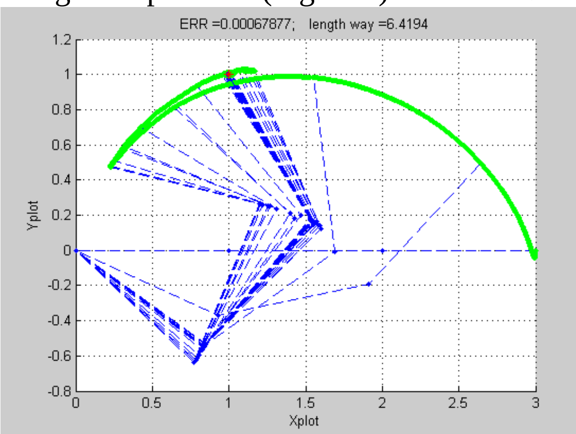
b. Spatio-temporal correlation

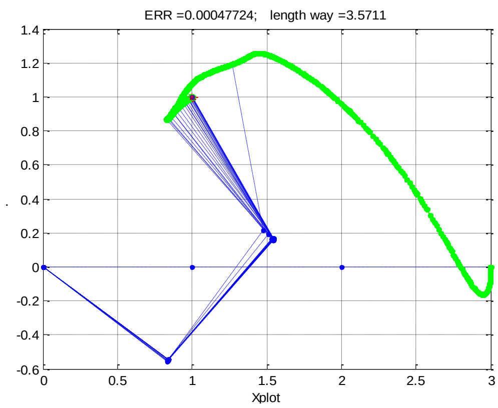


c. Temporal correlation

Fig. 35. ***The consequences of changes in the initial conditions.***

On Fig. 36 simulation results based on soft computing (Fig. 36a) and on Quantum computing KB optimizer (Fig. 36b) are shown.





a) Soft computing optimization *b) Quantum computing optimization*

Fig. 36. ***Robot manipulator simulation.***

From simulation result in Fig. 36 we can concludes, that fuzzy controller based on QCO has the better performance of control quality.

Let us considered a Benchmark of robotic systems as “cart - pole” based on quantum soft computing technology.

5. Modeling of mobile autonomous macro-robot based on quantum soft computing technology

“Cart – pole” control object is a non-linear dissipative system. This is typical task of control theory, they demonstrating quality of control system. Task of control is the stability of inverted pendulum in vertical position. Solution of this task it’s a PID controller in global negative back connection, but this control not effective and not robust. We are use methods of artificial intelligence for most robust control. Fuzzy controller is a central element of intelligent control system. They change P, I and D coefficients in PID controller with using base of knowledge integration in controller.

5.1. *Soft computing technology application* This base includes a fuzzy input and output value of membership function in production rules. Most actuality problem in intelligent control systems design is obtaining optimal and robust knowledge base which guarantees high level of control quality in presence all mentioned above difficulties in complex dynamic systems control. For building fuzzy controller we use a Soft Computing Optimizer (SCO) (http://www.qcoptimizer.com/). The Soft Computing applied to design of intelligent control systems represents a combination of the following approaches: Fuzzy Systems Theory for a fuzzy control, Genetic Algorithms for global optimization of control laws, and Fuzzy Neural Networks for physical realization of optimal control laws and for knowledge base design of FC using the extraction of necessary information by learning and adaptation methods.

In result, we have a completed base from SCO. They description is shown in Table 13.

Table 13

Description of knowledge base from SCO

Description	**KB**
Fuzzy inference type	Sugeno
Membership function (MF)	Triangle
Count of MF:	[3 3 5].
Count of rules	15 from 45

For experiments we are used a robot that is shown on Fig. 37.

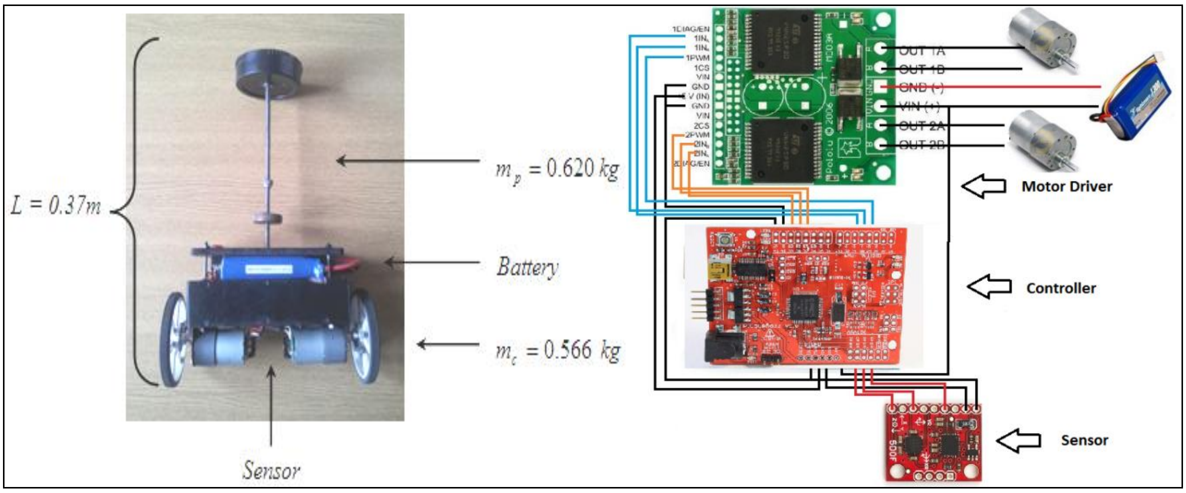


Fig. 37. ***Balancing robot for experiments.***

In this article modeling behavior CO has been made (pendulum with variable length) based on QFI. The obtained simulation results show that designed KB of FC is robust in terms of criteria for control quality such as minimum error control and entropy production, as well as the minimum applied control force. Presented design technology allows achieving control goal even in unpredicted control situations.

Verification model with GA For verification the model needs to know the parameters of the model. Often, in practice, to identify some of them are not possible, so the expert has to select the settings manually. Table 14 presents a classification of parameters, some of which has been determined accurately, but a set of parameters that are calculated with sufficient accuracy was not possible.

Table 14

Parameters of model

Chromosome

Known parameters	**Undefined parameters**
Mass of pendulum	Friction in pendulum shaft
Mass of cart	Spring force
Length of pendulum	Power gain (normalizing)
Control force boundaries	Noise of control force
Time step	Noise in sensors
PID gains	Wheel friction coefficient
Controller input and output data (2000 points).	

Underdetermined problem of finding values of parameters can be solved by using the method described below, based on a genetic algorithm (GA). The GA can select the parameters of the model so that the output data from robot according to the output values used in the simulation in Matlab. As the fitness function used the difference between the variances of simulink Matlab-model and real robot (3):

$$F(e,u)=\frac{1}{1+\left(\frac{Var(e_{\mathrm{mod}})-Var(e_{rob})}{Var(e_{\mathrm{mod}})}\right)^2+\left(\frac{Var(ie_{\mathrm{mod}})-Var(ie_{rob})}{Var(ie_{\mathrm{mod}})}\right)^2+\left(\frac{Var(u_{\mathrm{mod}})-Var(u_{rob})}{Var(u_{\mathrm{mod}})}\right)^2}, \quad (3)$$

where, $Var(e_{\mathrm{mod}})$ — dispersion control error in model, $Var(ie_{rob})$ — dispersion control error of robot, e — control error, ie — integral error, $Var(u_{\mathrm{mod}})$ и $Var(u_{rob})$ — dispersion of control force model and respectively robot.

By using this fitness function, it is possible to achieve adequate model parameters. We will use the GA, and the result was working PID gains. After the determination of the gains test them on the robot. If the result is not satisfactory, then perform the same steps, beginning with model verification. If the correction fails, you should, if possible, to change the number of undefined parameters by fixing one or more of them in a mathematical model.

The verification scheme of the mathematical model is presented in Fig. 38:

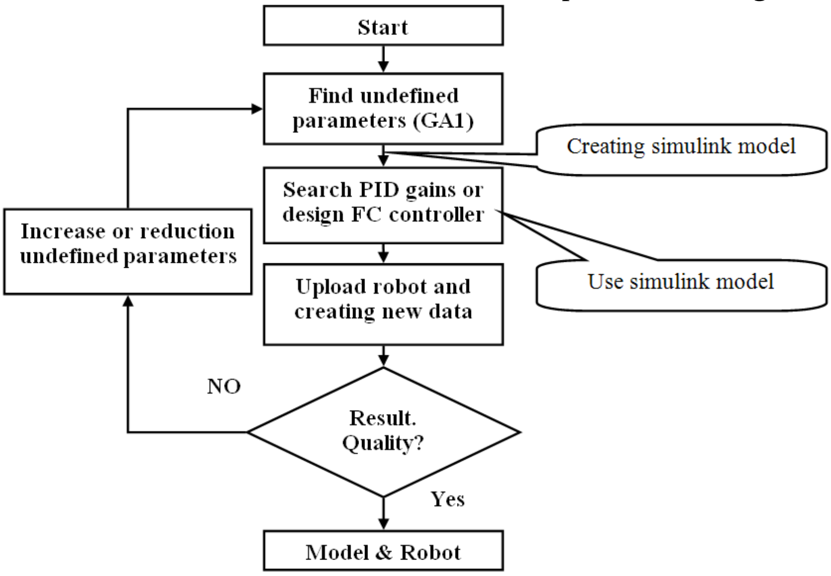


Fig. 38. ***Algorithm of verification with using GA.***

The result of verification of model presented in Fig. 39:

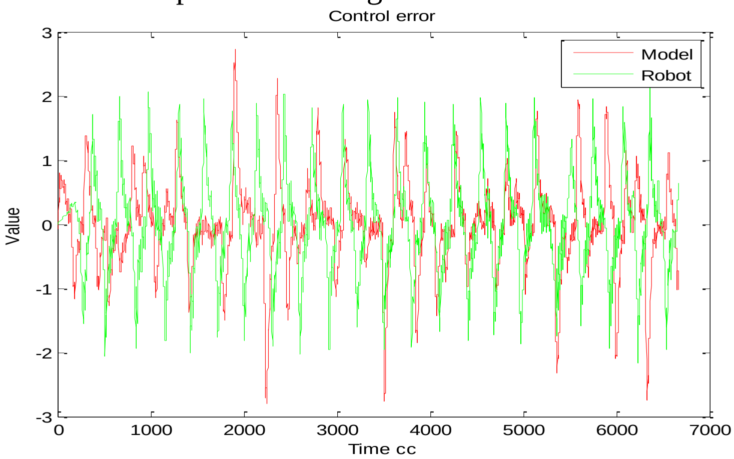


Fig. 39. ***Result of verification. Control error.***

The implementation of a genetic algorithm in on line for creating teaching signal The following discussion focuses on the technology of intelligent robust control systems, based on the quantum and soft computing. There are different ways to set the controls. Usually, the control settings in the absence of the model is accompanied by a lot of experimentation and a lot of difficulties. One of the most important stages of this technology is a step of creating a teaching signal. For using our technology on real objects, the automatic control system (ACS) to add block tuners or adaptation, when can replace expert and get useful information. The adaptation is ability of technological devices or systems to adapt in changing environmental conditions or changing its internal structure, which increases the efficiency of their operations. Our design problem is create intelligent control system such as in operation to cope with the changes in the external and internal conditions, changing its parameters and structure in order to improve control and increase robustness.

In general, the diagram of the ACS adaptation is as follows Fig. 40:

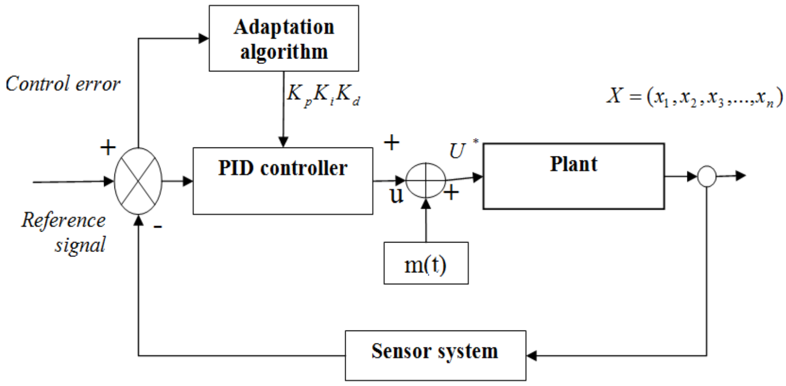


Fig. 40. ***ACS with adaptation block.***

For the task of control was developed and implemented control system with based on GA and define the following fitness function of chromosomes — a square integrated error of control:

$$fit(P) = \frac{1}{1 + (ae + b\int edt + c\dot{e})^2}, a + b + c = 1, \tag{4}$$

here, the coefficients *a*, *b*, *c* can have different weight values for each error. Each gain is valuated in a separate function of fitness. In this case, larger values of the fitness function correspond to small values of control errors, hence, better quality control PID. The range of integration — it's working time one of the solutions (each solution is the same working time). The scheme of GA is shown on Fig. 41.

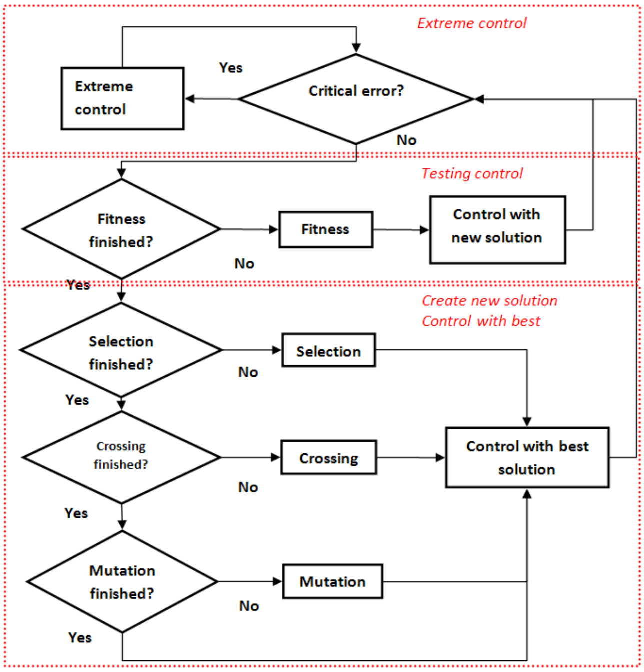


Fig. 41. ***Scheme of GA-On-Line(best solution).***

The best solution is chooses after each iteration which allows the GA to continue to work and not lose control of the pendulum. The inclusion of extreme control is to increase the time control errors up to a certain threshold. The PID gain range value is set expert based dynamic behavior of CO. At the time of selection, crossover and mutation, CPU time processing solutions, and GA is calculated with the best solution $K_pK_iK_d$.

The convergence of the system GA shown in Fig. 42. The advantage of the GA compared to other methods of extremum is that you do not need to calculate the derivative of the undefined function.

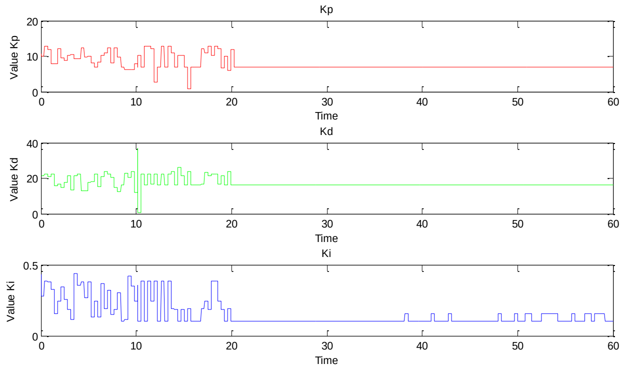


Fig. 42. ***The convergence of the PID gains in the robot GA-process.***

The resulting information can be used as a teaching signal for the approximation to a fuzzy neural network.

5.2. *Quantum Computing Optimizer* We can design several fuzzy controllers for various situations, using SCO. But which one to use in the new unforeseen situation? Quantum fuzzy inference (QFI) algorithm implemented in quantum computing optimizer (QCO) is able to select appropriate signal for current error from the set of fuzzy controller outputs. Like so, we can design the set of KB for all possible control situations or controller types, but we still need the algorithm for on line switching between outputs of different fuzzy controllers. Moreover, there are control situations when intelligent control system based on SCO is not able to control without the additional operational information. So, for these purposes we have developed a quantum fuzzy inference algorithm and a QCO to adjust this algorithm for particular CO. Then, Fig. 2 designates QFI algorithm. The algorithm uses quantum mathematics formalism: the output gains of all FCs are converted to kind of qubits, after that their superposition is created by the tensor product. We will not need to dwell on it in detail, it is important that means that there is a interdependence between the PID controller gains. This dependence can be laid before to the quantum fuzzy inference algorithm initially as a design parameter. This relationship is given in the form of the correlation matrix. This correlation can be made by different ways.

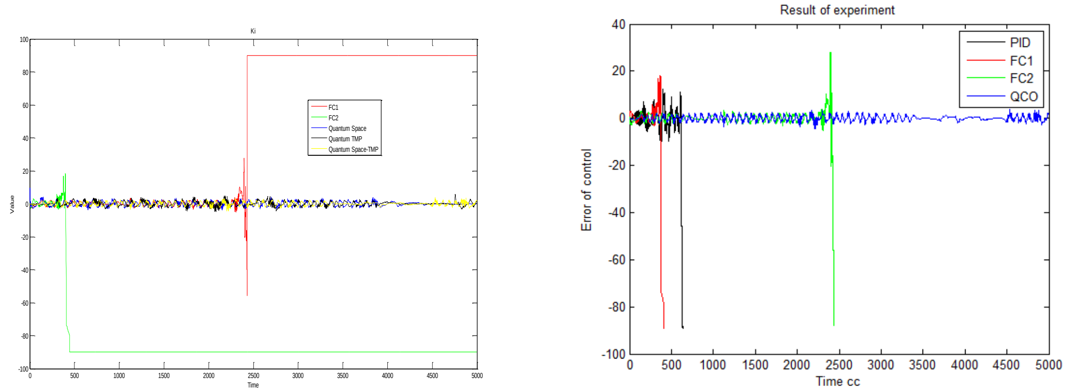
One way is to use correlation between various control gains at the same point of time. Such correlation we call spatial. Correspondingly, we can take the values of the one control gain (*Kp* for example) at the different points of time. This is temporal correlation. The third main correlation is the mixture of the first two. This is spatio-temporal correlation. Also we can introduce more complex correlations and consider internal and external correlations. Well, by means of correlation matrix and superposition the set of the states and corresponding probability amplitudes are formed.

To create a quantum state, we use the integral function of the probability of input signal. It is assumed that the probability amplitudes reflect the degree of suitability of these coefficients in terms of control quality the higher the probability amplitude, the better the value. It is assumed that is because the probability amplitudes are introduced at the conversation to quantum bits stage on the basis of the teaching signal, which is obtained in such way that is the best by the minimum control error criterion. Thus, we choose the optimal state — the state with maximum probability amplitude. After that we covert qubits to the specific values of the PID gains. This was a brief overview of the technology being developed.

The modern control theory has methods to create control systems for well-formalized and well-described control situations. However, control systems are often faced with unforeseen situation. Quantum fuzzy inference technology ensures the required level of robustness, without changing the lower level of control, only through the use of software level. For experiments and modeling we use QFI with temporal correlation, between FC1 and FC2.

Experiment and result We has three situations of control. First situation images simple situation. We use uniform noise in control channel, Gaussian noise in wheel friction and delay of control action — 0.01 s. and the third situation has delay of control action equal 0.03s.

Simulation and experimental results are shown on Fig. 43.



(a) *(b)*

Fig. 43. ***Control error. Unpredicted situation: (a) modeling; (b) physical model.***

PID controller and fuzzy controllers don't reach the goal in unpredicted situation. But quantum controller based on these fuzzy controllers, successful in unpredicted situation

Conclusion

This design technology ICS based on SCO includes: multiple using GA to search for the optimal control, fuzzy neural network for approximation found by the GA optimal control signal and retrieval based on this "optimal" KB, as well as fine-tuning KB based on GA using information and entropic criteria. SCO let: to implement the principle of designing optimal ICS with the highest level of reliability and controllability of complex CO in conditions of uncertainty of the initial information; to reduce the required minimum number of sensors required to collect and transmit information, as in the control loop, and in the measurement system without loss of accuracy and quality control.

The design of robust ICS based on this approach requires a minimum initial information about the behavior of the CO as well as of external perturbations.

The performance of the quantum fuzzy controller is higher than the performance of fuzzy controller implemented with Soft Computing Optimizer; classical control system with PID controller.

The strategy of quantum fuzzy inference allows to reach the control goal even in unpredicted situations.

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ALGORITHMS FOR IDENTIFYING THE CONTROLLABLE OBJECTS BASED ON DYNAMIC ESTIMATION

H.Z. Igamberdiev, E.A. Yusupov, H.I. Sotvoldiev

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45, E-mail: uz3121@rambler.ru

Tashkent University of Information Technology, Ferghana Branch
86a Ferghana Street, Ferghana, Uzbekistan
Tel.: +998937350200, E-mail: tatuffdek@rambler.ru

Keywords: *control object, identification, adaptation, regularization*.

Modern manufacture of products demonstrates: the complexity of technological facilities and connections between them; dismemberment of process facilities and production functions; the growing number of management and share of cost management systems in overall capital cost of the equipment. The appearance of new technological processes is the result of the intensification of scientific and technological progress, not only in this particular area, but also associated with the complex developments in the various fields of science and technology. For each production line, as well as for the individual processing facility are typical obtaining semi finished or finished product with the desired properties. As a result of the technological process of the specific properties of input materials is output product with other properties.

In order to be able to abstract from the concrete representations of input and output characteristics of the product, as well as the characteristics of the process or the parameters characterizing the current conditions of the technological process, you need to escape from a specific chemical, physical, technological nature of these characteristics. You must do this because, for the general theory of management to process control problems to their presentation as objects of control and this naturally has to be used the language of the general theory of control [1,2]. The use of general methods for presenting objects in the control theory leads to the concept of the technological process in a multi-dimensional object into which the action vector of variables describing the properties of raw materials and the technological process, and output - vector characterizing the performance of the product or intermediate product.

The multidimensional system, when the input signal u (t) is the m-dimensional vector, and the output signal *y(t)* – *l* -dimensional vector:

$$y(t)+A_1y(t-1)+...+A_py(t-n_a)=B_1u(t-1)+...+B_qu(t-n_b)+e(t), \qquad (1)$$

where A_i – $(l\times l)$ – matrices, a B_i – $(l\times m)$ – matrices, n_a, n_b – memory depth, $e(t)$ – a hindrance.

To solve the problem of identification it is necessary to make the parameterization of equation (1). To do this, you can include all the elements of (1) the total number $(pl+qm)l$ units in the parameter vector θ. Then we can define $((pl+qm)\times l)$ - matrix

$$\theta=[A_1, A_2, ..., A_p, B_1,..., B_q]^T$$

and $(pl+qm)$ - dimensional column vector

$$\varphi(t)=\begin{bmatrix}-y(t-1)\\ \vdots\\ -y(t-p)\\ u(t-1)\\ \vdots\\ u(t-q)\end{bmatrix},$$

and rewrite (1) as

$$y(t)=\theta^T\varphi(t)+v(t). \qquad (2)$$

When the parameterization is applied additional structure [3], appropriate to form such *d*-dimensional column vector θ and $(l\times d)$ - matrix $\varphi^T(t)$, to express (1) as

$$y(t)=\varphi^T(t)\theta(t)+v(t). \qquad (3)$$

$$\theta(t+1)=\theta(t), \qquad (4)$$

where $M\{v_i\}=0$, $M\{v_i v_k^T\}=R\delta_{ik}$.

In order to estimate the state vector $\theta(t)$ of the dynamical system (4) and (5) are commonly used traditional Kalman filter equations [2,4,5]:

$$\hat\theta(t+1)=\hat\theta(t)+K(t+1)\left[y(t+1)-\varphi^T(t)\hat\theta(t)\right],\ \hat\theta(0)=\hat\theta_0, \qquad (5)$$

$$K(t+1)=P(t+1|t)\varphi(t)\left[\varphi^T(t)P(t+1|t)\varphi(t)+R(t+1)\right]^{-1}, \qquad (6)$$

$$P(t+1|t+1)=[I-K(t+1)\varphi^T(t)]P(t+1|t),\ P(0|0)=P_0. \qquad (7)$$

Evaluation $\hat\theta(t)$ converges in mean square to a vector $\theta(t)$, if mean square error is $\Delta^2(\hat\theta(t))\to 0$.

It can be shown [6,7] that between the estimates $\hat\theta(t)$ and the solution $\theta_\alpha(t)$, derived by minimizing Tikhonov smoothing functional :

$$M_\alpha[\theta(t),\hat y(t)]=\left\|\varphi^T(t)\theta(t)-\hat y(t)\right\|^2+\alpha\left\|\theta(t)-\theta_0\right\|^2,$$

there is a connection, which consists in the fact that $\alpha=1/t$, then $\theta_\alpha(t)$ it coincides with the estimate $\hat\theta(t)$, where $\left\|\hat\theta(t)\right\|^2=(\hat\theta(t),B\hat\theta(t))$, and $\hat y(t)=\sum_{i=1}^{t}y(i)/t$, B – positive definite matrix.

In the absence of prior information about $\theta(0), P_0$ it's appropriate to construct on the vector $y(1)$ an estimate of the generalized least squares $\theta_{HK}=(\varphi(t)R\varphi^T(t))^{-1}\varphi(t)R^{-1}y(1)$ method and calculate the correlation matrix $D_{HK}=(\varphi(t)R^{-1}\varphi^T(t))^{-1}$. Taking $\theta(0)=\theta_{HK}$, $P_0=D_{HK}$ and the model (3), (4) for the Bayesian estimates $\hat\theta(t)$ can be obtained recurrence relation (5), where the matrices $K(t+1), P(t+1|t+1)$ where the matrices are determined by expressions of a positive definite matrix

$$K(t+1) = (\varphi(t+1)R^{-1}\varphi^T(t+1))^{-1}\varphi(t+1)R^{-1}/(t+2),$$

$$P(t+1|t+1) = (\varphi(t+1)R^{-1}\varphi^T(t+1))^{-1}/(t+2).$$

The practical implementation of (5) - (7) encounters considerable computational difficulties [8,9] due to the fact that in this case the matrix $P(t+1|t+1)$ is ill-conditioned. This may be the reason that the calculation of the matrix inverse to $\varphi^T(t)P(t+1|t)\varphi(t)+R(t+1)$, in cases where $P(t+1|t+1)$ approximately equal $P(t+1|t)$, can be quite inaccurate. Besides, the whole calculation procedure (5) - (7) of the matrix $K(t+1)$ is based on a priori data matrices φ, Q, R. Therefore, any error in the knowledge of these matrices leads to a distortion of estimates $K(t+1)$ that can cause a divergence of the filtering process [8].

Based on adaptive filtering techniques [2,8,9] we can show that to adapt the filter (5) - (7), i.e. providing robustness to prior data changes , it is appropriate to use instead of (7), the expression of the form

$$P(t+1|t) = K(t)M(v(t)v^T(t))K^T(t) + P(t).$$

This procedure allows for "bind" the theoretical covariance matrix $P(t+1|t)$ to the actual value, i.e. eliminate the isolation of the process of calculating matrices $K(t+1)$ out of actual measurements.

Taking into account of the aforementioned solution of practical problems of filtration is more appropriate, than of (5) - (7) if using the following relationship:

$$K(t+1) = P(t+1|t)\varphi^T(t+1)G_\alpha\{D(t+1)\},$$

$$G_\alpha\{D(t+1)\} = [D(t+1)+\alpha I]^{-1}, \text{ p},$$

$$P(t+1|t) = K(t)M(v(t)v^T(t))K^T(t) + P(t),$$

$$P(t+1) = P(t+1|t) - P(t+1|t)\varphi^T(t+1)G_\alpha\{D(t+1)\}\varphi(t+1)P(t+1|t),$$

where $G_\alpha\{D(t+1)\}$ – generating system functions for the method of regularization [10], α – regularization parameter, I – identity matrix. Here the regularization parameter α can be selected based on the method of modeling or model examples [11].

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MODELING INTERACTIONS BETWEEN COGNITIVE ROBOT AND ITS ENVIRONMENT ON THE BASIS OF PSEUDO-PHYSICAL LOGICS AND GENERALIZED CONSTRAINTS

Dedicated to 80th Anniversary of Prof. Dmitry A.Pospelov

Valery B. Tarassov, Anastassia P.Kalutskaya

Bauman Moscow State Technical University, 5 2nd Baumanskaya Street, Moscow, 105005 Russia
tarasov@rk9.bmstu.ru, k_a_p@rbcmail.ru

Abstract*: Both static and dynamic spatial logics for mobile autonomous cognitive robots are introduced. Our approach is based on combining Pospelov's pseudo-physical logics and Zadeh's generalized constraints. Some ways of generating fuzzy linguistic constraints from the analysis of spatial situation are investigated. Various solutions of the problem how to construct robot motion trajectory depending on the obstacle position and size are considered.*

Keywords*: Artificial Intelligence, Cognitive Robot, Intelligent Manufacturing System, Fuzzy Control, Robot-Environment Interaction, Pseudo-Physical Logics, General Uncertainty Theory, Granular Computing Generalized Constraints.*

1. INTRODUCTION

This paper faces the problems of Cognitive Robotics – a new branch of robotics aimed at generating an intelligent behavior in robot by enhancing its cognitive capacities. Cognition is the process of acquiring knowledge and understanding through thought, experience and the senses. It opens new possibilities of learning and reasoning about how to behave in response to complex goals in complex and ill-defined environments. Here goals may be formulated by a user (either directly or indirectly) or may come from the robot itself.

Generally mobile cognitive robots are intended to perform complex tasks in an extreme environment (space robots, submarine robots, fire-extinguishing robots, etc.)

Cognitive capabilities of autonomous (or more precisely, semi-autonomous) robots include perception processing, attention allocation, anticipation, planning, reasoning about proper actions and other agents. These activities suppose information granulation [Zadeh, 1979]. Below we will consider granulation as a basic feature of cognitive agent [Tarassov, 2011].

The arrival of information granulation means the transition from ordinary machine-centric to human-centric approach in information gathering and knowledge discovery [Bargiela and Pedrycz, 2003]. According to Zadeh, *granule* is a collection of objects which are drawn together by the relations of indistinguishability, similarity, functionality or proximity [Zadeh, 1997]. Typical interpretations of granule are: part of the whole, sub-problem of the problem, variable constraint. Generally, information granules are complex dynamic information entities which are formed to achieve some goal [Tarassov, 2011]. The concept of information granulation is closely related to data abstraction and derivation of knowledge from information. By selecting different levels of granulation one can obtain different levels of knowledge.

Nowadays granular computing is often used as an umbrella term to cover methodologies, theories, techniques and tools that make use of granules in complex problem solving. Introduction of granular computing supposes building granulation theory and development of computation theory. Granulation theory includes studies in classification, generation, representation, interpretation and use of granules.

There are various classifications of granules: physical and conceptual granules, one-dimensional and multidimensional, information and knowledge granules, time and space granules, crisp and fuzzy granules, etc. Below we will focus on practical application of granular computing on the basis of Zadeh's theory of fuzzy information granulation (TFIG) by using generalized constraints in cognitive robotics.

2. PSEUDO-PHYSICAL LOGICS IN ROBOTICS

The development of intelligent manufacturing systems supposes the construction of cognitive transportation robots enabling the transference of products between warehouses and intelligent manufacturing cells. By cognitive robot we mean an autonomous mobile robot equipped with sensor devices and actuators which is able to obtain and process the information from various sources, including its proper sensor system, knowledge base and the human-operator.

The modeling of interactions between intelligent robot and its environment requires the construction of granular models to express specific features of involved spatial, temporal, causal relations. In this paper we suggest the integration of Pospelov's pseudo-physical logics approach [Pospelov, 1980, 1981 and 1987] and Zadeh's general uncertainty theory based on generalized constraints [Zadeh, 2006]. Here by pseudo-physical logic we mean any logic that models the perception and interpretation of environmental properties by cognitive robot. Among the examples of pseudo-physical logics we may cite spatial, temporal, action, valuation logics and so on. These logics have the following properties: 1) they widely use Zadeh's linguistic variables as basic propositional variables; 2) ordinal scales with strict ordering relations are constructed; 3) inferences in pseudo-physical logics take into account both ordinal and metric scales, as well as the position of objects on these scales. Such logics already found applications in robotics (see, for instance, [Aliev, 1995; Ulyanov et al., 1995]).

The more difficult thing in the use of linguistic variables to model human perception and reasoning is the construction of membership functions characterizing term-sets of linguistic variables [Pospelov, 1987]. The standard approach that needs carrying out a psychological experiment to construct membership function is often unsatisfactory. The results of such experiments are unstable and strongly depend on the experimental methodology and the way of forming expert groups. An attempt to eliminate this influence consists in introducing the universal scale onto which semantically colored values of linguistic variables are projected. For instance, such a scale may be used in the case of frequency logic dealing with the linguistic variable "Frequency" which assumes such values as "never", "very rarely", "rarely", "neither rarely nor often", "often", "almost always", "always"; here the numerical variable can take values {0, 1/6, 1/3, 1/2, 2/3, 5/6, 1} [Pospelov and Ezhkova, 1977]. Such universal scales may be used in other pseudo-physical logics, e.g. spatial logics.

Moreover, the links between ontologies and logics become crucial [Kalutskaya and Tarassov, 2011]. In this paper we consider ontology based on generalized constraints of the type X is$r$ R [Zadeh, 1997 and 2006], where X is a variable which takes values in a universe of discourse U, R is the constraining relation, is$r$ is a variable copula and r is a discrete variable whose value defines the way in which R constrains X.

Two kinds of spatial logics are taken into consideration. Static spatial logics enable us to model objects mutual position with taking into account the distance between them, their relative orientation and size. Dynamic spatial logics allow us to specify both direction and values of robot's motion velocity and describe the trajectory of robot's spatial motion.

Thus, to specify such a spatial situation we need both static and dynamic spatial models [Pospelov, 1980 and 1981; Kandrashina et al., 1989]. An architecture of cognitive robot as an open semi-autonomous system is given in Figure 1

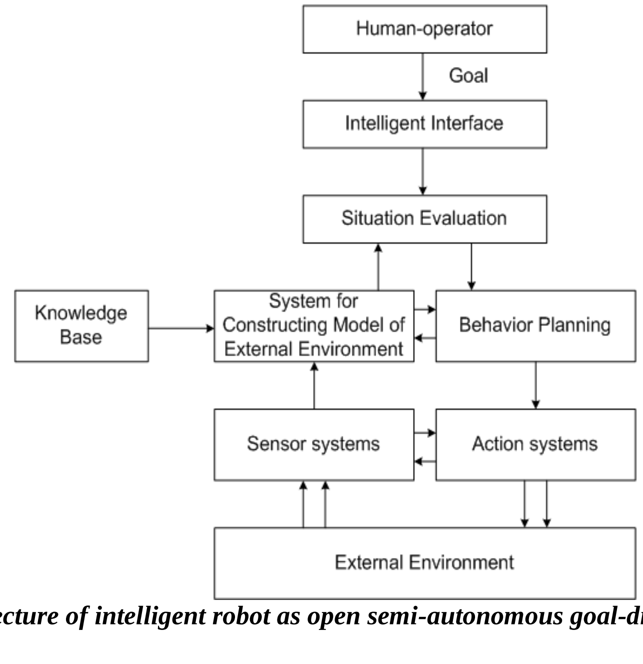

Fig.1. ***Architecture of intelligent robot as open semi-autonomous goal-directed system.***

It is obvious from Figure 1 that in practice a pseudo-physical logical system may be viewed as a family of interrelated logical subsystems which can be associated with two different levels. On the first level we specify spatial, temporal, causal, action logics, whereas on the second level we place evaluation logic, belief logics, deontic (norm) logics and so on.

It is worth stressing that the first level logics are directly related to agent's interactions with external environment.

A classification of spatial logics for cognitive robots is shown in Figure 2.

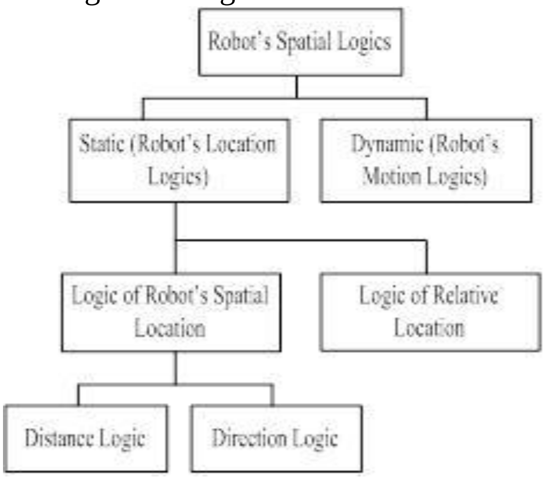

Fig.2. ***Classification of spatial logics for robots.***

These logics are not independent while facing robot's behavior planning and control problems. Robot's actions in physical environment are deployed in space and time; besides in performing decision-making and reasoning for action it is necessary to consider possible consequences of actions (i.e. to use inference rules of causal logics). Another important feature of pseudo-physical logics is employing different scales (absolute, relative and fuzzy); just on these scales logic formulas are projected and inference rules operate.

Pospelov's pseudo-physical logics are based on linguistic relations representation, but from engineer's viewpoint using various constraints is more suitable. So we propose to combine Zadeh's general uncertainty theory based on generalized constraints with Pospelov's pseudo-physical logic.

3. SPACE MODEL

In spatial logics for robotic systems fuzzy binary spatial relations of three types are most frequently used: a) distance relations; b) direction relations; c) mutual position relations. To perform a formal interpretation of fuzzy relations we will use L. Zadeh's generalized constraints (see his papers [Zadeh, 1997 and 2006]).

Distance relations usually have initial values "close-far", they serve as basic labels to construct composite values such as "very close", "rather far" etc. Here values of linguistic variable "Distance between objects *a* and *b*" are given by membership functions (possibility distributions). These distributions are obtained as a result of the distance assessment by human-operator; they can be described as generalized constraints:

$$X(a;b) \ \textit{is} \ d_j, \ \ j=[0;6], \tag{1}$$

where d_j are terms of linguistic variable "Distance": d_1 – *tightly*, d_2 – *very closely*, d_3 – *closely*, and etc. Each constraint forms a granule, and modification of the granule size allows us to vary a precision degree of spatial situation description.

Mutual angular orientation between objects is usually determined by basic directions, connected with co-ordinates of observer. In the simple case we use such terms as "in front of – behind" and "left –right". Their combination provides eight basic directions and linguistic variable "Direction" takes value f_i, i=1,2,…8, where f_1 – "in front of", f_2 – "in front of and on the left", f_3 – "on the left" and etc. Fuzzy constraints for the linguistic variable "Direction" are described by:

$$X(a;b) \ \textit{is} \ f_i, \ \ i=[1;8], \tag{2}$$

For two objects *a*, *b* a generalized constraint X_{ab} *is* f_2 corresponds to the statements: “*b* is in front of *a* and a bit on the left”; X_{ab} *is* f_8 – «*b* is in front of a and a little on the right» and so on.

Mutual objects’ position can be expressed by a conjunction of generalized constraints for distance and direction [Kalutskaya and Tarassov, 2010]:

$$[X(a_1;a_2)\ is\ d_j]\&[X(a_1;a_2)\ is\ f_i]=[X(a_1;a_2)\ is\ d_j]\ is\ f_i$$

For example, the relation “robot *a* is far and on the right from object *b*” can be expressed as (X_{ab} *is* d_9)&(X_{ab} *is* f_7) = (X_{ab} *is* d_9) *is* f_7.

4. STATIC SPATIAL LOGICS

The propagation of fuzzy constraints from antecedents to consequents plays the main role in the organization of robot’s fuzzy spatial reasoning. For instance, “if the robot *a* is located near the robot *b* and the robot *b* holds by mechanical gripper the object *c*, then the robot *a* is near-by the object *c*”.

Here the reasoning constructed on the basis of heterogeneous constraints is of special concern. In particular, let us consider the links between linguistic variable “Distance” and “Size”.

A hypothesis about objects’ size influence on the human-operator’s estimation of distance between them was discussed in [Pospelov, 1987; Kandrashina et al., 1989]. It allows us to replace spatial distance relations on the objects’ size and vice versa according to Table 1.

For example, “if the robot *a* is located closely to the robot *b* AND between the robot *b* and the object *c* another object is placed which has a very big size (like building), then robot *a* is located not much closely to the object *c*”.

Table 1

Interaction of spatial relations “Distance” and “Size”

№	Distance	Size
0	zero	Zero
1	very close	very small
2	close	Small
3	neither far – nor close	Medium
4	far	Large
5	very far	very large
6	very-very far	very-very large

Now let's consider a case when objects are located on a plane (Figure 3). Distance relations between objects of the various sizes can be received, using the links between sizes and distances from Table 1 [Kalutskaya and Tarassov, 2010].

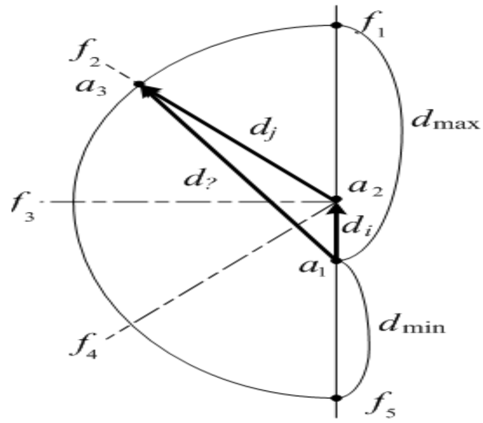

Fig.3. ***A diagram of objects position on the plane.***

For the sake of simplicity, directions on a plane are fixed and their quantity is limited by the number of relations for mutual angular orientation of objects in (2). In other words, we will consider that the object a_3 can move only on eight fixed directions. On Figure 3 three pointwise objects on a plane are represented. We will take object a_2 for a reference point. Then we trace a circle with the centre a_2 and radius d_j for fixing the directions on a plane. The scheme of inference looks like:

$$\{[X(a_1;a_2)\ \text{is}\ d_i]\ \text{is}\ f_m\} \& \{[X(a_2;a_3)\ \text{is}\ d_j]\ \text{is}\ f_n\}$$
$$\Rightarrow [X(a_1;a_3)\ \text{is}\ d_k]\ \text{is}\ f_p$$

To construct logic on a plane, inference rules for directions are originally defined with using distances between objects depending on mutual angular orientation of objects For determining distances we consider objects located on the crossing of this circle with a vertical line. It is evident from Figure 3 that the required relation satisfies an inequality: $d_{\min} \leq d_? \leq d_{\max}$.

The limits of inequality are defined by the formulas:

$$d_{\max} = d_i \oplus d_j; \quad d_{\min} = d_i \Theta d_j, \tag{3}$$

Here the operations $\oplus$ and Θ are specified by the following rules:

$$d_k \oplus d_k = d_k \dot{+} 1; \quad d_k \oplus d_{k+1} = d_{k+1} \dot{+} 1;$$
$$d_k \oplus d_{k+i} = d_{k+i},\ \text{if}\ i \geq 2.$$
$$d_k \Theta d_k = d_0;\ \text{where}\ d_0\ \text{tightly};$$
$$d_{k+1} \Theta d_k = d_{k-1};\ d_{k+i} \Theta d_k = d_{k+i},\ \text{if}\ i \geq 2.$$

To determine d_k we use the condition that in the constructed spatial model the directions are fixed. For the objects shown in Figure.3 we receive:

$$d(f_1) = d_{\max} \geq d(f_2) \geq d(f_3) \geq d(f_4) \geq d(f_5) = d_{\min}$$

The constructed logic on the plane allows us obtain new spatial distance relations which are functions of direction.

Example 1. We will illustrate the use of the logic constructed above on an example. Let us consider a flexible manufacturing module (FMM), containing machine tool with robot-manipulator, transportation robot, moving between a warehouse and FMM and providing the latter with crude product. A spatial location of flexible (intelligent) manufacturing system's components is described like: "Ahead of and neither far, nor close from transportation robot is located a FMM 1, very close and to the right from FMM 1 is FMM 2. The warehouse of crude product for FIM 1, 2 is placed closely and behind on the right from FMM 2" (Figure 4).

We denote by: a_1 – transportation robot; a_2 – FMM 1; a_3 – FMM 2; a_4 – warehouse. According to earlier taken denotations for values of linguistic variables "Distance" and "Direction" we will obtain the following initial constraints:

By using generalized constraints propagation we get new facts about transportation robot's spatial situation:

1) $[X(a_1;a_3)\ \text{is}\ d_3]\ \text{is}\ f_8$, as $n(d_3) - n(d_1) = 2 \geq 2$, $d_{\max} = d_{\min} = d_3$;

2) $[X(a_1;a_4)\ \text{is}\ d_2]\ \text{is}\ f_8$, as $n^* = n(d_{\max} = d_4) - n(d_{\min} = d_1) = 3$, then we find $d(f_4)$.

Thus, the constructed spatial logic on the plane allows us to obtain some extra fuzzy spatial constraints which evidently were not described by human-operator.

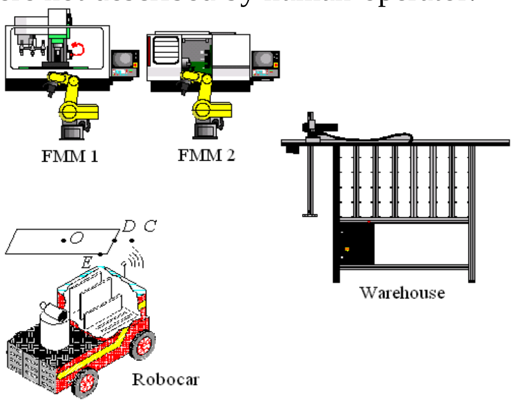

Fig.4. ***Flexible manufacturing system equipped with mobile cognitive transportation robot (robocar).***

5. DYNAMIC SPATIAL LOGICS

Dynamic spatial logic or the logic of motion is closely related to the logic of action and temporal logic. The motion logic faces the problem of selecting robot's motion direction and speed value and specifying motion path in the space. Both logics of motion and static spatial logic form together spatial logic. In this section the following problems will be discussed:

– Definition of the system of linguistic variables for speed and motion relations interpretation;

– Construction of the system of inference rules for logic of motion.

5.1. System of Linguistic Variables

To construct the logic of motion we will define the following linguistic variables.

Distance = {tightly, very close, close, neither far – nor close, far, very far, very-very far}.

$Direction_1$ = {in front, in front–on the left, on the left, behind–on the left, behind, behind–on the right, on the right, in front–on the right}.

Linguistic variables *Distance* and *Direction* are related to the static spatial logic. In the framework of dynamic logic of motion these variables are necessary for specifying robot's direction of motion and speed. Linguistic variables of dynamic spatial logic are given below

Speed L_1={quickly decreases, decreases,constant, increases, quickly increases}.

Time = {simultaneously, a bit later, later, much later, very much later}.

$Direction_2$ = {forward, forward–to the left, left, backward–left, backward, backward–to the right, to the right, forward–to the right}.

Motion = *Speed* × *Direction.*

For example, motion can be performed with increasing speed and to the right; with quickly decreasing speed and forward, etc.

5.2. Constructing Granular Model

A granular model founded on the linguistic variable *Speed* accepting such values as *increase-decrease* and their interpretation as granular derivatives was considered by Batyrshin [Batyrshin, 2002; Batyrshin, 2003]. Linguistic estimations of granular derivative are given by the following term-set L_2={positive big, positive average, zero, negative average, negative big}. As a result from L_1 we will address to the dependencies described in Table 2.

Table 2

Links between the values of linguistic variables time and speed

Time	Speed derivative (dV/dt)
almost at once	positive big
a bit later	positive average
later	zero
much later	negative average
very much later	negative big

Perceptive functions can be presented as a set of rules like:

$$\text{IF } T \text{ is } T_k, \text{ THEN } V \text{ is } S_k \qquad (4)$$

Generally it is supposed in (4) that the term T_k is expressed by a fuzzy interval. An interval [-5,+5] is taken as a scale for derivatives values. Here each term S_k from L_2 is associated with fuzzy set of derivative values *p*.

Scale gradation L_2 can be associated with the following values of parameter p_k:L_3={5, 2, 0, -2, -5}. A fuzzy granule of function change directions corresponds to each scale gradation.

Fuzzy derivative P_k defines fuzzy differential $dY= P_k\Delta x$ as fuzzy function from (precise) argument increment. As a result, each rule (4) specifies a fuzzy increment of function defined as S_k on fuzzy interval of argument values, corresponding to T_k. Fuzzy differential can be calculated as a result of cylindrical extension of fuzzy subset in direction defined S_k. [Batyrshin, 2002].

5.3. Inference Rules for the Logic of Motion

The links between mentioned linguistic variables are defined by three groups of rules which express physical laws expressed in the language of linguistic values. Rules of time definition from known linguistic values of speed and distances are shown in Table 3.

$$(S_R \ is \ d_i)\,\&\,(V_R \ is \ v_j) \Rightarrow T_R \ is \ t_?$$

Rules of distance definition from known linguistic values of speed and time, as well as, rules of speed definition from known linguistic values of distance and time are defined similarly.

Table 3

Rules of time definition with using known linguistic values of speed and distance

	1	2	3	4	5
0	almost at once	almost at once	almost at once	almost at once	almost at once
1	a bit later	almost at once	almost at once	almost at once	almost at once
2	Later	a bit later	almost at once	almost at once	almost at once
3	much later	later	a bit later	almost at once	almost at once
4	very much later	much later	later	a bit later	almost at once
5	very much later	very much later	much later	later	a bit later
6	very much later	very much later	very much later	much later	later

Example 2. If the robot *a* moves at the moment of time t_1 with *constant* speed and is located at time t_2 on the distance *far* from the point of start f, then t_2 can be defined as *later* with respect to t_1.

5.4. Robot's Motion Path Definition

To define robot's motion path, we will take the following assumption: the robot tends to move in a shortest path or by the previously selected way. It allows us to consider the direction from starting point to finishing point as known. There are some obstacles on robot's trajectory; it means that the robot should change the direction of its motion several times. Hence, robot's path consists of many steps.

If the robot knows the location of all obstacles, all times corresponding to different paths can be calculated using inference rules, and the selection of shortest time means the solution of problem.

But more realistic situational behavior consists in determining the path sequentially by considering only one obstacle at once which is in front of the robot. As a result of using such a strategy, the constructed motion path cannot be minimal.

Problem 1: Let us take as known both distance and direction to the robot's target, and distance and direction to some boundary points of obstacle. It is necessary to define robot's motion path. We will consider the case when the target is in front of the robot, because this robot can move only forward and turn. The solved problem of motion path specification is represented in Figure 5.

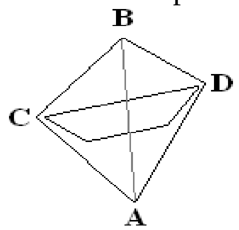

Fig.5. ***Robot's motion path search.***

Here *A* is a point of robot's location, *B* is its target's location, *C* and *D* are boundary points of obstacle between this robot and its target. From the statement of the problem distances d_{AB}, d_{AC}, d_{AD} and directions f_{AB}, f_{AC}, f_{AD} are known. Using direction f_{AB}. (forward) and rules of distance relation inference from direction relations we find by the formula (3) that $d_{AB} = d_k = d_{\max}$. Then we define $d_j = d_{CB}$ depending on the difference between order number of distance relations d_k and d_i. By using the dependence of order numbers for distance relations d_i and d_j, and for direction relation f_{AC} and f_{AB} we determine direction relation f_{CB}. Similarly we define distance d_{DB} and direction f_{DB}. To compute the length of possible robot's paths d_{ACB} and d_{ADB} we add order numbers of distance relations d_{AC} and d_{CB}, as well as d_{AD} and d_{DB} respectively. The robot's motion speed is limited by its design features, therefore its motion time is defined only by the length of robot's path. Thus, the least of two distances d_{ACB} or d_{ADB} will specify the best robot's motion path. If these distances are equal, then the robot may choose any path from two.

Example 2. According to Figure 5 it is known that the target is in front of and far from the robot. The point *C* is located very closely and in front of – on the left from the robot, and the point *D* – neither far – nor closely and in front of – on the right from the robot. The problem is to determine robot's motion path.

By using generalized constraints we write the initial data in the form:

[*X* (*A*, *B*) *is far*] is in front of, i.e. [*X* (*A*,*B*) *is* d_4] is f_1;

[*X* (*A*, *B*) *is very closely*] is in front of – to the left, i.e.

[*X* (*A*, *B*) *is* d_1] is f_2;

[*X* (*A*, *B*) *is neither far nor closely*] is in front of – to the right, i.e. [*X* (*A*, *B*) *is* d_3] is f_8.

1. Definition of path's length *ACB*.

$$d_k = d_{\max} = d_i \oplus d_j = d_4;\ d_i = d_1 \Rightarrow d_j = d_4,\ as\ k-i \geq 2\cdot$$

By taking $f_{AC} = f_2$ and $f_{AB}=f_1$ we obtain the direction $f_{CB} = f_8$. The order number of distance relation for the path *ACB* is equal to 4+1=5. The length of the path $d_{ACB} = d_5$.

2. Definition of path's length *ADB*.

$$d_k = d_{\max} = d_i \oplus d_j = d_4;\ d_i = d_3 \Rightarrow d_j = d_3,\ as\ k-i = 1.$$

By taking $f_{AD} = f_8$ and $f_{AB}=f_1$ we obtain the direction $f_{DB} = f_2$; here the order number of distance relation *ADB* is equal to 3+3=6 and the length of the path $d_{ADB} = d_6$.

Here $d_5 < d_6,\ i.\ e.\ d_{ACB} < d_{ADB}$

Thus, robot's motion path *ACB* is preferred.

Problem 2: Let us consider as known both distance and direction to the target, as well as distance and direction to the obstacle. We are also aware about obstacle size. We need to determine robot's motion path. We will consider the case when the obstacle has circular form, and the distance to the obstacle is specified by taking its nearest point with respect to the robot.

Case 1. Both target and obstacle are located in front of the robot. In this case it makes no difference, from which side walk round the obstacle, because here path lengths are equal. It is necessary to determine robot's motion direction in order to go round the obstacle in a safe distance. The solved problem of motion path search is represented in Figure 6.

Here *A* is the point of robot's location, *B* stands for target's, *C* is the point of safe distance from the obstacle, *D* is obstacle's boundary point, *E* is the nearest point of the obstacle with respect to the robot, *O* stands for the obstacle center. According to the statement of this problem, the robot knows both distances d_{AB}, d_{AE}, and directions f_{AE}, f_{AB}, and obstacle's size.

To reduce this problem to the problem 1, it is necessary to define distance d_{AC} and direction f_{AC}.

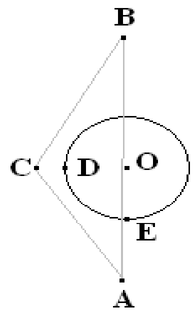

Fig.6. ***Robot's motion path search with taking into account obstacle's size.***

By using Table 1 we define the order number of size for the obstacle $n(s)$. The order number of the distance *OD* relation is specified as $n(d_{OD}) = n(s)/2$, and, if $n(s) \leq 2$, then $n(d_{OD}) = 1$. The order number of the distance *OC* is $n(d_{OC}) = n(d_{OD})+1$, because minimal possible safe distance from the robot to the obstacle is "very close". The order number of the distance *AO* is $n(d_{AO}) = n(d_{AE})+n(d_{OD})$. We obtain the following inference scheme

$$\{[X(A;O)\ is\ d_{AO}]\ is\ f_1\} \& \{[X(O;C)\ is\ d_{OC}]\ is\ f_7\}$$
$$\Rightarrow [X(A;C)\ is\ d_k]\ is\ f_p$$

Basing of inference rules for static spatial logic, we determine f_p, then the distance d_k. Later on we find distance and direction from the point *C* to the target as it was described in considering problem 1.

Case 2. The target is located in front of the robot, and the obstacle blocks a direct way to the target (figure 7). Both the distance from the nearest point of the obstacle to the robot and direction to the obstacle center are known.

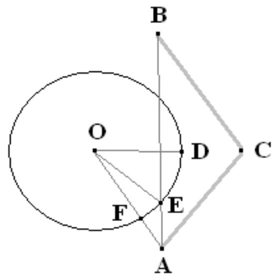

Fig.7. ***Robot's motion path search with taking into account obstacle's locationю***

Here A is the point of robot's location, B is the point of target's location, C is the point of safe distance from the obstacle, D is the boundary point of the obstacle, E – the nearest point of obstacle with respect to the robot, O is the obstacle center. According to the statement of the problem, both distances d_{AE}, d_{AB}, and directions f_{AO}, f_{AB} and the size of the obstacle s are known. To reduce this case to the case 1, it is necessary to define d_{AO}. The order number of the distance OF is $n(d_{OF})=n(s)/2$, distances d_{AE} and d_{AF} are approximately equal, therefore we obtain the order number of the distance AO as $n(d_{AO})=n(d_{OF})+ n(d_{AF})$. Further solution is reduced to the case 1.

Example 3. According to Figure 6 it is known that the target is in front of and very far from the robot. The robot motion is troubled by a big obstacle located very close and in front of–on the left. It is necessary to determine robot's motion path.

On the basis of the generalized constraints the initial data can be written in the following form:

$$[X(A;B) \text{ is very far}] \text{ is ahead}; \ [X(A;B) \text{ is } d_5] \text{ is } f_1;$$
$$[X(A;E) \text{ is very close}] \text{ is ahead}; \ [X(A;E) \text{ is } d_1] \text{ is } f_1;$$
$$X(A;O) \text{ is ahead}-\text{left}; \ X(A;D) \text{ is } f_2.$$

An obstacle is large, so we have $n(s) = 4$.

The solution of the problem includes the following steps

1. Specify the distance AO, $n(d_{AO}) = n(d_{OF})+ n(d_{AF})= n(s)/2+ n(d_{AE})= 4/2+1= 3$.

2. Specify the distance OC, $n(d_{OC}) = n(d_{OD}) + 1= n(s)/2+ 1= 4/2+1= 3$.

3. Specify the distance and direction AC, $d_{AO} = d_{OC} = d_3$, $f_{AO} = f_2$, $f_{OC} = f_7$. By using direction search rules we obtain $f_{AC} = f_8$, $n(d_{\max}) = n(d_{OC}) +1= 3+1= 4$, $n(d_{\min}) = n(d_{OC}) – n(d_{AO})= 0$, $n^*= n(d_{\max}) – n(d_{\min}) = 4–0 = 4$, $d_{AC}(f_8)= d_{AC}(f_2)= d_{\max}–1= d_3$.

4. Specify the distance and direction CB.

$$d_{AB} = d_{\max} = d_{AC} \oplus d_{CB} = d_5; \ d_{AC} = d_3 \Rightarrow d_{CB} = d_5.$$

On the basis of inference rules in static spatial logic we obtain the direction $f_{CB} = f_2$.

Example 4. According to Figure 4, the following description of FMS is given: FMM 1 is located in front of and very-very far from transportation robot. Moreover, FMM2 is located very closely and on the right from FMM 1. The warehouse of crude product is located closely and behind–right from FMM 2. The transportation robot's path to FMM 1 is blocked by the medium-sized obstacle located closely and in front of the robot. The following problem is faced by cognitive transportation robot (robocar): "Approach later to FMM 1,take manufactured part and transport it in FMM 2".

Let us take additional designations (with respect to Example 1): O – the obstacle center, E – the nearest obstacle point with respect to robocar, D – the boundary point of the obstacle, C – the point of safe distance from the obstacle. By using inference rules of static spatial logic we obtain:

$$[X(a_1;a_3) \text{ is } d_6] \text{ is } f_8, \ [X(a_1;a_4) \text{ is } d_2] \text{ is } f_8.$$

Here robocar's motion path to FMM 1 is specified according to the case 1 of the problem 2 path's search.

1. At first specify the order number of size for the obstacle $n(s) = 3$ and order number of distance relation OC $n(d_{OC}) = 2+1=3$.

2. By using inference rules in static spatial logic specify motion distance and direction to the point C: $f_{AC} = f_8$, the order number of distance relation is $n\{d(a_1;C)\}= n(d_{\max}) –1 = 3$.

3. Using the known direction $f(a_1,a_2)$ "in front of", find that $d(C, a_2) = d_6$ and $f(C, a_2) = f_2$.

4. Total length of robocar's motion path is $n\{d(a_1;a_2)\} = n\{d(a_1;C)\} + n\{d(C; a_2)\}= 3+6= 6$.

Now it is necessary to determine the speed of robocar's motion to the target. Using the table for distance *very-very far* and time *later* we get robocar's motion speed *quickly increase*.

6. CONCLUSION

Some versions of robot's static and dynamic spatial logics are introduced by combining Pospelov's pseudo-physical logics approach and Zadeh's generalized constraints. The application of fuzzy constraints propagation techniques to the problems of spatial situation analysis is considered. Various cases of constructing robot's motion trajectory depending on the obstacle size and location are discussed.

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ALGORITHMS FOR THE SOLUTION OF THE PROBLEM OF THE CHOICE OF ADMISSIBLE STATIONARY MODES OF CONTINUOUS TECHNOLOGICAL PROCESSES ON THEIR INTERVAL MODELS

N.R. Yusupbekov[1], N.R. Kul'muratov [2], S.N. Nosirova[2]

Tashkent State Technical University[1]
Navoi state mining institute[2]

Abstract*: Algorithms for a solution of a problem of a choice of admissible stationary conditions of continuous technological processes on their interval models are offered. The developed algorithms are approved by a choice of admissible conditions on an example of process of deriving of press materials.*

Keywords: *algorithm, solution, technological process, interval model, material.*

Normal condition of functioning of plant is the static established condition, satisfying to production schedules of conducting process and ensuring demanded quality of a made yield. Hence, an important problem of control of technological processes (TP) is the problem of a choice of a stationary (static) operating mode at which all requirements for the weekend and intermediate indicators on quality and process engineering are fulfilled. The given problem, can be decided or by labor-consuming selection of conditions on plant that is connected with the big industrial costs; or a choice of a stationary condition on model of technological process, especially in the presence of inspected, but not operated entering actions.

In actual practice solutions should be accepted in the conditions of uncertainty, the nature which can have various characters. As uncertainty radiant's errors (instrumentations, uncontrollable perturbations operating on TP, ambiguity of associations, no stationary and drift of performances, in particular, can serve, etc.

Connections with it the attention of contributors is attracted recently in methods of solution of problems of control in the conditions of uncertainty, as to the methods working at more realistic premises, than stochastic. One of approaches of exposition of plants with uncertainty is the approach assuming roundedness amplitude of noise and perturbations, operating on plant in a condition of normal operation, and the interval analysis which has learnt a title [1]

In this case the problem of a choice of an admissible stationary, (static) condition of continuous technological process on its interval model is reduced to construction of sets with the guaranteed properties. The given problem belongs to the class of problems with "the inexact" data which are a subject of study of the interval analysis [1-3].

In the given work the problem of a choice of admissible stationary conditions is formulated, as the problem of definition of set of operating actions at realization of each of which a plant exit guaranteed will belong to the set interval of technological restrictions on process.

More low we will assume acquaintance to bases of the interval analysis and to adhere to labels accepted in [1-3]. In work intervals and interval magnitudes will be designated by a bold type, for example, **A**, **B, W, a, b, x, y …** whereas not interval (real, point wise, etc.) are not selected specially in any way. And operations with interval magnitudes are operations of classical interval arithmetic's. Underlining and striping - $\underline{a}, \overline{a}$ - designate the lower and upper extremities of an interval $\mathbf{a}$.

The analysis of technological processes of continuous type (for example chemical manufacture, power), shows that to the factors leading to uncertainty of their work, first of all, it is necessary to refer errors of measurement of entering and output magnitudes, ambiguity of performances of plant. Drifts and nonstationary associations presence of the person-operator in a control contour, distribution in space of entering and output magnitudes and etc. Besides, operating conditions of such plants are presented by narrow corridors of possible values in which limits the linearization of performance data is possible, as a rule.

In these conditions the plant response on entering action can be presented some corridor of possible values of an output variable, and, hence, for plant models is expedient search in the form of two boundary real functions describing a corridor of uncertainty irrespective of its nature [4].

Algorithms of a solution of a problem of a choice of admissible stationary conditions on interval model of technological process. Let the many-dimensional plant is described by a set of equations:

$$y_i^0 = \sum_{j=1}^{n} \alpha_{ij}^0 u_j + \sum_{j=1}^{v} \beta_{ij}^0 x_j, \qquad i = \overline{1,m} \tag{1}$$

$$y_i = y_i^0 + e_i^0,$$

where y_i^0, y_i – accordingly the true and measured values of an exit of technological process; $\vec{u} = (u_1,....,u_n)$ - operated entering variables, $\vec{x} = (x_1,....,x_v)$ - uncontrollable, but controllable entering variables; $\alpha_{ij}^0 . \beta_{ij}^0$ - unknown parameters of plant.

It is thus supposed that the joint operation of factors of uncertainty can be shown to the additive error e_i^0 limited on amplitude $|e_i^0| \le \varepsilon_i$.

Let's assume that at a stage of identification of model of plant are received in an aspect:

$$y_i = \sum_{j=1}^{n} \alpha_{ij} u_j + \sum_{j=1}^{v} \beta_{ij} x_j, \qquad i = \overline{1,m} \tag{2}$$

$$\vec{\alpha} \in Q_\alpha, \quad \vec{\beta} \in Q_\beta,$$

where $\vec{\alpha} = \{\alpha_{i1}, \alpha_{i2},..., \alpha_{in}\}$, $\vec{\beta} = \{\beta_{i1}, \beta_{i2},..., \beta_{iv}\}$ - a vector of parameters of interval model $Q_\alpha = +\{\underline{\alpha_{ij}} \le \alpha_{ij} \le \overline{\alpha_{ij}}, i = \overline{1,m},\ j = \overline{1,n}\}$, $Q_\beta = +\{\underline{\beta_{ij}} \le \beta_{ij} \le \overline{\beta}_{ij}, i = \overline{1,m},\ j = \overline{1,v}\}$ - sets of admissible values of parameters.

Supposing that values of controllable entering variables $\vec{x}$ are known at the moment of decision-making, we can consider - restrictions on a process engineering $Q_Y^0 = +\{\underline{y_{iT_0}} \le y_{iT_0} \le \overline{y_{iT_0}},\ \ i = \overline{1,m}\}$ as set of the new corrected values of intervals of technological restrictions $Q_Y = +\{\underline{y_{iT}} \le y_{iT} \le \overline{y_{iT}},\ \ i = \overline{1,m}\}$, where $\underline{y_{iT}} = \underline{y_{iT_0}} - \sum_{j=1}^{v} \beta_{ij} x_j$ $\overline{y_{iT}} = \overline{y_{iT_0}} - \sum_{j=1}^{v} \beta_{ij} x_j$, which ensure normal functioning of technological process at control realization on plant model:

$$y_i = \sum_{j=1}^{n} \alpha_{ij} u_j,\ \vec{\alpha} \in Q_\alpha, \quad i = \overline{1,n} \tag{3}$$

Further, we introduce concepts of sets of admissible and conditionally admissible stationary conditions.

Definition 1. As set of admissible stationary conditions is called the set of the vectors, satisfying to expression:

$$Q_u^* = \{u \,|\, \sum_{j=1}^{n} \alpha_{ij} u_j = y_j \in Q_Y,\ \forall \vec{\alpha} \in Q_\alpha,\ i = \overline{1,m}\ \} \tag{4}$$

The set (4) is defined by system of inequalities:

$$Q_u^k = \begin{cases} \min\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum_{j=1}^{n} \alpha_{ij} u_j \right\} \ge \underline{y_{iT}} \\ \max\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum_{j=1}^{n} \alpha_{ij} u_j \right\} \le \overline{y_{iT}} \end{cases} \qquad i = \overline{1,m} \tag{5}$$

The given set of vectors is set of the operated variables guaranteeing performance of technological restrictions on process for $\forall\, u \in Q_u^*$, at its realization on plant.

Definition 2. As set of conditionally admissible stationary conditions is called the set of the vectors, satisfying to expression:

$$Q_u = \{u \mid \exists \vec{\alpha} \in Q_\alpha, \quad \sum_{j=1}^{n} \alpha_{1j}\, u_j = y_i \in Q_Y, \quad i = \overline{1,m}\}, \tag{6}$$

which is defined as finite number association $k \le 2^n$ (number of quadrants in solution space X) subsets Q_u^k, in which limits signs of values of operated entering variables and. Remain constants for all j, $j = \overline{1,n}$:

$$Q_u = \cup Q_u^k;$$

where

$$Q_u^k = \begin{cases} \min\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_{j=1}^{n} \alpha_{ij} u_j \right\} \le \overline{y_{iT}} \\ \max\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_{j=1}^{n} \alpha_{ij} u_j \right\} \ge \underline{y_{iT}} \end{cases} \qquad i = \overline{1,m} \tag{7}$$

The given set is set of operated variables at which performance of technological restrictions is possible and guarantees lack out of its operating actions at which realization on plant normal functioning of system will be ensured.

To discover set Q_u^* or Q_u it is necessary to make system of inequalities (5) or (7), and then to solve it, I.e. it is necessary to select active restrictions and to calculate Co-ordinates of tops of a polyhedron. We will notice that system inequalities (7) it is necessary to note for each subset vector space E^n of operated variables, where signs values of entering variables are constant (E^2 for this purpose will be quadrants) that essentially complicates computing aspects solutions systems (7).

As it is known [1-3], at study of interval systems of a simple equation in concept of an interval solution the various sense can be put. It reduces not only in different answers, but also to different methods of their search.

Despite a various semantic content of such problems, all of them from the formal point of view are reduced to one general statement.

It is necessary to discover values of a vector of operating variables supplying a target function minimum

- for set of admissible solutions

$$F_u(u) = \begin{cases} O, \quad \text{если} \quad \overline{y_{iT}} \ge \overline{y_i} \quad , \quad \underline{y_{iT}} \le \underline{y_i} \\ \sum\limits_i (\overline{y_{iT}} - \max\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_j \alpha_{ij} u_j \right\})^2 + \sum\limits_i \ (\underline{y_{iT}} - \min\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_j \alpha_{ij} u_j \right\})^2 , \end{cases}$$

If $\overline{y_{iT}} \le \overline{y_i}$, $\underline{y_{iT}} \ge \underline{y_i}$,

where

$$\overline{y_i} = \max_{\alpha \in Q} \left\{ \sum_{j=1}^{n} \alpha_{ij} u_j \right\} \ \underline{\alpha_{ij}} \le \alpha_{ij} \le \overline{\alpha_{ij}} \ \ \underline{y_i} = \min_{\alpha \in Q} \left\{ \sum_{j=1}^{n} \alpha_{ij} u_j \right\} \tag{8}$$

- for set of conditionally admissible solutions

$$F_2(u) = \begin{cases} O, \quad \text{если} \quad \overline{y_{iT}} \ge \overline{y_i} \quad , \quad \underline{y_{iT}} \le \underline{y_i} \\ \sum\limits_i (\overline{y_{iT}} - \max\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_j^{n} \alpha_{ij} u_j \right\})^2 + \sum\limits_i \ (\underline{y_{iT}} - \min\limits_{\alpha_{ij} \in Q_\alpha} \left\{ \sum\limits_j \alpha_{ij} u_j \right\})^2 \end{cases}$$

If $\overline{y_{iT}} \geq \overline{y_i}$, $\underline{y_{iT}} \leq \underline{y_i}$,
where

$$\overline{y_i} = \max_{\alpha\in Q}\left\{\sum_{j=1}^{n}\alpha_{ij}u_j\right\} \underline{\alpha_{ij}} \leq \alpha_{ij} \leq \overline{\alpha_{ij}} \;\; \underline{y_i} = \min_{\alpha\in Q}\left\{\sum_{j=1}^{n}\alpha_{ij}u_j\right\} \tag{9}$$

$sign\, u_j = C_j, \quad C_j = const \qquad j = \overline{1,n}$

Functions $F_1(\vec{u})$ also $F_2(\vec{u})$ are not bent that allows to form and use a condition of existence of a solution, irrespective of concrete forms of their representation. If the discovered minimum of function $F_1(\vec{u}^*) \neq 0$ or the $F_2(\vec{u}^*) \neq 0$ set of admissible or conditionally admissible stationary conditions (depending on a task in view) is empty. Otherwise, if $F_1(\vec{u}^*) = 0$ or the $F_2(\vec{u}^*)= 0$ discovered vector $\vec{u}^*$ is realized on plant in an operational administration condition.

The analytical exposition of sets of admissible and conditionally admissible conditions is labor-consuming with growth of dimension of a problem. Graphic representation of such areas to the person - to an operator a little informatively. Recognizing that to an operator it is convenient to work with aspect restrictions: the base point a plus-minus tolerance on an operated variable, is offered to approximate set of admissible stationary written conditions in it of a n-dimensional rectangular parallelepiped of maximum volume. In a problem of approximation of set of conditionally admissible stationary conditions it suggested to search for a solution in the form of a gang of the n-dimensional rectangular parallelepipeds entered in each of convex subsets.

The problem of maximization of volume of the entered parallelepiped is a problem of convex programming which consists in determination of co-ordinates of the centre $\vec{u}^*$ and the semi lengths of edges of a parallelepiped Δu maximizing target function of an aspect

$$F(\Delta\vec{u}) = \Pi(\Delta\vec{u}) \rightarrow \max_{\vec{u}^*\in\Delta u} \tag{10}$$

At restrictions of an aspect $\vec{u} \pm \Delta\vec{u} \in Q_u^*$ or $\vec{u} \pm \Delta\vec{u} \in Q_u$, i.e. all 2^n tops of a parallelepiped should satisfy depending on a solved problem to system of inequalities (5) or (7).

Thus, offered algorithms of definition of sets of admissible and conditionally admissible conditions, eventually, are reduced to algorithms of a solution of linear equation systems of linear and convex programming well worked in the program ratio.

The developed algorithms have been used at a solution of a problem of an improvement of operating conditions and regulations of conducting chemical technological process of deriving of a press material and have shown the working capacity that proves to be true good coincidence of the received outcomes to the rated.

The full integrated scheme of process of deriving of a press material [3] can be presented beside consecutive enough autonomous sub processes: deriving of pitch КМ-9; - deriving of pitch КМ-9К; varnish preparation (spirit a solution of pitch КМ-9К); - press material rolling.

Singularities of considered process is high manual skills and insufficient tie process by necessary registering devices that extremely complicates a problem of mathematical exposition of plant. Character of noise and the perturbations operating on plant, allows to draw a conclusion about realisations of premises of the analysis of the interval data.

On the basis of the data which has been removed on the operating plant, the exposition of one of phases of process of deriving of a press material, namely process of deriving of pitch КМ-9К, in the form of system of interval simple equations is received:

$$x_{18} = [0.008, 0.0091]x_{25} + [93.26, 93.76];$$

$$x_{19} = [0.712, 0.75]x_{25} + [146.7, 170]x_{26} + [-1206, -1047],$$

Where x_{18} - dry residual of pitch КМ-9К (%); x_{19} - time gelatin pitches КМ-9К (); x_{25} - time gelatin pitches КМ-9; x_{26} - pH 50 % of a solution of pitch КМ-9.

Under regulations of conducting process of deriving of pitch KM-9K dry residual (%) and time gelatin () should is in following ranges:

$$70 \leq x_{18} \leq 100;\ 60 \leq\ x_{19} \leq 480$$

The received outcomes it is possible to use for an improvement of operating conditions and regulations of conducting chemical technological process. Besides, they allow to reveal on the basis of the laboratory analysis of property of pitch KM-9 batches of the given pitch not suitable pitches for deriving KM-9K.

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MATHEMATICAL MODELLING BY INTERVAL METHODS UNDER CONDITION OF UNDETERMINED PARAMETERS

Yu.I.Shokin[1], M.B.Bazarov[2], P.Zh.Kalhanov[3], Z.H.Yuldashev[3]

[1] *Institute of Computing Technologies SB of the Russian Academy of Sciences, Russia*
[2] *Navoi State Mining Institute, Uzbekistan,*
[3] *National University of Uzbekistan, Uzbekistan*

Keywords: *Not determined data, sizes with the limited amplitude of fluctuation, interval methods, synthesis of mathematical models, a principle rational internalizations not determined parameters, , parametrical identification and synthesis of control systems by technological objects.*

In work the comparative analysis of the most important results on application of interval methods in the mathematical modeling, received by authors and their colleagues in the last of one and a half ten years is resulted. Thus application of interval methods is understood as certain technology of synthesis of interval models when not determined data limited on amplitude is considered as interval objects, the principle rational internalizations parameters is used, synthesis of mathematical model is made in space of interval sizes and interval calculation, working out and a substantiation of corresponding interval algorithms is spent. Examples of application of similar modeling for the technical, economic and ecological problems, proving the statement about objective features and problems of application of interval methods are resulted.

1. A problem of the account of not determined data at mathematical modeling

The problem of not determined data meets at the decision of some theoretical and practical problems. Especially this problem it is convex arises at modeling of some technical and ecology-economic problems as in a reality many indicators of processes are defined or on the basis of difficultly checked statistical data, or are not determined on sense of the problem. As a rule, the parameters uncertain or not determined on sense exist initially or a priori, or arise in the course of consideration of process within the limits of the chosen mathematical model. At modeling of real processes a number of parameters has empirical character and within the limits of synthesized model undertake with instructions of amplitude of fluctuations that at calculations can result to essential distortions of results.

At research of concrete model definition of those parameters which can be interval on sense and owing to statement of the problem is especially important. For example, the assumption about full undetermined signals in information systems, or the assumption about undetermined quantities of production offered by suppliers or time moments when indicators of economic process are defined, will obviously, unduly complicate a problem. Thereupon *preliminary differentiation of parameters on unequivocally material and interval is expedient.* Other feature of consideration of real problems within the limits of the interval analysis is not only construction and a substantiation of suitable algorithm of the decision of the synthesized or investigated model, but also the proof of theorems of inclusion of any material decision in interval, and also reception of aprioristic estimations for width of the interval decision.

It is important to notice that a measure of uncertainty within the limits of calculation of intervals is the width of interval size which should guaranteed contain required exact value as at problem statement so after decision reception, - discrete or continuous in shape value of interval functions. As consequence of paramount at designing of interval methods the preservation problem informatively is that from the point of view of the theory furnishes to necessity of the proof of the theorem of inclusion, namely in demonstration of inclusion of the decision of any "designed" material problem in the interval decision, and also estimation reception for width of the interval decision.

2. A principle rational internalizations not determined parameters

The problem of the account of not determined parameters meets at the decision of some theoretical and practical problems.

In works [4, 10, 11] the idea of necessity rational internalizations not determined parameters as it can be one of factors of reduction of loss informatively for the first time has been stated. Coming back for example with number π, it is possible to notice that actions on increase informatively can consist in consecutive increase in quantity of the parties of described and entered correct polygons in a circle with a diameter unit and use of adequate algorithm of extraction of a square root at calculation of perimeters. Clearly that these actions of increase informatively, have purely material character, all operations are more exact are carried out over steams of the same material sizes when it is known that they form the sequences converging to required size from above and from below. It is known that at the decision of problems interval methods, applying Moore's interval arithmetic’s with accordingly defined value of interval functions we receive intervals guaranteed containing required sizes if it is a question of one scalar size and external estimation, or a certain parallelepiped when set of values is searched. For example, result of external estimation of set of the material vectors, being decisions of system of the linear algebraic equations with interval factors, the n-dimensional parallelepiped turns out. If matrix elements reflect communications between objects the part from which is unequivocally determined corresponding components logically to consider material that according to principles of definition of interval operations will lead to reduction of volume of a corresponding parallelepiped. So far as concerns some value of interval modeling function for which according to model the proper expression is searched, quantity reduction a priori varied parameters, namely sizes assumed interval, also conducts to narrowing of the intervals which are values modeling value of interval of function in chosen points or estimations of width of the required decision turn out more preferable. We will notice that a number of works of authors of the given work definitely can be conceptually united as attempt to prove necessity and efficiency of idea rational internalizations not determined parameters. For example, in [5] research of a problem of distribution of investments on managing branches is resulted by interval methods. The problem of investment of branches of managing, in the assumption is particularly considered that indicators giving fund, efficiency of unit of new investments and a number of initial sizes are set as size with a known error. Thus, interval those sizes for which the limited amplitude of fluctuations is characteristic that allows not only to consider not determined parameters with known amplitude of fluctuations at a stage of synthesis of model and the decision many criterion an extreme problem within the limits of corresponding calculation of interval sizes are accepted only, but also to receive substantial interpretations for the end results. Indicators of separate branches in the model are considered by construction of characteristic functions on the basis of the statistical given or expert estimations. So, for example, all parameters having type natural, obviously, to assume determined, and the characteristics having precisely measurable material values also to assume not interval, in avoidance of "effect of promotion” [1].

More particularly rational internalizations parameters we face idea in interval differential models [6, 7, 8, 9, 10] in which dynamics of process, namely in models with use of communications between parameters in the form of derivative of required modeling functions is considered.

The following interval logic-dynamic model

$$\frac{d\mathbf{x}}{dt} = -k\,[\mathbf{x}]^2 + \left[y_0 - \mathbf{q}(\mathbf{x}) \right] + \frac{\alpha\beta}{V}, \tag{1}$$

$$\mathbf{x}(0) = \mathbf{x}_0, \tag{2}$$

$$\mathbf{q} = \sum_{i=1}^{n} L_i^q \mathbf{q}_i \left(\sum_{j \in S \setminus L} L_j^{\varphi} \varphi_i(\mathbf{p}(t)), \sum_{j \in L} L_j^{\varphi} \varphi_i(\mathbf{p}(t)), L_i^j t \right), \tag{3}$$

$$Q = \left| \int_0^T \mathbf{u} \left(\mathbf{x}(t), \sum_{j \in L} L_j^{\varphi} \varphi_i(\mathbf{p}(t)), t \right) dt \right| \to \min, \tag{4}$$

Describes in interval statement a problem of management of level of concentration of some averaged ecological toxicant ***x** (t)*, with not determined primary volume that natural as emission level disappears originators, and a number of parameters, as for example time *t* as a rule is, volume of the conservative environment *V* where can extend ecological toxicant ***x(t)***, α - volume growth rate of production wastes, **β**- concentration ecologically disported in production wastes it is possible to consider quite determined.

Thus, the **principle rational internalizations parametres** can be formulated as follows: at synthesis of mathematical models of real processes, interval parametres with the limited amplitude of fluctuation which arise as ineradicable errors are considered only.

3. Interval methods of parametrical identification and synthesis of control systems by technological objects

By cursory examination of interval methods and interval modeling there can be a judgment that is enough in known model or at a stage of synthesis of new model, to replace material sizes on interval, to assume that it is necessary to consider all material operations and corresponding functions, concepts and objects further as interval and all will be good". However there is a set of examples showing that it is far not so.

In work [12] concepts, methodology are formed, theoretical positions, methods and the algorithms are developed, allowing to put and effectively to solve problems of construction of models and synthesis of control systems by technological processes in conditions interval - parametrical uncertainty and their application at construction of control systems by concrete technological processes.

Let's consider linear multidimensional interval - the set object of the management which mathematical model in space of conditions looks like

$$\dot{x}(t) = \mathbf{A}\mathbf{x}(t) + \mathbf{B}\mathbf{u}(t), \quad \mathbf{x}(\mathbf{t}_0) = \mathbf{x}_0, t \in [\mathbf{t}_0, \infty], \tag{5}$$

where a $x(t) \in R^n -$ condition vector, an $\mathbf{A} \in \mathbf{IR}^{n \times n} -$ interval matrix of dimension $n \times n$, $\mathbf{A} = (\mathbf{a}_{ij})$, $(\mathbf{a}_{ij}) = [\underline{a}_{ij}, \overline{a}_{ij}]$, $1 \le i, j \le n; u(t) \in R^m$ - a vector of operating influences; an $\mathbf{B} \in \mathbf{IR}^{n \times m} -$ interval matrix of dimension $n \times m$ $\mathbf{B} = (\mathbf{b}_{ij})$, $(\mathbf{b}_{ij}) = [\underline{b}_{ij}, \overline{b}_{ij}]$, $1 \le i \le n, 1 \le j \le m; \mathbf{IR}(\mathbf{IR}^{n \times m})$ - set of interval numbers (matrixes).

Let's understand further interval the set model of object of management (5) as family of mathematical models of stationary objects of the kind $\dot{x}(t) = Ax(t) + Bu(t)$ which matrixes belong to the set interval matrixes, i.e. $A \in \mathbf{A}$, $B \in \mathbf{B}$ that in mathematical designations it is possible to write down as

$$\{x(t) \in R^n \mid (\exists A \in \mathbf{A}, \exists B \in \mathbf{B})(x(t) = Ax(t) + Bu(t))\}. \tag{6}$$

Thus, the term «properties interval the set object of management» means properties of all objects of management of a kind

$$\dot{x}(t) = Ax(t) + Bu(t) \text{ For } A \in \mathbf{A},\ B \in \mathbf{B}. \tag{7}$$

One of the basic problems of application of the device of the interval analysis is correct definition of intervals of uncertainty on the basis of the initial data in the presence of various sources of uncertainty.

Let's consider some initial hypotheses which will be necessary further at use of concepts of the interval analysis:

H_1: the Object is described linearly – parametrically kind functions

$$y(x) = \beta_1\varphi_1(x) + \beta_2\varphi_2(x) + \ldots + \beta_m\varphi_m(x) = \varphi^T(x)\beta\ , \tag{8}$$

where-vector $x \in R^n$ entrance variables, $\varphi^T(x)$ - unknown basic functions from a vector of independent variables, $\beta \in \beta$ - a vector of unknown interval parameters of model.

H_2: the experiment Data is described by set n experiences

$$x_j = (x_{1i}, x_{2i}, \ldots, x_{ni})^T,\quad [\underline{y}_i, \overline{y}_i],\quad i = 1,2,\ldots,n\,, \tag{9}$$

Where $\underline{y}_i$, $\overline{y}_i$ set in i - that experience of border of possible values of true size y_i, i.e.

$$\underline{y}_i \le y_i \le \overline{y}_i\text{, For } \forall\ i = \overline{1,n}\,. \tag{10}$$

H_3: Adequate model of object is any function $y(x) = \varphi^T(x)\mathbf{b}$ passing through all interval measurements, i.e. satisfying to a condition

$$\underline{y}_i \le \varphi^T(x_i)\mathbf{b} \le \overline{y}_i\ ,\ i = 1,2,\ldots,n, \tag{11}$$

Thus it is necessary to find an estimation b of an unknown vector of factors β, such that

$$\underline{y}_i \le \varphi^T(x_i)b \le \overline{y}_i\ , i = 1,2,\ldots,n. \tag{12}$$

Expression (12) is system n linear inequalities rather m unknown factors $b_1,\ldots,b_m$. In case of compatibility it has set of decisions Q_b:

$$Q_b = Q_\beta = \{b \in R^m \,|\, \underline{y}_i \le \varphi^T(x_i)b \le \overline{y}_i, i = 1,2,\ldots,n\}\,, \tag{13}$$

which is a convex polyhedron in space R^m. Generally, when $(n > m)$, Q_b can have difficult enough form.

In work for external estimation the Q_b expression based on use of rectangular parallelepiped Π^+ of a kind is offered:

$$\Pi^+ = \{b \in R^m \,|\, \underline{b}_i \le b_i \le \overline{b}_i, i = 1,2,\ldots,m\}\,.$$

Then the problem of parametrical identification can be considered as a problem of search of tops of rectangular parallelepiped Π^+ or an approximating bar. We will show it. Let - $\mathbf{F} = [\underline{F}, \overline{F}] = [F_c - \Delta, F_c + \Delta]$ interval $m \times n$- a matrix, $\mathbf{y} = [\underline{y}, \overline{y}] = [y_c - \delta, y_c + \delta]$ and $\mathbf{b} = [\underline{b}, \overline{b}] = [b_c - \gamma, b_c + \gamma]$ - interval vectors of dimensions *m* and *n*, accordingly. Then considering an initial problem as the problem of interval linear programming can be written down:

$$\min\{\varphi^T b \,|\, Fb = y,\ b \ge 0\}, \tag{14}$$

$$F \in \mathbf{F},\ b \in \mathbf{b},\ \beta \in \boldsymbol{\beta}\ , \tag{15}$$

Where

$$F = \begin{vmatrix} \varphi_1(x_1) & . & \varphi_m(x_m) \\ . & . & . \\ \varphi_1(x_1) & . & \varphi_m(x_n) \end{vmatrix}.$$

As for each problem of linear programming (14) it is had certain optimum value is unique $f(F,b,y)$, it is natural to consider area of values of an optimum on set of the data (13-15), entering into size consideration

$$\overline{f}(\mathbf{F},\mathbf{b},\mathbf{y}) = \sup\{\, f(F,b,y) \mid F \in \mathbf{F}, \mathrm{b} \in \mathbf{b},\ \beta \in \upbeta\ \},$$
$$\underline{f}(\mathbf{F},\mathbf{b},\mathbf{y}) = \inf\{\, f(F,b,y) \mid F \in \mathbf{F}, \mathrm{b} \in \mathbf{b},\ \beta \in \upbeta\ \}.$$

Thus, for a parity $\mathbf{\Pi}^* = [\underline{f}(\mathbf{F},\mathbf{b},\mathbf{y}), \overline{f}(\mathbf{F},\mathbf{b},\mathbf{y})]$ following operations of inclusion and crossing are fair: $\Pi^* \subset \mathit{\Pi}^+\ \mathit{\Pi}^+ \cap Q_b \neq \varnothing$.

Criteria of controllability and observables of dynamic systems with interval uncertainty of parameters are considered. For steady interval matrixes necessary and sufficient conditions of controllability and observability in the form of the requirement of positive definiteness of Grammiana of controllability and observability are formulated. At the assumption that all roots of a characteristic polynomial of a matrix $A \in R^{n\times n}$ lie strictly in the left semi plane and $A \in \mathbf{A}\ G \in \mathbf{G} = \mathbf{G}^T > 0$, the matrix equation is received

$$(\mathbf{XA} + \mathbf{A^T X} + \mathbf{G} = 0) = \{XA + A^T X + G = 0 \mid \ A \in \mathbf{A}, G \in \mathbf{G}\}, \tag{16}$$

Defined as Lyapunov's interval equation. It is shown that for the decision (16) fairly analytical representation

$$\mathbf{X} = \{X = \int_0^\infty \exp[A^T t]\ G\ \ \exp[At]dt \mid A \in \mathbf{A}, G \in \mathbf{G}\}. \tag{17}$$

In the conclusion it is necessary to notice that in some cases, especially when not determined data has the limited amplitude of fluctuation; interval methods are shown as alternative to is likelihood-statistical methods and methods of the theory of indistinct sets. As a whole, certainly each of the specified approaches has “the problems” and these methods do not exclude, and supplement each other more likely.

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METHODOLOGY OF INTEGRATED EVALUATION AND FUZZY DECISION MAKING OF THE PROCESSES SAFETY OF THE COMPLEX INDUSTRIAL OBJECTS

A.R. Marakhimov, H.Z. Igamberdiev, A.N. Yusupbekov, I.X. Siddikov

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45, E-mail: uz3121@mail.ru

Abstract: *The following paper focuses on some issues of fuzzy modeling in technological security of petrochemical plants and making decisions on their control of the original information in in the face of uncertainty and vagueness on fuzzy set theory.*

Keywords: *information networks, soft-computing, fuzzy set theory, neural networks, fuzzy logic, fuzzy model, fuzzy decision making, complex industrial objects, process safety.*

Introduction

A major focus of the industrial organization is regarded to provide technological process (TP) safety, which is largely determined by compliance with the requirements for the safety and efficiency of its control. Analysis of the principles of diagnostic systems and the control of technological security of petrochemical plants and complexes leads to the conclusion that it belongs to a class of complex systems and decision making problems which bear multi-criterion optimization character.

Additional difficulties in solving the problems of diagnosis and control of technological safety of petrochemical plants and complexes arise from the fact that most decisions are made in conditions of uncertainty and lack of the initial information clarity and virtually no possibility of using existing deterministic-stochastic models [1,2,3,7]..

It is necessary to develop new approaches to the diagnosis and control of state technological safety of complex industrial objects based on the use of modern information technologies and intelligent decision supporting tools and the implementation of effective control systems to meet these requirements [1,2,4,6].

This paper describes one of the probable approaches of integrated assessment of process safety and building effective systems of the control of plants and petrochemical complexes in the face of uncertainty and vagueness of the original information.

Problem statement

Let there be a process represented in the general form as follows: $TP=\{M^{TO},R^{M},S\}$, where: $M^{TO}=\{M_1^{TO},M_2^{TO},\cdots,M_n^{TO}\}$ is the set of models of technological equipment and devices (process system) $,R^{M}$ - the set of relationships between objects; S - set of states of objects.

Operation of any TP can be seen as a sequence of changing states $S_t\in S=\{S_1,S_2,\cdots S_n\}$ at a certain time interval $[t_0,t_k]$. S_{t^*} State at a time $t^*\in[t_0,t_k]$ characterized by a set of parameters: $Y_{t^*}=\left\langle Y_i^{TP},Y_j^{TO},Y_l^{СУ}\right\rangle$ where: Y_j^{TO}, $i=\overline{1,J}$ – is the state of technology parameters of the process; $Y_i^{ТП}$, $i=\overline{1,I}$ is the parameters of the equipment; $Y_l^{СУ}$, $l=\overline{1,L}$ is the parameters of the control systems.

Normal operation restrictions may be applied to TP $\Psi\{\overline{Y^{TP}},\overline{Y^{TO}},\overline{Y^{СУ}}\}\leq 0$, depending on a variety of parameters $\{Y_i^{TP},Y_j^{TO},Y_l^{СУ}\}$. Shifting out of these restrictions means moving of TP into contingency. Thus, these constraints divide the space of all states in which the TP can be in two sets: S^{OC} a set of dangerous conditions and S^{PC} a lot of sound states, i.e. $S=S^{OC}\cup S^{PC},\ S^{OC}\cap S^{PC}=\varnothing$.

In turn, a lot of dangerous situations can be divided into two disjoint subsets $S^{OC} = S^{OC_1} \cup S^{OC_2}$, $S^{OC_1} \cap S^{OC_2} = \varnothing$., where S^{OC_1} is a subset of hazardous conditions in the area of TP warning and maximum allowable values of process parameters S^{OC_2} is a subset of hazardous conditions in the area of TP critical values of the process parameters. In the set of safe states of greatest interest is the area or the point at which the operation of TP is the safest which is regarded the center of process safety $S_0 \in S^{PC}$ [2] .

If the process hazard parameters, all the values of which lie in the zone of permissible values S_0, the current threat can be considered zero. If one or more parameters go into the danger zone S^{OC_1}, the actual risk is increased, and it will increase as the parameter to the area of critical values is S^{OC_2}. Intuitively, the current risk of the process should depend on a variety of dangerous parameters, ranging from the degree of approximation of each parameter to the region and to the influence degree of each parameter on the dangerous possibility of an emergency.

Thus, the evaluation problem of process safety and sound decision-making can essentially be formulated as a problem of multi-criteria selection of a feasible solution from the set of feasible solutions (alternatives), which takes the system from a state S_t^0 into S_t^*, in which the sets of system parameters $\{Y_{i^*}^{TP}, Y_{j^*}^{TO}, Y_{1^*}^{CY}\}$ were at the center of technological security.

The concept of solving the problem

We go through the methods of an integrated assessment of process safety. This methodology is based on the fact that the information about the states of TP, on the base of which a decision to choose the Security Center $S_0 \in S^{PC}$ is made, appears in the form of fuzzy preference relations in a variety of alternatives to choose [3,5]. Vagueness allows experts (operators, technologists), which can be determined by this relation on the set of possible states of the TP, to describe the extent of their belief in the preferences of the numbers from the interval [0,1]. This is a convenient form, a source of information for decision-making, which means that the experts do not often have completely clear judgments about preferences and /or their knowledge cannot be formalized in the model due to excessive complexity. If ***U*** is a universal set of alternatives, ***A*** - fuzzy set of feasible alternatives, the membership function of which is $\mu_A(x)$, then the choice of an alternative

$$x^* = \arg\max_{x \in U} \mu_A(x) \tag{1}$$

can be considered rational. It is assumed that the expert did not have any other information on the set of alternatives. We describe the proposed approach to the problems of choice of alternatives with additional source information.

Suppose that there is additional information in the form of a binary preference relation on the set of alternatives ***U***. In this case, the rational choice is made from a more restricted class of so-called non-dominant alternatives. Let's look at the construction of this class of alternatives.

Suppose that ***U*** is given fuzzy relation of strict preference RS on the set of alternatives. According to the accepted interpretation for $\mu_{R^S}(x, y)$, if we fix y *, then $\mu_{R^S}(y^*, x)$ will be interpreted as a function of fuzzy set of alternatives ***x***, which strictly dominates alternative y *. Hence fuzzy set of alternatives x, non-dominated alternative y *, is determined by the operation of add-ons for fuzzy relations and is given by the membership function type of $1 - \mu_{R^S}(y^*, x)$. Consequently, the intersection of the fuzzy sets, membership function of which $1 - \mu_{R^S}(x, y)$ will be allocated to U fuzzy set of alternatives $R^{НД}$, each with a certain degree does not dominate any alternative from of ***U***. We obtain a fuzzy set of non-dominated alternatives described by the membership function.

$$\mu_{R^{НД}}(x) = 1 - \max_{y \in U} \mu_{R^s}(y, x), x \in U \tag{2}$$

Here $\mu_{R^{НД}}(x^*)$ is interpreted as the degree to which alternative x * is not dominated by any one other alternative to the ***U***.

Fuzzy set of non-dominated alternatives reflects the fact that, if $\mu_{R^{НД}}(x^*) = \alpha$, then ***x**** can dominate the other alternatives, but the degree is not greater than 1 - α.

Thus, here is described the method of obtaining a fuzzy set of non-dominated alternatives when the original fuzzy information for decision-making procedure is presented in the form of a fuzzy preference relation. In this case, the choice of an alternative set of non-dominated alternatives as: $x^* = \arg\max_{x \in U} \mu_{R^{НД}}(x)$ can be considered rational.

If we take into account the evaluation of alternatives to be carried out on a number of criteria, it makes sense to use an advance assessment of the importance of the criteria. This expands the range of tasks and ensures a more realistic ranking of the studied alternatives. In these terms, the appropriate use of an extended version of the method of non-dominated alternatives [4,5] is based on the following states.

On the set of alternatives X = { $x_1, x_2, \ldots, x_n$ }, characterized by feature set $G=\{g_1, g_2, \ldots, g_k\}$, set the ratio of non-strict preferences $R_m = \langle \mu_{R_m}(x_i, x_j) \rangle$, $m = \overline{1,k}$, $i = \overline{1,n}$, $j = \overline{1,n}$, taking into account only the sign of g_m and ignoring the rest. The matrix R_m $\mu_{R_m}(x_i, x_j)$ indicates the degree of confidence, reflecting that a sign g_m is shown at *i*-like alternative is better than the *j*-like.

$$R_m = \begin{array}{c} \\ x_1 \\ x_2 \\ \vdots \\ x_n \end{array} \begin{array}{c} \begin{array}{cccc} x_1 & x_2 & & x_n \end{array} \\ \begin{bmatrix} \mu_{R_m}(x_1, x_1) & \mu_{R_m}(x_1, x_2) & \cdots & \mu_{R_m}(x_1, x_n) \\ \mu_{R_m}(x_2, x_1) & \mu_{R_m}(x_2, x_2) & \cdots & \mu_{R_m}(x_2, x_n) \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{R_m}(x_n, x_1) & \mu_{R_m}(x_n, x_2) & \cdots & \mu_{R_m}(x_n, x_n) \end{bmatrix} \end{array} \tag{3}$$

A matrix of preference is also constructed like $R = \langle \mu_R(g_i, g_j) \rangle$, $i = \overline{1,k}$, $j = \overline{1,k}$, to determine the priority of evaluation criteria, where the numbers $\mu_R(g_i, g_j)$ indicate the degree of certainty that the ***i-*** like feature is more important than the *j*-like.

$$R = \begin{array}{c} \\ g_1 \\ g_2 \\ \vdots \\ g_k \end{array} \begin{array}{c} \begin{array}{cccc} g_1 & g_2 & & g_k \end{array} \\ \begin{bmatrix} \mu_R(g_1, g_1) & \mu_R(g_1, g_2) & \ldots & \mu_R(g_1, g_k) \\ \mu_R(g_2, g_1) & \mu_R(g_2, g_2) & \ldots & \mu_R(g_2, g_k) \\ \ldots & \ldots & \ldots & \ldots \\ \mu_R(g_k, g_1) & \mu_R(g_k, g_2) & \ldots & \mu_R(g_k, g_k) \end{bmatrix} \end{array} \tag{4}$$

The aim is the rational choice of alternatives from a set of alternatives X = { $x_1, x_2, \ldots, x_n$ }, using the original data presented in the form of matrices $R_1, R_2, \ldots, R_k$ and R.
This is achieved by the following algorithm:

Step 1. We find the intersection of fuzzy relations $R_1, \ldots, R_k$ formula and call it Q_1:

$$Q_1 = R_1 \cap R_2 \cap \ldots \cap R_k . \tag{5}$$

Step 2. We find for the Q_1 non-dominated set of alternatives $Q_1^{НД}$ according sub-algorithms:

• To specify inverse matrix:

$$\mu_{Q_1^{-1}}(x, y) = \mu_{Q_1}(y, x) \tag{6}$$

• Each element of the matrix Q_1^{-1} is the subtraction of the corresponding element of the matrix Q_1. In this case, if the result is negative, it is replaced by zero. The result is a matrix Q_1^0 :

$$\mu_{Q_1^0}(x,y) = \max(0, \mu_{Q_1^{-1}}(x,y) - \mu_{Q_1}(x,y)) \tag{7}$$

• In each row the matrix includes Q_1^0 the maximum value of $r(x_i)$, $i=1,2,...,n$. The value is then subtracted from the unit. The result is $\mu_{Q_1^{НД}}(x_i)$ - the desired degree of membership of our non-dominated alternatives:

$$\mu_{Q_1^{ND}}(x_i) = 1 - r(x_i), i = 1,2,...,n \tag{8}$$

Thus, the non-dominated set of alternatives Q^{ND} is a set of elements of x_1, x_2, ... , x_n, each of which has a degree of membership. This set will be written as:

$$\mu_{Q_1^{ND}}(x_i) = \left\{ \mu_{Q_1^{ND}}(x_1) / x_1, \mu_{Q_1^{ND}}(x_2) / x_2, \ldots, \mu_{Q_1^{ND}}(x_n) / x_n, \right\} \tag{9}$$

Step 3**.** Non-dominated $R^{НД}$ is similarly situated to R. The resulting degree of membership $\mu_{R^{НД}}(g_1), \mu_{R^{НД}}(g_2), \ldots, \mu_{R^{НД}}(g_k)$ is denoted by $l_1, l_2, \ldots, l_k$ and calculated weights for each of the features as follows:

$$t_i = \frac{l_i}{\sum_{j=1}^{k} l_j}, i = 1,2,\ldots,k$$

Step 4. We form the matrix Q2, the elements of which are calculated by the following formula:

$$\mu_{Q_2}(x,y) = \sum_{m=1}^{k} t_m \mu_{R_m}(x,y) \tag{10}$$

Step 5. Sub-algorithms is located Q_2^{ND} described above:

$$\mu_{Q_2^{ND}}(x_i) = \left\{ \mu_{Q_2^{ND}}(x_1) / x_1, \mu_{Q_2^{ND}}(x_2) / x_2, \ldots, \mu_{Q_2^{ND}}(x_n) / x_n \right\}; \tag{11}$$

Step 6. Intersection is constructed: $Q = Q_1^{НД} \cap Q_2^{НД}$:

$$Q = \left\{ \frac{\min(\mu_{Q_1^{НД}}(x_1); \mu_{Q_2^{НД}}(x_1))}{x_1}, \cdots, \frac{\min(\mu_{Q_1^{НД}}(x_n); \mu_{Q_2^{НД}}(x_n))}{x_n} \right\} = \left\{ \mu_Q(x_1) / x_1, \cdots, \mu_Q(x_n) / x_n \right\} \tag{12}$$

Selection of an alternative that has the maximum degree of membership in the Q, is regarded rational.

Thus, the task of choosing the design decisions can be classified as non-structured problem that can be applied to solving methods of the theory of fuzzy sets and fuzzy inference as the most adequate description of weakly formalizing relationship between alternative solutions.

Conclusion

The paper has considered fuzzy modeling technology security complex of industrial projects and decision-making for their control in the face of uncertainty and lack of clarity of the initial information on the basis of the theory of fuzzy sets and fuzzy logic. The article suggests a formal model and method of integrated technology security evaluation of complex objects and the algorithm of the search center security has been developed by choosing the safe separation function of process parameters based on fuzzy binary preference relations.

The application of the above described system allows us to develop a set of measures aimed at the control of technological safety of industrial facilities and, consequently, to reduce losses and increase the efficiency of staff by improving the health status and prediction of failure of technology, equipment and control systems.

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EVOLUTION OF INTEGRATED SOFTWARE MODELS

D.A.Kuryazov, O.K.Khujaev, O.T.Allamov

26129, Oldenburg, Germany
Carl von Ossietzky University Oldenburg, Software Engineering
Phone: +49 15731459917, e-mail: kuryazov@se.uni-oldenburg.de

Abstract: *Software evolution is witnessing the increasing need of complex tools for calculating, visualizing, storing and analyzing differences between consecutive versions of software systems on all the levels of development including requirements, design, code, and test. Modern version management systems should offer services like calculating and representing differences, possible merge after modifications, resolution of conflicts on model merging, and effective store model changes. This paper indents to illustrate a survey for aforementioned problems.*

Keywords: *Software models, software evolution, object of management, intellectual system, management system, calculating, sorting and analyzing of software system.*

1. Introduction

During the evolution of software systems, different kinds of changes are done by users for different reasons including all the level of development that a system undergoes throughout its entire life cycle. Nowadays, the most programming languages and concepts, hardware systems are constantly increasing and new concepts tend to replace existing components and systems to improve their reliability or simplify and optimize services by using software trends. Additionally, user needs and requirements for quality of software systems demand to extend and improve system’s functionality and quality constantly. For above mentioned reasons, a software system should be modified and version to apply these changes during evolution process. These changes might be done because of following reasons:

- Changes because of user requirements
- Changes in hardware environment
- Changes in software components
- Changes in a way optimization of system
- Changes because of implementation to another environment

Changes are essential features of the evolutionary development of software systems and recognizing the changes is essential to understand how and why a system has reached its current state from previous one. Therefore, it is very important for software engineers to understand differences between consecutive versions of a software system. Current most version tools supply a text based approach to represent differences plain text documents (for instance cf. Diff with is applied in RCS [1], CVS [2], SCCS [3] and subversion [4]). Tool approaches for representing version differences for design and requirements levels only exist in research prototypes.

According to the ”everything is model” principle [5], this proposal illustrates an approach to specify differences as models. Models are widely using on modeling of business processes, work-flows and web services. Recently, software models have become widely used in abstraction of software systems to understand and trace system aspects in different viewpoint of users. A model is an abstraction of some aspect of an existing or planned system. Models are created to serve particular purposes, for instance, models could serve as representation or description of some behavioral and structural aspects or even changes of a real system, or to present information in a form that can be easily analyzed.

2. Motivation

In order to provide a comprehensive methodology for software system’s state changes (the delta), mining and storing version histories, merging models during the evolution of software including an integrated view on all levels of software abstraction, below, we will state a list of use cases that requires further research and refers to software model evolution.

3. Collaborative modeling

The evolution and maintenance of complex software systems require the collaboration of several designers. For the sake of minimizing conflicts, models are often strictly separated into different parts and assigned to team members. And every member of the team usually feels responsible for his/her work. It also is needed an organized and disciplined way of sharing information among the team members.

Often the present of a software system is understandable by looking at the past. Moreover, working in parallel enables users to visually compare their current work with previous versions or other user’s versions of the same model. It also provides users with information about all the modification in semantics and syntactic of a model and users can specify changes they want to save and changes they want to discard.

Most collaborative applications involve the shared use of some artifact by a number of users. Infrastructures for supporting such applications must implement mechanisms to deal with consistency in the shared artifact, the degree to which the views and data shared by the team members are the same, and structurally interacted.

Thus, there is a need for an adapted process of collaborative modeling that addresses the challenges raised by having models as the subject of evolution. Supporting collaboration among multiple developers in a distributed system is an essential requirement in complex software projects. In such as collaboration, each developer, located in a geographically distributed environment, needs to manipulate (create, analyze, delete, and modify) software artifact’s that are shared among the team members.

4. Comparing models and calculating changes between consecutive versions of a model

In the context of model-driven engineering, comparison models and calculation differences are very common use cases to supply model evolution and maintenance. Hence, software system users, developers, and designers have needs to trace a system and gather information about models of their software product. Of course, they may see the differences on design level using some way of representation or visualization. But before visualizing or representing model differences, models need be compared and differences between them should be calculated in a way that suitable for visualization and representation. After that designers can understand how and why a system has reached its current state from previous one. It demands to create efficient ways to compare given two models and calculate differences between them. Moreover, comparing and calculating of model differences is supposed as a sketch for some other user cases. Moreover, analyzing entire life cycle of a software system and obtaining numerical data about differences lead to solution for some other issues in this paper.

The process of comparing models contains of the two sub processes: model matching and difference calculation. The model-matching sub process concerns the discovery of relations between model elements that model the same entity in the models being compared. There are four recognized types of model matching: static-identity based, signature based, similarity based and language specific. Each of these approaches leverage different knowledge on the syntax and semantics of matched models, in order to provide as accurate matching as possible. Once the model elements are matched, a differences-calculation sub process uses the discovered matching's, and returns the differences between two models.

5. Representation and visualization model differences (the delta)

Representation and visualization are the central ingredients for any model comparison solution. Representation of the information obtained from the difference calculation process needs to be properly represented in a difference model, so that it can be used for subsequent analysis and manipulation. Finding a suitable representation and visualization techniques for model differences is crucial for its exploitation, as for instance deriving refactoring operations from the delta document describing how a model evolved during its life cycle. Such a representation notation assists designers to trace models' evolution process. The representation and visualization may be model based and enable automatic manipulation of the differences but the visualization and the representation tend to overlap and the overall technique is affected by the way models are compared and the differences are calculated.

The information obtained from the difference calculation process needs to be represented in different ways, so that it can be used for subsequent analysis and manipulation [6]. Finding a suitable representation for model differences (Δ) [14] is crucial for a software system's users. Differences between consecutive versions of a model often need to be presented according to a specific need or scope of users. We can differentiate existing methods of presentation [9]:

Text-based presentation lists the differences in form of plain text or in some structured format, e.g. XML. Modern text-based visualization techniques, for example, the technique described in [8] provide means for overview, zooming, filtering. However, the overview, zooming and filtering in this case are syntax-based and do not provide much insight into the meaning of differences.

Graph or tree-based visualization, (e.g. [9] and [10]) the view shows all model elements in a list or in a tree if they have a hierarchical structure. But getting the overview of the differences is still not so easy for larger models because the size of the visible part of the tree is limited by the size of the display. Also, the details of the differences are still not easy to comprehend, since the user needs to interpret the tree representation of the differences.

Diagrammatic visualization. The approach offers diagrammatic view for differences. But, it is hard to extract all element types having a certain property, because these element types might be in different parts of the system, and thus they might only be visualized in different diagrams [11].

Coloring differences, in this approach[9], elements which exist only in one of the models are colored differently, e.g. red and green. Updates elements are marked with a third color; unchanged elements remain black. Moves cannot be displayed sufficiently.
However, the approach does not scale up to large models, due to display limitations.

Table view. The table view gives a first overview about those software objects complying with the appropriate query. These query results are directly linked to the source code, if possible[12].

6. Storing model differences (the delta)

Since models are versioned, to compare them we will face a problem: how to support modification of large scale models to enable comparison of multiple versions. One naive approach is to duplicate the entire model after each modification. For this reason, a model repository may store the differences between consecutive versions of a model instead of complete models, by saving storage space. Hence, it serves to restore the previous version of step before changed sub-models in case some of them damaged or waste of information. For instance, modifying one package in a system with 100 packages requires make 99 useless copies or if a designer knows about damaged parts of the system, he/she may restore the damaged part of the system using a model repository [13]. In this case, another important issue is how to store differences and supply access time efficiency into repository when it is needed.

Moreover, to describe how designers communicate their local changes with master copy of repository, architecture of repository needs to be well-organized. For instance, for demand of collaborative modeling use case, models need to be versioned. If a designer needs to be out of work for a while on time modifying, the system also should be in sleeping status. In this case, the developer's version of model has to be stored on local workspace or master repository.

There two forms are listed below to build up architecture of a model repository [7].

Centralized. In this client-server model, users access a master repository through as a client. Their local workspaces store only a working copy of the master repository. And designers commit their changes to the master repository. In this case, the version history is only available in the master repository.

Distributed. In this form, each user has own repository on his (her) local machine in addition to their working copies. The repository can be optionally synchronized with other repositories. There is no need to establish a connection to a server. Operations such as commit, viewing history and checkout are fast.

7. Merging models after modifications and resolution of merge conflicts

Modeling in parallel and versioning in an optimistic way raises several different challenges like merging models after modifications and detecting and resolving conflicts during merge process. In the same vein, merging models, resolution and detection conflicts are common and partly overlapped by current approaches among the modeling community. Therefore, a model merge mechanism is suggested as key issue of integration of different model version and collaborative modeling.

As aforementioned, to supply collaborative work among the team members on a large scaled model, it needs to be versioned and assigned to team members; of course after all, copies of a model will have to be merged. Merging models inevitably leads to a problem those resolving and detecting conflicts. However, current experiences are that at present the support for model merge is far from optimal.

A merge process can be thought of modification operations like add, delete and edit. Two problems can result from carrying out such operations: inconsistencies, and conflicts. An inconsistency occurs when applying changes to master model, if any operation in the changes sequence of operations fails (e.g., because of a non-existent element).

All merges can be classified to one of these three types: raw, two-way, and three-way merges[7].

A raw merging applies a change to a context different from the sequence of change operations. In raw merging the last change simply overwrites what has gone before it.

A two-way merging compares two versions and merges them into a single version without having access to the master version from the local versions. In the two-way comparison, one modeler cannot synchronize local version for last updates with the master model.

A three - way merging. This type of merging more effective than above two types. In this type, modeler's can synchronize their versions with master model for last modification. This allows modeler's may be aware of conflicts in time working and resolve them before committing local changes.

A conflict is a contradictory pair of change operations; that is the two operations do not commute (e.g., giving different names to the same method or updating deleted element etc.). Research on detecting and resolving conflicts is still on its early stage.

Resolution conflicts is mostly done manually or automatically[7].

Semi-automatic. In an interactive resolution process requires interaction with the modelers.

Automatic. In this way, users may prefer a fully automated conflict resolution phase.

8. Conclusion

Software systems are continuously in flux because of different aspects on internal and external environment. To supply stability and maintainable of a software systems, advanced and configurable version management tools need to be developed. We may be witness of multiple approaches which intend to solve model versioning problems. But all of them focus on specific aspects of the versioning process and currently none of them provides a universal solution, which realizes a complete versioning system [7].

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ALGORITHMS FOR FIND OF THE DETERMINANT OF THE MATRIX WITH INTERVAL ELEMENTS OF THE ARBITRARY WIDTH

L.O.Otakulov, O.H.Boyeva, S.I.Salomova

Uzbekistan, Navoi state mining institute

***Abstract**: In work find algorithms of a determinant of a matrix with interval elements of an arbitrary width are offered.*

Methods of synthesis P and PI regulators for plant with indeterminacies of parameters are based on its representation in the state space in the form of linear dynamic system with interval matrixes of dynamics and inputs. At control system designing usually investigates controllability of the initial plant which sufficient indication is the no degeneracy of the square matrix constructed of columns of an interval matrix of controllability. If all elements of a square matrix are no degenerate interval numbers determination of its determinant represents a challenge, computing expenditures by which solution increase with magnification of an order of initial plant.

In the present work algorithms which allow to discover a determinant of a matrix with interval elements of an arbitrary breadth less, than for 2^{n^2} evaluations of determinants of numerical matrixes are developed. The virtue of the algorithms offered the present work consists in a possibility of deriving of exact boundaries of determinants for a class of matrixes of special structure.

The given work is logic prolongation of work [1] where algorithms for an evaluation of values of factors of characteristic polynomials of interval matrixes are offered.

More low we will assume acquaintance to bases of the interval analysis and to adhere to the labels accepted in [2]. In work intervals and interval magnitudes will be designated by a bold type whereas not interval (real, pointwise, etc.) are not selected in any way. Underlining and striping - $\underline{a}, \overline{a}$ - designate the lower and upper extremities of an interval $\mathbf{a}$.

The problem of determination of a determinant is considered on an example of an evaluation of determinants of interval matrixes of a random order special and sheathe structures. At a conclusion of formulas it is used properties of symmetric intervals of type $\varepsilon = [-1, 1]$.

Algorithm 1. Definition of a determinant of a matrix with one line from symmetric intervals. A determinant of an interval matrix

$$\mathbf{A} = \begin{pmatrix} a_{11}\varepsilon & \dots & a_{1n}\varepsilon \\ a_{21} & \dots & a_{2n} \\ \dots & \dots & \dots \\ a_{n1} & \dots & a_{nn} \end{pmatrix} \qquad (1)$$

Which first line consists of symmetric intervals ε, it is possible to define under the formula

$$\det \mathbf{A} = \left|\det \hat{A}\right| \varepsilon, \ (2)$$

Where the numerical matrix $\hat{A}$ satisfies to a following condition

$$\begin{gathered} \det \hat{A} = \det A(L_2^*) = \max\left|\det A(L_2)\right|, \\ L_2 = (l_1, \dots, l_n)^T \\ l_i \in \{0,1\} \\ \sum_{i=1}^{n} l_i < n \end{gathered} \qquad (3)$$

$$A(L_2) = \begin{pmatrix} a_{11}\kappa(l_1) & \dots & a_{1n}\kappa(l_n) \\ a_{21} & \dots & a_{2n} \\ \dots & \dots & \dots \\ a_{n1} & \dots & a_{nn} \end{pmatrix} \qquad (4)$$

$$\kappa(l_j) = \begin{cases} -1, \ if & l_j = 1 \\ 1 \quad if & l_j = 0 \end{cases} \qquad (5)$$

In equality (3) $L_2 = (l_1, \dots, l_n)^T$ - binary n - the vector, each component l_i can accept value 0 and 1, and their sum does not exceed number n $k(l_i)$ - the two-valued function defined on set $\{-1, 1\}$ and intended for a variation of signs at elements of the first row of a matrix $A(L_2)$ (4). The matrix $A(L_2^*)$ has maximum modulo a determinant among determinants of the matrixes $A(L_2)$ received at various combinations of signs at elements of the first line.

Algorithm 2. An evaluation of a determinant of a matrix with several lines from symmetric intervals. A determinant of an interval matrix

$$\mathbf{A} = \begin{pmatrix} a_{11}\varepsilon & \cdots & a_{1n}\varepsilon \\ \cdots & \cdots & \cdots \\ a_{n1}\varepsilon & \cdots & a_{nn}\varepsilon \end{pmatrix}$$

All the line long which contain symmetric intervals ε, it is possible to calculate under the formula (2) - (5).

Algorithm 3. An evaluation of a determinant of a matrix with a diagonal from symmetric intervals the Determinant of an interval matrix

$$\mathbf{A} = \begin{pmatrix} a_{11}\varepsilon & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22}\varepsilon & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn}\varepsilon \end{pmatrix}$$

Principal diagonal which contains symmetric intervals $\boldsymbol{\varepsilon}$, it is possible to discover under the formula

$$\det A = \left|\det \hat{A} - \det \hat{B}\right|\varepsilon + \det B, \tag{6}$$

Where

$$\det \hat{B} = \det B(M_2^*) = \max\left|\det B(M_2)\right|,$$

$$M_2 = (m_1, \ldots.., m_{n-1})^T$$

$$m_j \in \{0,1\}$$

$$\sum_{j=1}^{n} m_j < n-1$$

$$B(M_2) = \begin{pmatrix} 0 & a_{12}R(m_1) & \cdots & a_{1n}R(m_{n-1}) \\ a_{21} & 0 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n-1} & a_{n2} & \cdots & 0 \end{pmatrix}$$

$$B = B(0, \ldots.,0)^T = \begin{pmatrix} 0 & a_{12} & \cdots & a_{1n} \\ a_{2n} & 0 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & 0 \end{pmatrix}$$

And the matrix $\hat{A}$ is defined from relations (2) - (5).

Algorithm 4. An evaluation of the interval containing a determinant of an interval matrix of a general view. Interval boundaries $\mathbf{D} \supseteq \det \mathbf{A}$, guaranteed containing a determinant of an interval matrix

$$A = \begin{pmatrix} a_{11}^0 + a_{11}^1\varepsilon & \cdots & a_{1n}^0 + a_{1n}^1\varepsilon \\ \cdots & \cdots & \cdots \\ a_{n1}^0 + a_{n1}^1\varepsilon & \cdots & a_{nn}^0 + a_{nn}^1\varepsilon \end{pmatrix} = A_0 + A_1$$

where $a_{ij}^0 = mid(\mathbf{a_{ij}})$, $a_{ij}^1 = 0.5 \cdot wid(\mathbf{a_{ij}})$ - the centres and semilengths of elements $\mathbf{a_{ij}}$ of an interval matrix $\mathbf{A}$, are calculated on the basis of equalities

$$\underline{D} = \det A_0 - S_n, \quad \overline{D} = \det A_0 + S_n$$

Where

$$S_n = \sum_{i=1}^{n-1}\sum_{k=1}^{m}\left|\det \hat{A}_k^i\right| + \left|\det \hat{A}_1\right| \tag{7}$$

Where matrixes $\hat{A}_1$ from (7) it is defined on the basis of matrixes

$$A_1(\tilde{L}_2) = \begin{pmatrix} a_{11}^1 R(\tilde{l}_1) & \cdots & a_{1n}^1 R(\tilde{l}_n) \\ a_{21}^1 & \cdots & a_{2n}^1 \\ a_{n1}^1 & \cdots & a_{nn}^1 \end{pmatrix}$$

Under formulas (2) - (5), the matrix $\hat{A}_k^i$ gets out of sets of matrixes

$$A_k^i(L_2)=\begin{pmatrix} a_{11}^0 R(l_1) & \cdots & a_{1n}^0 R(l_n) \\ \cdots & \cdots & \cdots \\ a_{p1}^1 & \cdots & a_{pn}^1 \\ \cdots & \cdots & \cdots \\ a_{p+i-1,1}^1 & \cdots & a_{p+i-1,n}^1 \\ \cdots & \cdots & \cdots \\ a_{n1}^0 & \cdots & a_{nn}^0 \end{pmatrix}$$

Containing i lines of an aspect $(a_{p1}^1,\ldots,a_{pn}^1)$, $p=\overline{1,i}$ and $(n-i)$ lines of an aspect $(a_{k1}^0,\ldots,a_{kn}^0)$, $k=\overline{1,n-i}$ in correspondence under formulas (2) - (5).

Example. For a matrix

$$\mathbf{A}=\begin{pmatrix} [-3,\ -2] & [-6,\ -5] \\ [3,\ 4] & [-3,\ -2] \end{pmatrix} \tag{8}$$

Applying algorithm 4, we will discover an interval $\mathbf{D}\supseteq \det \mathbf{A}$.

Let's present a matrix $\mathbf{A}$ (8) in an aspect $\mathbf{A}=A_0+\mathbf{A}_1$ where matrixes A_0 and $\mathbf{A}_1$ have the following structure:

$$A_0=\begin{pmatrix} -2.5 & -5.5 \\ 3.5 & -2.5 \end{pmatrix},\quad \mathbf{A}_1=\begin{pmatrix} 0.5\varepsilon & 0.5\varepsilon \\ 0.5\varepsilon & 0.5\varepsilon \end{pmatrix},\quad \boldsymbol{\varepsilon}=[-1,1].$$

It is obvious that $\det A_0=25.5$. We will note a matrix $A_1(L_2)$

$$A_1(L_2)=\begin{pmatrix} 0.5R(l_1) & 0.5R(l_2) \\ 0.5 & 0.5 \end{pmatrix}$$

Applying algorithm 1, we will calculate $\left|\det \hat{A}_1\right|=\max\limits_{L_2}\left|\det A_1(L_2)\right|=0.5$

Let's discover $m_1=C_2^1=2$. Using algorithm 1, we will define

$$\det \hat{A}_1^{\,1}=\max_{L_2}\left|\det\begin{pmatrix} 0.5R(l_1) & 0.5R(l_2) \\ 3.5 & -2.5 \end{pmatrix}\right|=3,$$

$$\det \hat{A}_2^{\,1}=\max\left|\det\begin{pmatrix} -2.5R(l_1) & 5.5R(l_2) \\ 0.5 & 0.5 \end{pmatrix}\right|=4,$$

Let's calculate $S_n=\left|\det \hat{A}_1^1\right|+\left|\det \hat{A}_2^1\right|+\left|\det \hat{A}_1\right|=7.5$

Interval boundaries $\mathbf{D}\supseteq \det \mathbf{A}$ we will define under formulas (19):

$$\underline{D}=25.5-7.5=18,\quad \overline{D}=25.5+7.5=33$$

Let's compare the received interval $\mathbf{D}=[18,33]$ to value of interval expansion of the function $\det(\cdot)$, calculated for matrix elements $\mathbf{A}$

$$\det \mathbf{A}=[-3,\ -2]\cdot[-3,\ -2]-[-6,\ -5]\cdot[3,4]=[19,33]\subseteq[18,33]=\mathbf{D}$$

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SEARCH OPTIMAL ARCHITECTURE OF NEURAL NETWORKS FOR TIME SERIES PREDICTION

O.K. Khujaev[1], R.Paredes[2]

*[1.] Tashkent university of information technology, 100202, Uzbekistan, Tashkent,
108 Amir Temur str., E-mail: otabek.hujaev@gmail.com)*
[2.] Polytechnic university of Valencia, 46071 Valencia, Spain, E-mail: rparedes@dsic.upv.es

***Abstract**: This paper presents applying two neural network models for time series prediction problems. focused choosing optimal architecture of Elman and feedforward neural networks for time series prediction. Topics discussed include neural network design, overview methods of forecasting, sliding window method, training and testing of network, training algorithms and all results obtained with neural network toolbox in MATLAB.*

***Keywords**: Elman recurrent neural networks, feedforward neural networks, sliding window, backpropagation*

1. Introduction

In recent years, artificial intelligence methods have been used widely in forecasting, such as expert system, artificial neural network, and so on. There are many models of neural networks. In forecasting most commonly used feedforward neural network and Elman recurrent neural networks, which employ a sliding window over the input sequence. This paper is focused choosing optimal architecture of Elman and feedforward neural networks for time series prediction

2. Time series prediction and sliding window.

A time series is a sequence of vectors, x(t), t=0,1,….., where t represents elapsed time. For simplicity we will consider here only sequences of scalars, although the techniques considered generalize readily to vector series. Theoretically, x may be value which varies continuously with t, such as temperature, but in practice, for any given physical system, x will be sampled to give a series of discrete data points, equally spaced in time. For example time series by hour, by day, by week, by month. Method of sliding window helps us for creating training dataset, For example: *x(1),x(2), x(3) ……x(n)* is a time series vector. After using sliding window which size equal to *d*, we can create this input output mapping dataset.

inputs	Targets
x(1), x(2),x(3),…….x(d)	*x(d+1)*
x(2),x(3),x(4)…..x(d+1)	*x(d+2)*
.	.
.	.
.	.
x(n-d-1), x(n-d),x(n-d+1)…….x(n-1)	*x(n)*

3. Feedforward and Elman recurrent neural network model.

The feedforward neural network contain input layer, hidden layers, output layer. In feedforward networks all neurons and input units connected with forward neurons and no connection with neurons which situated same layer and previous layer. Elman network is recurrent network and it is proposed by Elman in 1990. It is similar feedforward but in hidden layers have a feedback. You can see schema of feedforward and Elman neural network in Fig.1. which we use forecasting.

Theoretically there will be many hidden layers but in practice commonly used one hidden layer. Number units of input layer will be equal with size of window. We can not say what how much neurons we put in hidden layer, because much hidden neurons much computation. Therefore optimal number of hidden neurons will be different for every dataset.

As a activation function usually used following easy differentiable nonlinear logistic function.

$$f(x) = \frac{1}{1+e^{-x}} \qquad (1)$$

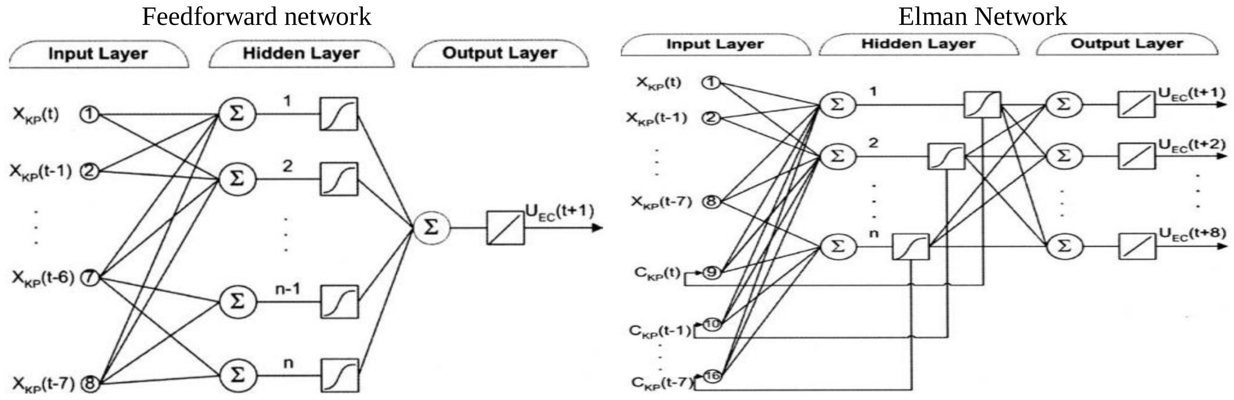

Fig. 1. ***Feedforward and Elman neural network architecture.***

If we are forecasting a variable that may take negative values, it is better to use the hyperbolic tangent as an activation function:

$$f\ (x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \tag{2}$$

4. Neural network training and testing

We use the backpropagation method in training. Backpropagation is one of simplest and most general methods for supervised training of multilayer neural networks. The basic approach in learning is to start with an untrained network, present a training pattern to the input layer, pass the signals through the net and determine the output at the output layer. Here these outputs are compared to the target values; any difference corresponds to an error. This error or criterion function is some scalar function of the weights and is minimized when the network outputs match the desired outputs.

We consider the training error on a pattern to be the sum over input units of the squared difference between the desired output t_k given by a teacher and the actual output z_k , much as we had in the least mean square (LMS) algorithm for two-layer nets.

$$J(w) = \frac{1}{2}\sum_{k=1}^{c}(t_k - z_k)^2 = \frac{1}{2}\| t - z \|^2 \tag{3}$$

There are t and z the target and the network output vectors of length c and w represents all the weights in the network.

The backpropagation learning rule is based on gradient descent. The weights are initialized with random values, and then they are changed in a direction that will reduce the error:

$$\Delta w = -\eta \frac{\partial J}{\partial w} \tag{4}$$

where η the learning rate, and merely indicates the relative size of the change in weights. The power of Eqs. 4 is in their simplicity: They merely demand that we take a step in weight space that lowers the criterion function. It is clear from Eq. 3 that the criterion function can be negative; furthermore, the learning rate guarantees that learning will stop, except in pathological cases. This iterative algorithm requires taking a weight vector at iteration m and updating it as

$$w(m+1) = w(m) + \Delta w(m) \tag{6}$$

where m indexes the particular pattern presentation.

The completion of the training algorithm optimized the synaptic weighted connections to establish reliable relationships between the inputs and outputs. During the testing and validation step, these free parameters are held constant while new inputs are fed to the network to produce a series of outputs. These outputs are compared to a set of test data matching the actual produced outputs. If the actual output deviates from the target test set output above a threshold error value, the training need to be adjusted and the neural network retrained.

5. Experiments

We can see, training algorithm calculate only error of network and update weight matrix by gradient descent method, but minimum error of network is also related with configuration of network. In feedforward and Elman multilayer networks are commonly used one hidden layer. Overview structure of network will be *M:N:K*, which *M* is number of inputs or size of sliding window, *N* is number of hidden neurons, *K* is a number of neurons in output layer. In forecasting problems K is equal 1, but optimal of M and N may be different for every dataset. For experiment we use datasets of Evolutionary and Neural Computation for Time Series Prediction Minisite. You can find short description about these dataset through following table.

Table 1

Time series datasets for forecasting which we used as a experiment

№	Name of dataset	Acronym	About dataset	Number of data
1.	Sunspot time series	STS	This time series contains the average number of sunspots per month measured from January of 1749 to March of 1977	305
2.	North Atlantic Oscillation time series	NAO	A time series with the normalized NAO index over each month from 1950 till 2005	667
3.	Exchange Rates: US Dollars / Euro	ECU	This is a time series provided by the Spanish Central Bank that shows the mean value of the US Dollars per Euro rate, taken each month since January 1979 till July 2005	319
4.	Consumer Price Index of Spain	CPI	This is a time series provided by the Spanish Central Bank that shows the CPI per month in Spain, since January 1960 till June 2005	535
5.	Spanish Electric Energy Demand	SEED	Here we have a collection of time series showing the electric energy demand (GWh) in Spain for each month from 1959 till 2000	492

These datasets contain time series data by monthly, therefore we can forecast next month, full next year or next two year, but in this case we can’t forecast for next week or next day.

6. Results

We create feedforward and Elman networks with different architecture for every dataset. Input units size *M* ($1<M<18$), because monthly time series sequences may be repeatedly by a year. Number of hidden neurons *N*, we increase it by power of 2, but very much hidden neurons is more computations, therefore we cheek until 64 ($2^1<N<2^6$). We take results with MATLAB. In the MATLAB has a Neural Network Toolbox, and we also use different training functions data division functions for improving generalization in training process.

We obtained following results for different architecture For dataset ECU:

Table 2

Average MSE errors for different architecture of feedforward network for ECU dataset

Number of hidden neurons \ Size of input units	5	6	7	8	9	10	11	12
2	6,83E-04	7,57E-04	3,52E-04	9,22E-04	3,38E-04	1,02E-03	9,83E-04	1,17E-03
4	6,40E-04	9,34E-04	1,40E-03	8,17E-04	6,59E-04	1,09E-03	3,97E-04	8,78E-04
8	6,19E-04	1,20E-03	1,01E-03	8,17E-04	4,69E-04	7,23E-04	8,08E-04	1,16E-03
16	7,14E-04	7,88E-04	8,05E-04	9,19E-04	6,72E-04	8,41E-04	4,50E-04	8,37E-04
32	1,09E-03	7,86E-04	6,34E-04	6,66E-04	1,92E-03	9,17E-04	1,13E-03	2,05E-03
64	8,78E-04	8,37E-04	4,34E-04	1,56E-03	6,24E-04	1,69E-03	2,43E-03	1,43E-03

We can see for this dataset 9:2:1 configuration of feedforward network reached minimum error and trained network with these configuration give us following prediction results for next year.

We can see for this dataset 17:4:1 configuration of Elman network reached minimum error and trained network with these configuration give us following prediction results for next year.

Table 3

Average of MSE errors for different architecture of Elman network for ECU dataset

Size of input units

Number of hidden neurons		11	12	13	14	15	16	17	18
	2	2,31E-03	9,76E-03	1,09E-02	1,38E-02	1,02E-02	1,39E-02	2,25E-02	1,18E-02
	4	3,38E-03	3,74E-03	4,72E-03	2,76E-03	5,39E-03	1,50E-02	1,30E-03	6,35E-03
	8	1,40E-02	5,65E-03	2,68E-03	5,55E-03	1,50E-02	2,51E-03	4,02E-03	3,79E-03
	16	2,78E-02	1,10E-02	2,94E-02	2,87E-03	7,01E-03	3,61E-02	5,44E-02	2,14E-02
	32	3,54E-02	7,25E-02	4,02E-02	9,27E-02	5,59E-02	1,95E-02	1,70E-02	3,96E-01
	64	4,28E-02	1,14E-01	8,87E-02	1,17E-01	3,61E-01	1,15E-01	2,45E-01	3,07E-01

For another dataset we have done these computations and we have obtained following results

N	Name of dataset	Optimal architectire for feedforward network	MSE	Optimal architectire for the Elman network	MSE
1	STS	12:4:1	3,00E+01	8:4:1	2.1058e+002
2	NAO	11:2:1	0.85	17:2:1	0.92
3	ECU	9:2:1	7.9752e-004	17:4:1	0.0015
4	CPI	17:2:1	0.0774	16:4:1	28.061
5	SEED	12:16:1	3.7969e+005	11:4:1	2.3497e+006

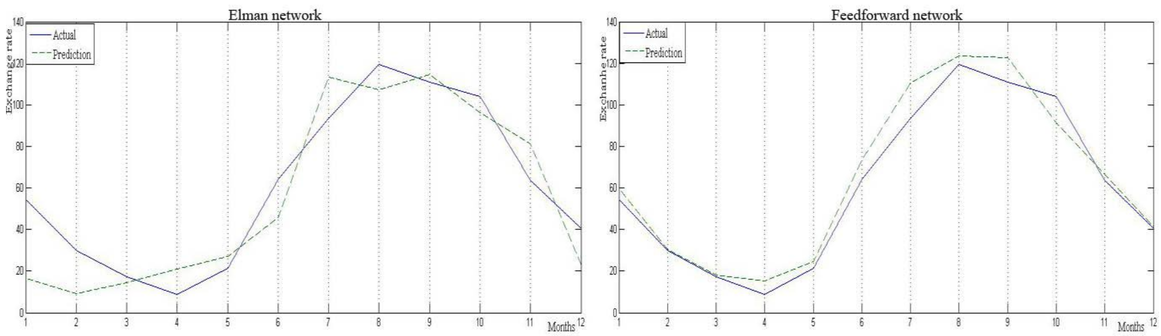

*Fig.2. **Prediction results for next 12 months with Elman and Feedforward networks for STS dataset.***

The STS data, which is considered investigation, contains the annual number of sunspots from January of 1749 to March of 1977. we use all data in training except last twelve months, because we use them in testing. Testing or prediction results you can see in fig.6 and the results are good for twice model, but results of feedforward network is better than Elman network.

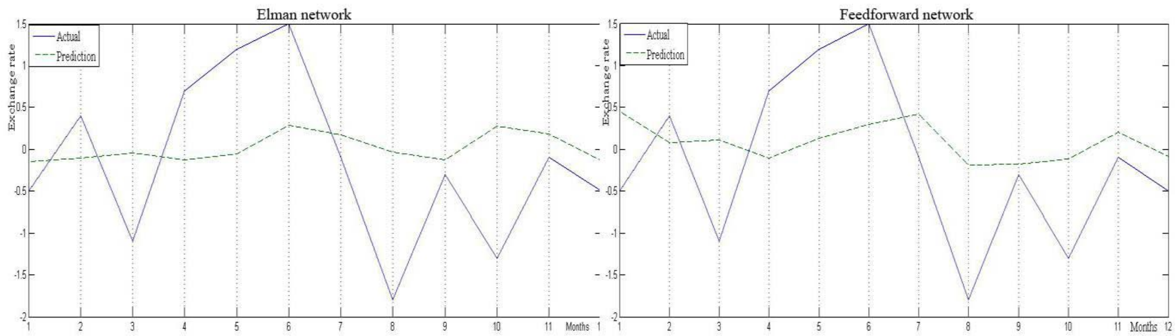

*Fig.3. **Prediction results for next 12 months with Elman and feedforward networks for NAO dataset.***

This dataset contain a time series with the normalized NAO index over each month from 1950 till 2005. Neither with feedforward nor with Elman we could not obtain good prediction for this dataset, because values of time series are very different and also have negative values, therefore we used hyperbolic tangent activation function for the hidden layers. We try improve generalization and used different training functions, different preprocessing and postprocessing functions in neural network toolbox in MATLAB, but prediction results are not good. These models of neural network count capable for prediction for this dataset.

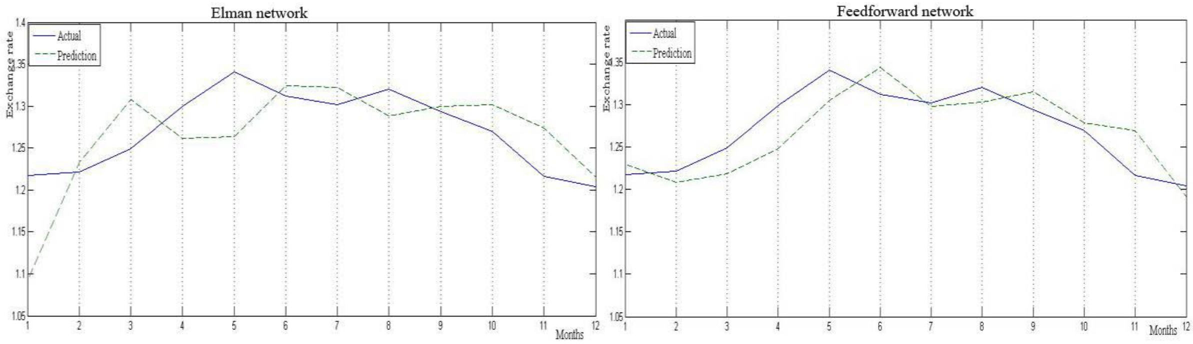

Fig.4. ***Prediction results for next 12 months with Elman and feedforward networks for ECU dataset.***

The third data set that is considered in this investigation is the exchange rate between Euro and United States dollar. Predicting exchange rate is an important yet difficult task in international finance. This dataset shows the mean value of the US Dollars per Euro rate, taken each month since January 1979 till July 2005. prediction results of twice model of neural network are good. Elman network the best fitted in 9:2:1 architecture for this dataset and feedforward is 17:4:1.

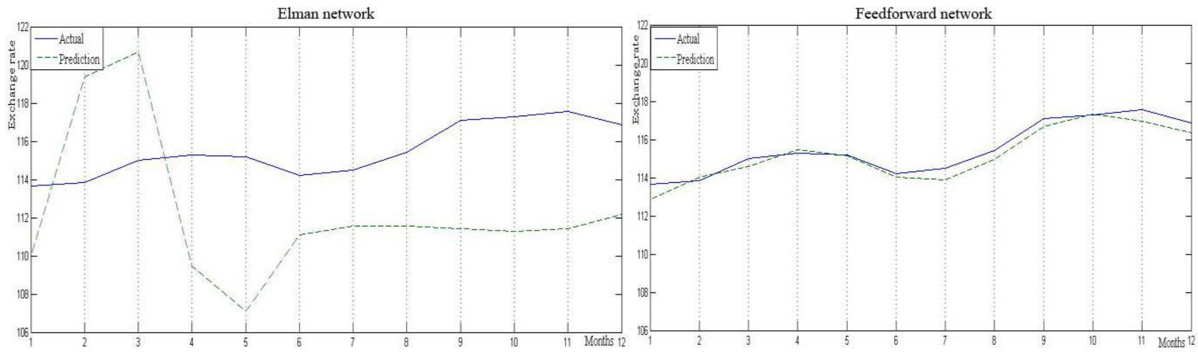

Fig.5. ***Prediction results for next 12 months with Elman and feedforward networks for CPI dataset.***

This dataset shows the Consumer Price Index per month in Spain, since January 1960 till June 2005. We obtained very good prediction results for this dataset. You can see this in Fig.8 and results of Elman network is not good. We also tried improve generalization for Elman network, but we cannot solve overfitting problem. The best result obtained with Feedforward network in 17:2:1 architecture

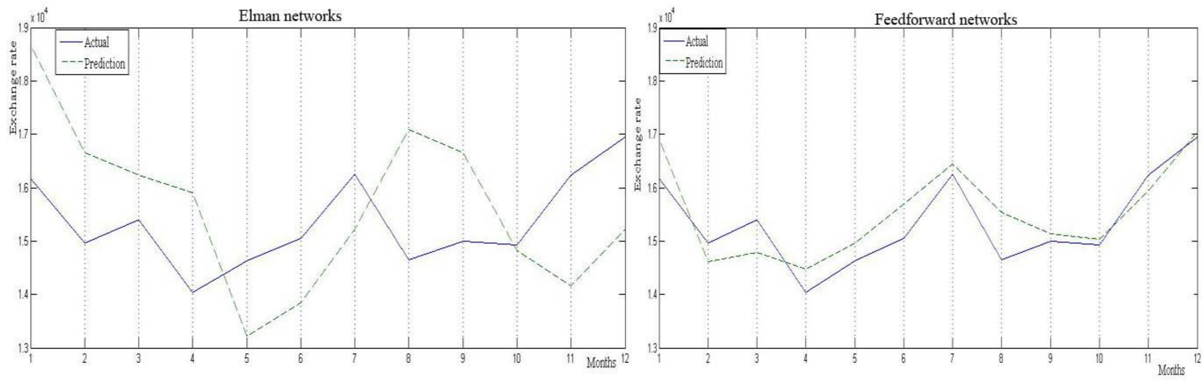

Fig.6. ***Prediction results for next 12 months with Elman and feedforward networks for SEED dataset.***

The last dataset have a collection of time series showing the electric energy demand (GWh) in Spain for each month from 1959 till 2000. Feedforward network prediction results is also good for this dataset. The best is in 12:16:1 architecture. Really values of the dataset may be recapitulative, therefore input size of window is equal to twelve in the best architecture.

7. Conclusion

Our study found that feedforward and Elman neural networks are good capable for time series prediction. For training we used backpropagation algorithm for neural networks. We also found that the number of hidden neurons and number of input units (or size of sliding window) have a effect on the neural network's performance, but number of hidden neurons and input units are different for every dataset. Therefore for solving of forecasting problems with neural networks, we have to train with different number of input points and hidden neuron. In our experiment datasets we use only last 12 data in testing, because we want to forecast only next year. Usually in testing is used 15% data of the datasets. This approach give us help to choose the best architecture of the network for that dataset.

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CHECKING OF AUTHENTICITY OF INFORMATION TRANSFER BY USING THE STATISTICAL REDUNDANCY FROM TRANSMITTED TEXT ELEMENTS IMAGES

Akhatov A.R., Zaripova G.I.

Department of Information Technologies, Samarkand State University
Samarkand, 15, University blvd., 140104, Uzbekistan,
Phone: +998662206881
e-mail: akmalar@rambler.ru, a-axatov@samdu.uz

Keywords: *authenticity, textual information, man-operator, units of data input, data transfer, checking, controlling, structural and statistical redundancy, probability of undetected mistakes, cost of realization.*

1. Introduction

The information, transmitted and processed in telecommunication systems, significant part of which is text, is deformed by various reasons, and it, in turn, results into erroneous decisions. In this connection, the tasks of controlling the text information transfer authenticity get large urgency and researches on development of the methods, algorithms, systems of the text elements (letters, symbols, words) control and correction require the special attention. The problem of the text information authenticity control was considered one of applications of the information transfer theory. At the same time, as one of the components of artificial intelligence, this problem has attracted the attention of researchers to the systems of speech synthesis and generation, automatic translation, control and correction of spelling mistakes etc. [1]. Nowadays, days certain successes have been achieved in the problem of spell checking, but many tasks for controlling text information transfer reliability and authenticity remain unsolved [2].

In present work the basic attention is paid to development of program methods for information authenticity control, conformed to a variable part of packets and containing the message, transmitted to the addressee. We offered the new approach to the use of information redundancy with various nature as a mechanism of information authenticity control in the structure of data transfer packets. The methods, algorithms and programmed monitoring systems are developed to correct mistakes of the man-operator and scanners, made at applied level of network service (Application, Presentation, Session layers of OSI).

The developed algorithms for increasing the information authenticity should remove shortcomings and successfully add opportunities of methods, used in the data transfer protocols. The effective program control of information authenticity improves efficiency of a network, quality and speed of information transfer at the expense of automatic mistakes detection and correction and at the expense of reduction of reaction time at systems dialogue.

2. The model of controlling authenticity of textual information transfer

Let *K* be the key (code of access) to used algorithm and software of the authenticity control; *I* be the container (part of a package), containing the information on the text element image; *B* be the specific mark, i.e. label of a reference sample of the images signal characteristics.

Then *W* as the result of transformation of the text by function *F* in the system of information authenticity controlling is represented by the following formalized model

$$F:\ I^{*}\times K^{*}\times B^{*}\rightarrow W^{*},\quad W=F(I,K,B), \tag{1}$$

where W^*, K^*, I^*, B^* are the designations of appropriate sets on reception part.

Generally, according to positions of the theory of continuous messages transfer, at representation of a text element by an image it is required that function *F* should provide necessary robustness of the transmitted container even if there is some non-stationarity caused by handicaps and mistakes at network layers of OSI model [3]. To provide the condition of robustness $F(I,K,B)\approx F(I+\varepsilon,K,B)$, when the text elements images transfer we use models and algorithms which control the information authenticity on the basis of statistical and structural redundancy and at the expense of taking into account changes of dynamic characteristics and probabilities of mistakes which occur at Application and Presentation levels [2].

The principle of the information authenticity control by model (1) in conditions of robustness is the following. Let's use the operator *T*, which modifies an element of the text *w* for transmission, and after that W^* is accepted by the receiver. The operator *T* should be chosen so that on the reception party the following condition was observed:

$$T(W,I_0)=T(W,I_W)=T(W,I'_W) \tag{2}$$

where I_0 is unfilled container appropriate to traditional structure of a package of transfer; I_W is a filled container including procedures of access to the bases of algorithms and software for information authenticity control, based on the use of statistical and dynamic characteristics of images signals; I'_W is a modified filled container using adaptive methods and algorithms of dynamic identification and smoothing images signal characteristics.

Let's note, that for the increase of robustness and equivalence problems of noise stability, security and reliability of the information, connected with them, the modern theory of continuous messages transfer has a set of methods and receptions for decision of tasks. Most widespread applications on practice are noiseproof codes, for example, BCH codes, convolve codes etc. [4]. In our opinion, perspective and poorly studied direction of issues is the increase of quality of image container transmission. Thus the construction of systems is effective on the basis of using the statistical, structural and natural redundancy and using the mathematical apparatus of wavelet-transformations, data processing by neural networks, recognition of text elements image, item coding and compression etc. [5]

In this connection, we offer basic approaches to construction of the system for information authenticity control, which are based on the use of redundancy with various nature and principles of control according to the models of transfer and processing of text elements images listed above.

3. Approach to construction of system for information authenticity controlling on the basis of using the redundancy of images

The process of display of the specific characteristics $W(i, j)$ on a plane of signals with the built-in redundancy in the initial image $I(i, j)$ is presented as a superposition:

$$\varepsilon: \ I^* \times W^* \times L^* \rightarrow I_W^*, \text{ i.e. } I_w(i, j) = I_0(i, j) \oplus L(i, j) W(i, j) P_{ij}, \qquad (3)$$

where $L(i, j)$ is the mask of embedding which takes into account the nature of the container for maintaining robustness; $\oplus$ is designation of superposition including addition, truncation and quantization; P_{ij} is probability function of estimation distortions, which depends on used algorithms of coding and compression.

It is necessary to note, that function P_{ij} is also used as a major factor when rating the quality for either system of information reliability control and development of theoretical rules of researches in reliability control. So, it is necessary to examine distribution of this function over the field of changes of the images characteristics. The consideration of such hypothesis allows to use the statistical characteristics of the images having certain structure in space and correlation properties. Besides it allows to develop a wide spectrum of methods and algorithms for the information authenticity control based on the use of statistical and structural redundancy.

Let’s present three approaches to the development of methods, algorithms and systems for information authenticity control using statistical, structural, natural and artificial redundancy of the information submitted as containers of images.

According to the first approach the system for texts authenticity control in the structure of data transfer packages can be constructed by the following principles :

- detection of the deformed information is carried out by a control rule based on the use of calculated factors of correlation between signals, transmitted by encoder and accepted by decoder. Thus, if calculated factor of correlation exceeds some threshold, the correctness for the checked text element reception is made up;
- control of information authenticity is carried out on the basis of using the modal characteristics (amplitude-frequency, spectral) and function of images information distribution, which are compared with their analogs, i.e. empirical modal characteristics, placed as databases in memory of system;
- the transmitted and received image of text elements is compared and divergences are allocated within the limits of the established borders. In the case of profound overshoot, trajectories of the image are smoothed out, and then statistical parameters of smoothing methods are corrected. As the mathematical apparatus of such adaptive adjustment for detection and correction of error elements it is offered to use optimum filters, spline-functions with various degrees, Fourier transformation, wavelet-analysis etc.

According to the second approach systems for information authenticity control are constructed by the following principles:

- checking code distances on two-dimensional, three-dimensional and k-dimensional metrics between transmitted and received images;
- superfluous coding by rules of bitwise, digital, numbered summation, summation on modules q etc.;
- using beforehand given code book for the images of all elements and characteristics of a source, moreover it is possible to increase the effectiveness of control system at the expense of using frequency characteristics of text elements or the wordform dictionaries as the code books.

According to the third approach we offer to construct systems of information authenticity control on the basis of using mechanisms of statistical coding, recognition of text elements, morphological, n-gram, parsing models of the natural language [6].

Let's note, that research in developing the system of information authenticity control on the basis of any approaches offered above requires, first of all, definition of the basic criteria for rating authenticity of packages transmission at the output of a network. In this connection, we present technique of finding the rating of transmitted information authenticity, which will serve as criterion of efficiency for developed methods and algorithms.

4. Algorithm of controlling of the text element images transfer based on statistical redundancy

Let the container of text image is represented by some function $W = f(S_0, W)$, where S_0 is the initial image. The algorithm for control of the text element images quality is based on the statistical averaging of the main signal characteristics such as amplitude, frequency, spectral characteristics, average value, correlation function, etc.

So, we offer the following principle of using the statistical redundancy for the information authenticity control.

For detection of data distortions the average characteristics of the transmitted image is calculated on the basis of information about several transmitted images. The sequences of images parameters in the container are considered as statistically independent.

At the receiver it requires the definition of parameters $S_0 + W$, $S_1 + W$, ..., $S_N + W$, and comparison is performed for the sums $T = NW + \sum_i S_i$ and $T^* = NW + \sum_i S_i$ calculated on transmitting and on receiving parties. Thus the checked up sums will appear equivalent, then it is possible to make a decision for information authenticity. As a rule, $\sum_i S_i$ will be close enough to NW with large N .

Let's note, that during information control by the offered rules, the developed algorithm admits mistakes of two sorts. First, mistakes of “false alarm”, i.e. the mistake of the first sort when the correct word W will be admitted as the wrong one. Second, the “error passing”, i.e. the mistake of the second sort when the word W is received incorrectly, but the algorithm considers it as correct. The rating of probabilities of such mistakes is one of the basic subjects in research for establishing an effective control program.

We designate mistakes of the first sort as P_1, and the second sort as P_2.

To check information authenticity we establish subsets of solved ($\{\alpha_S^{1,k}\}$) and forbidden ($\{\alpha_F^{1,k}\}$) code combinations of a controllable element α_i, which can be transformed as β_j on the receiving party.

We investigate possible variants of transitions $\alpha_i \to \beta_j$ and rules of receiving codes β_j and β_{j+1}. Rules of authenticity control of the information β_j are the following:

the information is considered received

$$-correctly, \quad if: \begin{cases} \alpha_i = \beta_j; \alpha_{i+1} = \beta_{j+1} \; and \; \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \notin \{\alpha_i^1\}, & (4) \\ \alpha_i = \beta_j; \alpha_{i+1} = \beta_{j+1} \; and \; \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_S^{1,k}\}, & (5) \end{cases}$$

$$-incorrectly, \quad if: \alpha_i \neq \beta_j; \alpha_{i+1} \neq \beta_{j+1} \; and \quad \beta_j \in \{\alpha_j^1\}; \beta_{j+1} \in \{\alpha_F^{1,k}\}, \tag{6}$$

where $k = (1, m)$; m is the possible classes of transformation $\alpha_i \to \beta_j$.

The two sorts of undetected mistakes can be described as follows:

for P_1, when the values β_j and β_{j+1} are erroneous, however conditions (4) and (5) are true. It is the "error passing";

for P_2, when the values β_j and β_{j+1} are correct, however condition (6) is satisfied. It is the "false alarm".

The probability of transitions is supposed equiprobable, i.e.

$$P_{\alpha_i \beta_j} = \begin{cases} 1 - P_{\alpha_i}, \quad when \quad \alpha_i = \beta_j; \\ P_{\alpha_i} \dfrac{1}{M-1}, \quad when \quad \alpha_i \neq \beta_j, \end{cases}$$

where $M = 10^m$ is a range of change for code combination, i.e. volume of set Ω

For completeness of definition the undetected mistakes probabilities P_1 and P_2 it is necessary to take into account the following cases: a) when the information β_j and β_{j+1} are received correctly; b) when β_j is received correctly, but β_{j+1} is incorrect; c) when β_j is received incorrectly, and β_{j+1} is correct; d) when β_j and β_{j+1} are received incorrectly.

According to this, the mistakes of the first and second sorts are calculated by the following probable situations, where for mistakes of the first sort, the probability is:

$$\begin{aligned} P_1 = \Re\{\alpha_i \neq \beta_j; \alpha_{i+1} = \beta_{j+1}\ u\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \notin \{\alpha_i^1\}\} + \Re\{\alpha_i = \beta_j; \alpha_{i+1} \neq \beta_{j+1} \\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \notin \{\alpha_i^1\}\}\Re\{\alpha_i \neq \beta_j; \alpha_{i+1} \neq \beta_{j+1}\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \notin \{\alpha_i^1\}\} + \\ \Re\{\alpha_i \neq \beta_j; \alpha_{i+1} \neq \beta_{j+1}\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_i^1\}\} + \Re\{\alpha_i = \beta_j; \alpha_{i+1} \neq \beta_{j+1} \\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_i^1\}\} + \Re\{\alpha_i \neq \beta_j; \alpha_{i+1} \neq \beta_{j+1}\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_i^1\}\}. \end{aligned} \quad (7)$$

Considering

$$\Re(\alpha_i = \beta_j) = \Re(\alpha_{i+1} = \beta_{j+1}) = 1 - P_{\alpha_i};$$

$$\Re(\alpha_i \neq \beta_j) = \Re(\alpha_{i+1} \neq \beta_{j+1}) = P_{\alpha_i};$$

and accepting $m = 3$, formula (7) was reduced to the expression:

$$P_1 \approx 2P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 10^{-2} + P_{\alpha_i}{}^2 \cdot 10^{-2} + 2P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 10^{-4} + P_{\alpha_i}{}^2 \cdot 10^{-4}.$$

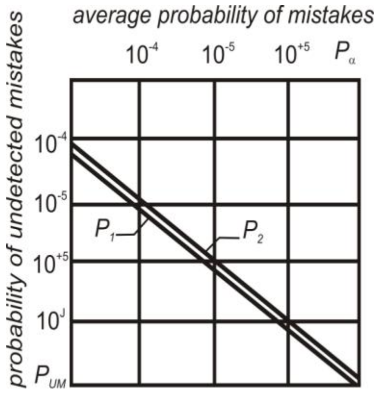

Fig. 3. ***Dependence P_{UM} on conditions of information.***

Taking into account, that $P_{\alpha_i}^2 \cdot 10^{-4}$ is much less than 1, the expression obtained for mistakes of the first sort probability is defined as

$$P_1 \approx 2P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 10^{-2} + P_{\alpha_i}{}^2 \cdot 10^{-2} + 2P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 10^{-4}. \quad (8).$$

For mistakes of the second sort, the probability is:

$$\begin{aligned} P_2 = \Re\{\alpha_i = \beta_j; \alpha_{i+1} = \beta_{j+1}\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \notin \{\alpha_F^{1,\kappa}\}\} + \Re\{\alpha_i \neq \beta_j; \alpha_{i+1} \neq \beta_{j+1} \\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_F^{1,\kappa}\}\} + \Re\{\alpha_i = \beta_j; \alpha_{i+1} \neq \beta_{j+1}\ and\ \beta_j \in \{\alpha_i^1\}; \beta_{j+1} \in \{\alpha_F^{1,\kappa}\}\}. \end{aligned} \quad (9);$$

Formula (9) is reduced to the expression:

$$P_2 \approx (1 - P_{\alpha_i})^2 \cdot 1.5 \cdot 10^{-5} + P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 1.5 \cdot 10^{-5}. \quad (10)$$

The total probability of undetected mistakes for algorithm is:

$$P_{UM} \approx 2P_{\alpha_i}(1 - P_{\alpha_i}) \cdot 10^{-2} + (1 - P_{\alpha_i})^2 \cdot 1{,}5 \cdot 10^{-5}. \quad (11)$$

On figure 3 there are given curves of dependences of the undetected mistakes probabilities (P_1 and P_2) out of conditions of information transfer P_{α_i}. It also provides the value of total probability P_{UM}. The average probability of mistakes P_{α_i} for tracts of information transfer is established by statistics of mistakes.

5. Analysis of efficiency for the devised methods and algorithms

To estimate the efficiency of algorithms we used criteria of probability of undetected mistakes P_{UM}, labour input T and cost of realization of controlling method C. The criterion of control labour input means the time of processor spent on controlling of the information unit, criterion of cost means cost of algorithms realization for the control of information unit and both criterions are calculated by special technique. To get the numerical results of theoretical researches we make the following assumptions for values of the parameters included in formulas and expressions: volume of the tested information is 8 Mbytes; experimentally established average probability of mistakes of the men – operators, scanning and recognizing devices are $P = 3{,}7 \cdot 10^{-3}$; the method of the control protects sequence of frames belonging to one package; the mistakes caused by failures of devices are not taken into account.

It can be observed, that under conditions close to practical, the devised algorithms increase reliability of the information almost on two folds, and the labour input and cost of realization decreases by two-three times. It can be seen from Fig. 4 and 5 that the diagrams which display the dependences of labour input and controlling cost criterions from probability of mistakes P and from volumes of the processed information, where axes of ordinates reflect the values of the appropriate criteria, and axes of abscissa reflect the given volume of tested information.

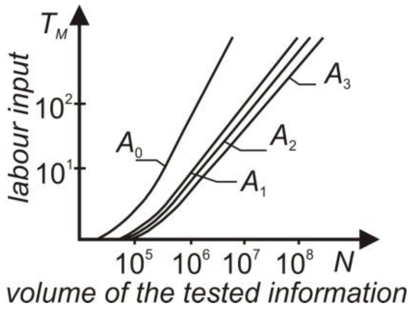

Fig. 4. ***Comparison of algorithms efficiency by criterion of controlling labour content.***

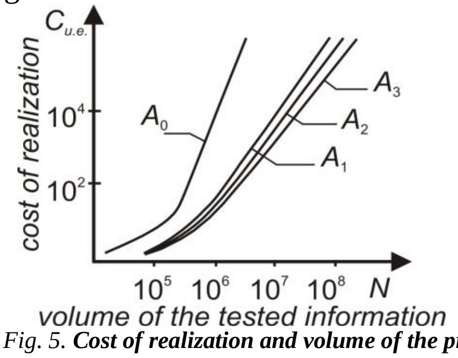

Fig. 5. ***Cost of realization and volume of the processable information.***

The most effect on information authenticity is reached at application of algorithm A_3 which uses mechanisms of statistical recognition and natural redundancy.

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PRESENT DAY SOLUTIONS IN AUTOMATIC CONTROL ON OIL PRODUCING PLATFORMS

L.R. Sorkin [1], O.Y. Pershin [1], F.T. Adilov [2]

ZAO Honeywell. 121059, Russia, Moscow, Kiev str. 7
Phone: +7(495)796 98 98, e-mail: leonid.sorkin@honeywell.com, oleg.pershin@honeywell.com,

Himavtomatika LLC, 100000, Uzbekistan,Tashkent, Niyozbek yuli,1
Phone: +99871 1501966, e-mail: farukh.adilov@himavtomatika.uz

Abstract: *The principles, objectives, and decisions on the use of modern means of automatic control systems for offshore platforms. The presentation is based on the products of the Honeywell Company. The means described in the paper have been successfully used in Russia for a long time in the process control in oil companies. The paper shows that the management of the process of extraction in the sea is a very promising field of application of modern means of automatic control.*

1. Introduction

Present day technical means and software products in the field of process automation and computerization allow us to solve a wide range of problems in effective management of oil and gas fields development. Actually, information technologies become one of the basic instruments for raising ultimate oil recovery of shelfs, stability and steerability of current production processes, transportation and trade treatment of oil and gas while reducing energy consumption of the development.

The requirements for safety, reliability and operational efficiency of technological devices are especially high in the operation of offshore platforms.. Offshore production is a high-cost manufacturing process with the maximum use of technology and unmanned operation in extreme environments. These features make it necessary to make the most of the equipment in the strictest technological restrictions for safety reasons. Solving such problems is a typical area of application of methods of optimal control of the process based on their performance in compliance with technical limitations.

The article discusses the concepts and possible use of advanced solutions for the automatic process control of production at offshore platforms. Discusses the tools, known in English literature as Advanced Process Control (APC). In Russian terminology, with reasonable proximity, these tools can be defined as a method of multiple regulation and optimal control with a forecast of object's reaction to the signal based on constructing a model of the object.

The discussion is based on Honeywell's commercial software package - Profit Suite ® for Advanced Control & Optimization, which implements patented Robust Multivariable Predictive Control Technology (RPMST). By now in Russia this package products have an established reputation in the oil refining, allowing the increase in efficiency and reliability of the process units. But, as world experience shows, these tools can be successfully applied in the oil industry Moreover, one of the most promising areas of their use, as mentioned above, is the extraction using offshore platforms of different types.

2. Control strategy

The package is based on the method of multiple regulation with forecast of controlled object's reaction to control signal.

Fundamentally, the process control is described as follows.

There are three types of variables representing physical characteristics of the technological process:

- *Controlled Variables* (*CVs*) – these are observed variables, which during the implementation of the technological process should take values within specified limits. Within the allowable control area, defined by these limits, the variables can be optimized for a given criteria of process efficiency.
- *Manipulated* or *control Variables* (*MVs*) – these are the variables that are manipulated to keep the CVs within the feasible region when the process conditions change and / or set the optimal values of the controlled variables in optimization. The MVs permissible regulation limits for a

controller are set by the operator. For every MV during the configuration of the regulator the operator sets a *weight* which determines the contribution of this variable in the control process of achieving the desired result, while manipulating several control variables.

- Disturbance Variables (DVs) – these are measurable variables that are not regulated in the control process, but will affect the values of the controlled variables. When configuring the controller the algorithms that predict the effect of DVs impact on CVs trajectory are set, this allows us to take steps to prevent interference in control process.

When you configure the controller the model of process in the form of matrix of connections between the variables (influence matrix) is built. Next, the model is adjusted online in the control process.

Figure 1 shows the basic structure proposed by Honeywell APC applications. Here Profit Max is a special development for non-linear processes, allowing us to linearize the process near the operating point and calculate the input data for linear regulators **Profit Controller** and **Profit Optimizer**. Profit Optimizer calculates in real time based on linear models the optimal consistent values of the controlled variables for units involved in the process. Profit Controller is a basic element of APC application that implements a multiple control of the unit, giving control actions on MVs variables, for example, when defining setpoints for PID controllers. Currently, the autonomous Profit Controller is widely used for multiple control of a separate unit to retain the values of the controlled variables in the feasible region defined by the operator.

3. Control problems in the process of oil production.

The greatest "strategic" effect in the management of field development, expressed in maximizing the final recovery factor with the scheduled time limit of field exploitation, is achieved by the simultaneous consideration of the whole production chain: the tank - well - fishing resettlement process systems [1]. In the case of such a complex problem solving APC technologies play a role in maintaining the prescribed limits calculated in the scope of solving the general problem of optimal field development, operation sequences of technological units of commercial systems for the collection and initial preparation of oil and gas and / or individual installations. As mentioned in the previous section, with a certain freedom in the value of the parameters the APC means can also address the problem of optimization of the plant on local criteria. Here we consider the solution of control problems in the "narrow" sense, i.e. discuss issues effectively solved by the APC, in the assumption that the restrictions on regulated processes are known and are set by the operator. It should also be noted that some of the APC applications described below are not limited to the capabilities of RPMST technology.

The standard process for offshore oil platforms are the processes of separation of water and oil (gas) mixture, gas treatment and compression. Gas is used for re-injection into the reservoir, domestic use and, sometimes, in accordance with the technical development of the field, for gas lift. Oil after primary treatment (dewatering and degassing) is transported to shore, where it undergoes further processing in industrial installations according to prescribed technological workflow. Water after preliminary treatment is discharged or injected back into the reservoir.

The APC tools can improve workflow for two main factors:

- Reduce downtime during production;
- Operation of equipment near the allowable limits of performance. The importance of control in this area increases as the reservoir pressure decline: reducing operating pressures in the hydraulic network within technological limits becomes the main goal of control.

A special place is occupied by gas lift system management tasks, where APC optimize the process in order to reduce costs.

An example of management tasks efficiently solved by means of APC, is the situation with the flow of produced fluids, caused by pressure drops in the entire hydraulic network from the well bottom to the tank farm, which often leads to a change in flow regimes of gas-liquid mixture (e.g., in the area where the horizontal line from the subsea well go into the vertical (riser) when approaching the platform.). APC tools allows execution devices (valves, throttles, flaps, etc.) to react more quickly and appropriately to changes in portion sizes of oil, gas caps and fluctuations in flow rate, allowing the separators to maintain the operating mode for longer periods..

Other examples of multiple control with forecast:

- Controlling the chain of compressors and separators (high, medium and low pressure) for the coordination of operating modes to reduce pressure on the inputs, which ultimately leads to a decrease in pressure on the wellhead and, therefore, increases their production rates.
- A perfect illustration of the effectiveness of APC is gas lift control. Using the APC to control compressors and / or turbines can produce the planned daily volume of oil at lower volumes of injected gas or increase production when injecting the planned volume. The proposed solution depends on the choice of the objective function of the optimization problem.
- Control of pressure and temperature in the separation plants and compressors to optimize the yield of the liquid phase, according to the planned targets and specifications of the primary oil and gas treatment.
- APC means can smooth the transition processes in data acquisition and initial preparation with scheduled or triggered by external conditions changes in operating modes of processing plants.

4. Conclusion

Technological processes of offshore oil are an ideal candidate for the use of APC. The economic effect is achieved quickly and without major capital expenditures. The economic effect is based on the optimization of the equipment's performance and on the stabilization of the technological process.

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METHOD OF THE ERRORS CONTROL FOR OPTIMIZATION OF LEARNING OF NEURONETWORKING SYSTEM OF NON-STATIONARY INFORMATION PROCESSING

O.I. Djumanov, S.M. Xolmonov

15, University blvd., 140104, Samarkand State University
Samarkand, Uzbekistan, Phone: +998663732155, e-mail: s-xolmonov@mail.ru

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1. Introduction

For today the problem of construction the systems for adaptive processing of continuous data is actual, especial, at the decisions of tasks visualization and recognition of microobjects images or manufacture parameters diagrams, tasks of analysis and forecasting, approximation of casual processes etc., where it is required the development of methods, algorithms and intellectualization tools for study the objects with various nature and it is required combination of opportunities of present methods which processes the digital information and signals [1]. As the perspective technology of construction the systems for adaptive processing of continuous data it is possible to represents the use of Data Mining concepts and methods, in particular, mathematical apparatus of artificial neural networks (NN), which successfully used now in artificial intelligence systems, at recognition and classification of images, approximation of multi-variable functions, and also for forecasting, optimization and management [2].

It is necessary to note, that for today there are some approaches to building of the continuous information processing systems. In one of directions the base principles are the ways of use of computer and information technologies, which allow to automate processes of information processing on the basis of mathematical statistics methods, calculation of statistical and dynamic characteristics of the information, for example, average value, dispersion, coefficients of correlation, variations of random variable etc. Moreover, the application of mathematical statistic models is based on the complete task of priory information about investigated processes, and it is not always feasible in practice because of limitation and non-stationarity of data, introduced for processing.

In this connection, in the present job for elimination of the noted lacks, for addition of the usual theoretical rules, for optimization of learning, and also for improvement of quality of an output in neuronetworking system for adaptive processing of a non-stationary data we devised the approach, method and algorithm which allow to reduce the errors of the information control.

2. Learning of neuronetworking system of data processing

The neuronetworking system of non-stationary data adaptive processing is represented to research as multioutput nonlinear converter with adaptive weighing of input signals. It is considered, that all neurons of network are connected among themselves by synapsical connections in the certain architecture. In model $x_1, x_2,..., x_n$ are input signals; $w_{j1}, w_{j2},.., w_{jn}$ are adjusted synaptical weights of j-th networks neuron; θ_j is the signal of displacement; $\sigma(\cdot)$ is sigmoidal function of activation; γ_j is the parameter, specifying "steepness," of activation function; Γ_j is the factor of strengthening defining the maximal and minimal values of target signal [3].

The output NN signal we represent as

$$y_i = \Gamma_j \sigma(\gamma_j w_j^T x_j),$$

where $w_j = (\theta_j, w_{j1}, w_{j2},..., w_{jn})^T$ are the weights of input vector; $\bar{x} = (1, x_1, x_2,..., x_n)^T$ is input identity vector.

Target NN signal, consisting of neurons we wrote down as function

$$y_i = \sum_{j=1}^{N} \Gamma_j \sigma(\gamma_j w_j^T x_j),$$

which approximates continuous function $f(x)$, providing an affinity condition $|y - f(x)| < \varepsilon$ for all probable inputs $x_j \in \{x_j\}$.

Further, for getting the results of analytical researches we used three-layered NN, which allows more evidently to look through process of time series approximation and on the other hand it allows to build more transparent algorithm of learning, to get qualitative output of network at testing the solutions of tasks of pollen grain visualization and image recognition, analysis and forecasting of time series.

The NN learning algorithm essence consists in adjustment of scale vector w_j, $j = 1,2,..., N$, with the help of a delta - rule. For their description we have taken advantage of a recurrent equation

$$w_{ji}(k+1) = w_{ji}(k) + \eta(k)\frac{\partial E_j(k)}{\partial w_{ji}(k)} \tag{1}$$

Here k is the current discrete time, $\eta(k)$ - is the parameter determining learning process speed, $E_j(k)$ is the local criterion of learning quality (error) calculated on expression

$$E_j(k) = \frac{1}{2} e_j^2(k),$$

where $e_j^2(k) = (d_j(k) - \sigma(\gamma_j u_j(k)))^2$; $d_j(k)$ - is designation of error at learning subset formation during control of non-stationary information; $\sigma_{out}(\gamma_j u_j(k))$ - is designation of a total neuronetworking transformation error; $u_j(k)$ - is output of NN nonlinear converter.

In this case the extreme value of function $E_j(k)$ is represented as the superposition of three components, i.e.

$$\frac{\partial E_j(k)}{\partial w_{ji}(k)} = \frac{\partial E_j(k)}{\partial e_j(k)} \cdot \frac{\partial e_j(k)}{\partial u_j(k)} \cdot \frac{\partial u_j(k)}{\partial w_{ji}(k)}.$$

Now the equality (1) is rewritten as

$$w_{ji}(k+1) = w_{ji}(k) + \eta(k) e_j(k) \frac{\partial \sigma(\gamma_j u_j(k))}{\partial u_j(k)} x_i(k) = w_{ji}(k) + \eta(k)\delta_j(k) x_i(k) \quad (2)$$

where $\delta_j(k) = e_j(k) \dfrac{\partial \sigma(\gamma_j u_j(k))}{\partial u_j(k)}$ is local learning error.

The adaptation of activation function in NN converter is carried out on the basis of

$$\gamma_j(k+1) = \gamma_j(k) + \eta(k) \frac{\partial E_j(k)}{\partial \gamma_j(k)} = \gamma_j(k) + \eta(k) e_j(k) \frac{\partial \sigma(\gamma_j(k) u_j(k))}{\partial \gamma_i(k)}. \quad (3)$$

The adaptation rules of weight coefficients and activation functions are made on the basis of association (2) and (3), i.e.

$$\begin{cases} w_{ji}(k+1) = w_{ji}(k) + \eta(k) e_j(k) \left(\sum_{l=0}^{L} (2l+1)(\gamma_j(k) u_j(k))^{2l} \varphi_j \gamma_j(k) \right) x_i(k), \\ \gamma_j(k+1) = \gamma_j(k) + \eta(k) e_j(k) \left(\sum_{l=0}^{L} (2l+1)(\gamma_j(k) u_j(k))^{2l} \varphi_j \gamma_j(k) \right) x_i(k). \end{cases} \quad (4)$$

Thus, the accepted learning process adaptation procedures allow to carry out parallel adjustment of neurons parameters, owing to what the calculation time reduces on each step of whole NN learning and adjustment time decreases.

Note, that the important moment at estimation of NN output quality and learning optimization parameters is the devising of estimation technique $\sigma_{out}(\gamma_j u_j(k))$ which is the total neuronetworking transformation error in view of each NN components error.

3. Estimation of mean-squared deviation of NN's basic components error

The basic components of NN, in which functions of "branching points" are carried out: adders and converters – transmit signals to NN output with some own errors, having formed a general error (accuracy of control) of target parameter, and consequently bring in the share to learning slope process [4].

Let's assume, that the own error ratings ε_{tv} of every NN components are given beforehand. It is required devising an estimation technique of the basic components errors influence on the target NN signals error on the basis of the mean-squared error control technique.

Let point of branching has own error ε_{tv} and mean-squared deviation of own error equally σ_{tv}. The own error ε_{tv} is added to each signal leaving a point of branching.

If at return distribution we get dispersion of branching point output signals $D_1, D_2, \ldots, D_k$ which are not equal among themselves, then as dispersion of branching point input signal, in view of own error, we must get

$$\min \{D_i\}_{i=1}^{k} - \sigma_{tv}^2. \quad (5)$$

For calculation of nonlinear converter mean-squared deviation we assumed, that mean-squared deviation of converter own error is equal σ_φ, and mean-squared deviation of converter output signal is equal σ_1. Then the own error of nonlinear converter can be added either to result of nonlinear converter $\varphi(A+\varepsilon)+\varepsilon_\varphi$, or to input signal of nonlinear converter $\varphi(A+\varepsilon+\varepsilon_\varphi)$. We researched both variants.

Let error ε_φ is added to result of nonlinear converter. We have dispersion

$$D(\varphi(A+\varepsilon)+\varepsilon_\varphi) = D(\varphi(A+\varepsilon)) + D(\varepsilon_\varphi) = \sigma_{own}^2 + \sigma_\varphi^2 = \sigma_1^2. \quad (6)$$

Thence, dispersion of nonlinear converter output signal is equal

$$\sigma_{own}^2 = \sigma_1^2 - \sigma_\varphi^2 . \tag{7}$$

Mean-squared deviation for nonlinear converter input signal is calculated as mentioned above.

As dispersion of output signal in the formula (6) calculated dispersion (7) is used. Mean-squared deviation of error for nonlinear converter input signal is equaled

$$\sigma = \sigma_{own} / |\varphi'(A)| .$$

Let now own error of the nonlinear converter is added to its input signal: $\varphi(A + \varepsilon + \varepsilon_\varphi)$. In this case error of input signal has expected value

$$M_{\varepsilon+\varepsilon_\varphi} \approx \int_{-\infty}^{\infty} (\varepsilon + \varepsilon_\varphi) \cdot \rho_\varepsilon d(\varepsilon + \varepsilon_\varphi) = 0$$

and dispersion

$$D_{\varepsilon+\varepsilon_\varphi} \approx \int_{-\infty}^{\infty} (\varepsilon + \varepsilon_\varphi - M_{\varepsilon+\varepsilon_\varphi})^2 \rho_\varepsilon d(\varepsilon + \varepsilon_\varphi) = \sigma^2 + \sigma_\varphi^2 .$$

We calculated expected value and dispersion of nonlinear converter output signal, using linear approximation $\varphi(A + \varepsilon + \varepsilon_\varphi)$:

$$M_{\varphi(A+\varepsilon+\varepsilon_\varphi)} \approx \int_{-\infty}^{\infty} (\varphi(A) + \varphi'(A) \cdot (\varepsilon + \varepsilon_\varphi)) \cdot \rho_\varepsilon d(\varepsilon + \varepsilon_\varphi) = \varphi(A),$$

$$\sigma_1^2 = D_{\varphi(A+\varepsilon+\varepsilon_\varphi)} \approx \int_{-\infty}^{\infty} (\varphi(A) + \varphi'(A) \cdot (\varepsilon + \varepsilon_\varphi) - \varphi(A))^2 \rho_\varepsilon d(\varepsilon + \varepsilon_\varphi) = \varphi'(A)^2 (\sigma^2 + \sigma_\varphi^2)$$

Thence we get $(\sigma^2 + \sigma_\varphi^2) = \sigma_1^2 / \varphi'(A)^2$, i.e..

$$\sigma = \sqrt{\sigma_1^2 / \varphi'(A)^2 - \sigma_\varphi^2} \quad \text{and} \quad \sigma = \min \{B_i\}_{i=1}^{k} - \sigma_{tv}^2 \tag{8}$$

The next stage of researches is calculation of adder input signals mean-squared deviations. Let a mean-squared deviation of adder output signal be equal σ, and own mean-squared deviation of the adder error be equal σ_Σ.

The own error of adder can be added either to output signal of adder - $\sum_{i=1}^{n} \alpha_i \cdot (x_i + \varepsilon_i) + \varepsilon_\Sigma$, or to each input of adder - $\sum_{i=1}^{n} \alpha_i \cdot (x_i + \varepsilon_i + \varepsilon_\Sigma^i)$, where $\varepsilon_\Sigma^i = \varepsilon_\Sigma / n$

Assuming that own error is added to adder output signal we calculated mean-squared deviation of errors for input signals of adder considering dispersion

$$D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_i + \varepsilon_\Sigma) + \sigma^2 .$$

To uniform distribution of mean-squared deviations, accepting that all σ_i are equal among themselves we get

$$D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_i + \varepsilon_\Sigma) = D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_i) + D(\varepsilon_\Sigma) = \sum_{i=1}^{n} \alpha_i^2 \cdot \sigma_i^2 + \sigma_\Sigma^2 , \text{ i.e. } \sigma_i = \sqrt{\frac{\sigma^2 - \sigma_\Sigma^2}{\sum_{i=1}^{n} \alpha_i^2}} .$$

At proportional distribution of mean-squared deviations we get

$$\sigma^2 = D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_i + \varepsilon_\Sigma) = \sum_{i=1}^{n} \sigma_i^2 + \sigma_\Sigma^2 , \text{ i.e. } \sigma_i = \sqrt{\frac{\sigma^2 - \sigma_\Sigma^2}{n}}$$

In case when own mean-squared deviation is added to each input of adder:

$$\sum_{i=1}^{n} \alpha_i \cdot (x_i + \varepsilon_i + \varepsilon_{\Sigma}^{i})$$

we calculated mean-squared deviation of errors for input signals of adder, considering dispersion

$$D(\sum_{i=1}^{n} \alpha_i \cdot (\varepsilon_i + \varepsilon_{\Sigma}^{i})) = \sigma^2 .$$

To uniform distribution of mean-squared deviations, accepting that all σ_i are equal among themselves we get

$$D(\sum_{i=1}^{n} \alpha_i \cdot (\varepsilon_i + \varepsilon_{\Sigma}^{i})) = D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_i) + D(\sum_{i=1}^{n} \alpha_i \cdot \varepsilon_{\Sigma}^{i}) = \sum_{i=1}^{n} \alpha_i^2 \cdot \sigma_i^2 + \sum_{i=1}^{n} \alpha_i^2 \cdot \left(\sigma_{\Sigma}^{i}\right)^2,$$

Thence

$$\sigma_i = \sqrt{\frac{\sigma^2 - (\sigma_{\Sigma}^{i})^2 \cdot \sum_{i=1}^{n} \alpha_i^2}{\sum_{i=1}^{n} \alpha_i^2}}$$

At proportional distribution of adder input signals mean-squared deviations we get

$$\sigma^2 = D(\sum_{i=1}^{n} \alpha_i \cdot (\varepsilon_i + \varepsilon_{\Sigma}^{i})) = \sum_{i=1}^{n} \sigma_i^2 + \sum_{i=1}^{n} \alpha_i^2 \cdot \left(\sigma_{\Sigma}^{i}\right)^2,$$

$$\sigma_i = \sqrt{\frac{\sigma^2 - (\sigma_{\Sigma}^{i})^2 \cdot \sum_{i=1}^{n} \alpha_i^2}{n}} . \qquad (9)$$

4. Definition of mean-squared error deviation at the control of NN output

The getting formulas to calculate the mean-squared deviations of each neuron component errors allow to calculate mean-squared deviation of output signals errors for whole NN by the following principle.

If mean-squared deviation of errors are given for network output signals, it is possible to calculate mean-squared deviation of errors for last network layer inputs. After calculation mean-squared deviations of all input signals errors at last layer, we can calculate mean-squared deviation of errors at next to the last layer and so on.

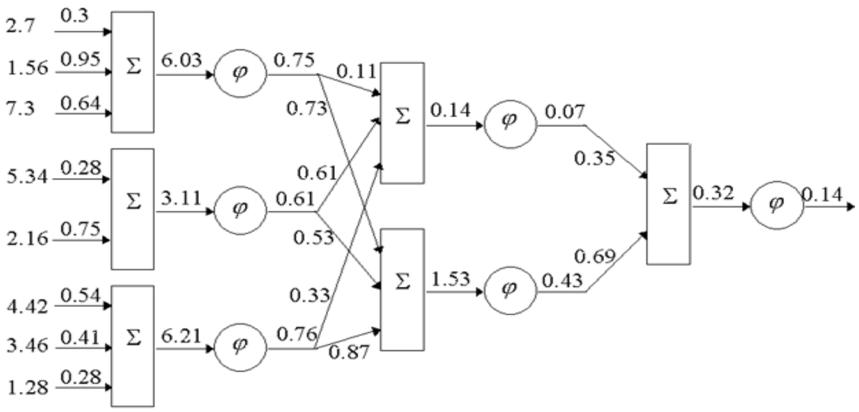

Fig. 1. ***Model of signal passage on the basic NN components.***

For simplification and more demonstrativity of the NN output signal error calculation technique we considered example, typical for researched applied problems. As example we considered NN with three neurons of input layer, two neurons of hidden layer and one output neuron.

On figure 1 the model of signal passage on NN is illustrated for case when vector of input signals and weight relationships are given beforehand. The characteristic function of nonlinear converters is $\varphi(x) = x/(2+|x|)$, where x is input signal of nonlinear converter. Mean-squared deviation of network output signals vector σ_{out} is equaled 0,01. Mean-squared deviation of errors on adder inputs was calculated with use of formula to uniform distribution of mean-squared deviations.

Calculating the mean-squared deviations for all network signals at the given input signals vector were carried out under the following formulas: the values $\sigma_1, \sigma_4, \sigma_5, \sigma_{11}, \sigma_{13}$ were calculated under the formula (8), the values $\sigma_8, \sigma_9, \sigma_{10}$ were calculated under (5), the values $\sigma_2, \sigma_3, \sigma_6, \sigma_7, \sigma_{14}, \sigma_{15}, \sigma_{16}$ were calculated under (9). All calculated values in this example are round up to two marks after point.

$$\sigma_1 = \frac{\sigma_{out}}{|\varphi'(A)|} = \frac{0.01}{2/(2+0/32)^2} = 0.03;$$

$$\sigma_2 = \sigma_3 = \frac{0.03}{0.35^2 + 0.69^2} = \frac{0.03}{0.77} = 0.04;$$

$$\sigma_4 = \frac{0.04}{2/(2+0.14)^2} = \frac{0.04}{0.44} = 0.08;$$

$$\sigma_5 = \frac{0.04}{2/(2+1.53)^2} = \frac{0.04}{0.16} = 0.23;$$

$$\sigma_6 = \frac{0.08}{0.11^2 + 0.61^2 + 0.38^2} = \frac{0.08}{0.7} = 0.11;$$

$$\sigma_7 = \frac{0.23}{0.73^2 + 0.53^2 + 0.87^2} = \frac{0.23}{1.25} = 0.18;$$

$$\sigma_8 = \sigma_9 = \sigma_{10} = \min\{\sigma_6, \sigma_7\} = 0.11;$$

$$\sigma_{11} = \frac{0.11}{2/(2+6.03)^2} = \frac{0.11}{0.031} = 3.55;$$

$$\sigma_{12} = \frac{0.11}{2/(2+3.11)^2} = \frac{0.11}{0.08} = 1.43;$$

$$\sigma_{13} = \frac{0.11}{2/(2+6.21)^2} = \frac{0.11}{0.03} = 3.67;$$

$$\sigma_{14} = \frac{3.55}{0.3^2 + 0.95^2 + 0.64^2} = \frac{3.55}{1.49} = 2.38;$$

$$\sigma_{15} = \frac{1.43}{0.28^2 + 0.75^2} = \frac{1.43}{0.8} = 1.79;$$

$$\sigma_{16} = \frac{3.67}{0.54^2 + 0.41^2 + 0.28^2} = \frac{3.67}{0.73} = 5.03.$$

Thus, developed technique to calculate the total mean-squared deviation error on NN output approves on the basis of the received formulas and by calculation the rational parameters on the basis of Backpropagation learning algorithm. It is established, that the NN components errors are increased, beginning from the given NN output error while inverse progress on all branching points, and by that reflect a nature of components errors appearance. Hence, it is reasonable to use as optimum borders for threshold control and error decrease the found mean-squared deviation when we want to introduce procedures of the errors control to minimize them in each of NN components. That, in turn, optimized learning of information adaptive processing neuronetworking system.

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TRAINING COMPLEX FOR MODELING AND MANAGEMENT OF TECHNOLOGICAL OBJECTS IN OIL AND GAS INDUSTRY

O.Y. Pershin [1], F.T. Adilov [2]

[1] ZAO Honeywell, 121059, Russia, Moscow, Kiev str. 7
Phone: +7(495)796 98 98, e-mail: oleg.pershin@honeywell.com,

[2] Himavtomatika LLC, 100000, Uzbekistan,Tashkent, Niyozbek yuli,1
Phone:+99871-150-1966, e-mail: farukh.adilov@himavtomatika.uz

1. Introduction

One of the most promising and important trends to improve the quality and safety of technological objects is to use the tools to simulate technological processes and control systems on a computer before entering the actual production facility. Here, we solve two main problems: training of the staff and selection of efficient operating practices.

Currently, there are different software and hardware means for the computer simulation of technological objects, the choice of technological modes and configuration of control loops. The main content of this paper is a description of a universal software package that provides a single chain through the implementation of the control process, which includes all of the above aspects: mathematical modeling of technological object, synthesis and tuning of control loops, stabilization and optimization of the process. The presence of such a complex allows both to work with individual modules listed above, and, most interestingly, to build and to see their interaction to achieve the ultimate goal of control: selection and maintenance of stable effective mode of operation for processing facility. On the basis of such a universal complex it is possible to hold practical classes as part of the educational process in several areas: process modeling, synthesis and tuning of control loops, the selection and maintenance of stable optimum operation settings.

The described complex is implemented in Gubkin State Oil and Gas University by a group of staff members and students with the help of experts of the Moscow office of Honeywell based on generally accepted in the world market products of Honeywell corporation, widely represented in the oil and gas industry in Russia. The use of the complex as the product of the individual modules of one firm guarantees their compatibility, in particular, uniform interface. Next, the paper gives a brief explanation of the features of the main modules listed below:

- UniSim – the set of programs for the static and dynamic process simulation;
- Experion PKS –distributed control system (DCS) by Honeywell;
- Profit Suite for APC – software package for managing multiply connected objects with forecast of controlled object’s reaction to control signal based on constructing a mathematical model of the object

and presents a schematic diagram of their joint use as a single complex.

2. Simulation module

UniSim Suite by Honeywell is used as a simulation module for technological objects and processes. The package allows you to simulate the processes of production and field oil and gas, as well as the processes of refining and petrochemicals. This package allows you to create static and dynamic model of technological objects and analyze their performance in the given operating conditions. Using this module allows you to perform the following tasks:

- build static and dynamic models of technological processes on the basis of model libraries, process facilities, customized to meet the specified operating conditions and the mathematical equations that describe the physical processes;
- play various "what - if" scenarios of the process, according to the different production purposes and conditions, selecting the most effective modes of operation, to assess the effects of changing raw material, stopping or changing the mode of the equipment in normal and abnormal situations;
- checking equipment’s real work characteristics against the characteristics listed in the specification;

- adjust production tasks in accordance with the capability of the equipment.

Basic structure of the package is shown in the table 1

Table 1

UniSim Suite Operator interface and technological platform (UniSim Platform)			
Modeling means UniSim Design		Control means Controls Environment	
The library of processes, technological objects and physical dependencies	Pluggable interfaces and third-party products	Automation equipment from main producers: Honeywell, Invensys, Emerson etc.	Tools

UniSim Platform provides a modular, configurable, and scalable architecture that allows extending the modeling environment with increase of the number of models and workstations.

3. DCS Module

As the control unit in the complex uses the latest distributed control system by Honeywell– DCS Experion PKS.

The basic structure of DCS Experion PKS is shown on Figure.1.

*Figure 1. **The basic structure of DSC Experion PKS.***

The main features of the system:

- Wide scalability, in which several separate Experion PKS systems work as a complex, providing direct access from any workstation to any controller and historical data of any system.
- Integration of all data of the various means of information gathering in a single database Uniformance from Honeywell, which allows a one-time entry of information from any source and it’s use by different users at different levels of control.
- Direct access to all information developed by the system through the Internet / Intranet.
- Transparency of the system, which is provided using industrial interface OPC (OPC client and OPC server), generic connection with a relational database - SQL and driver ODBC, all the standard software interfaces and Microsoft standards of building software, including COM / DCOM, OLE , ActiveX; usage as part of the system of most common, standardized information, industrial and field networks, the presence of drivers to technology of the world's leading manufacturers of automation products.

- Continuity of the technical solutions of the previous automation systems by Honeywell (TDS 2000, TDS 3000, TRS, PlantScape) and implementation of direct communication and integration with existing systems and controllers manufactured by Honeywell.

You can find the description of DCS Experion PKS in [2].

4. Multiple control and optimization module

This module uses tools known in English literature as Advanced Process Control (APC). In Russian terminology, with reasonable proximity, these tools can be defined as a method of multiple regulation and optimal control with a forecast of object's reaction to the signal based on constructing a model of the object.

The complex uses Honeywell's software package Profit Suite ® for Advanced Control & Optimization, which implements patented Robust Multivariable Predictive Control Technology (RPMST). By now in Russia this package products have an established reputation in the oil refining, allowing the increase in efficiency and reliability of the process units. The discussion about using APC tools to control offshore platforms can be found in [1].

The main purpose of APC is to find the most effective mode of operation for the technological object and maintain this mode [2].

The functions of APC:

- Control of the object in normal mode as well as when changing production tasks.
- Optimization of object's or group of objects performance according to economical criteria.

Basically, the control process is described as follows.

There are three types of variables representing physical characteristics of the technological process:

- *Controlled Variables* (*CVs*) – these are observed variables, which during the implementation of the technological process should take values within specified limits. Within the allowable control area, defined by these limits, the variables can be optimized for a given criteria of process efficiency.
- *Manipulated* or *control Variables* (*MVs*) – these are the variables that are manipulated to keep the CVs within the feasible region when the process conditions change and / or set the optimal values of the controlled variables in optimization. The MVs permissible regulation limits for a controller are set by the operator.
- *Disturbance Variables* (*DVs*) – these are measurable variables that are not regulated in the control process, but will affect the values of the controlled variables. When configuring the controller the algorithms that predict the effect of DVs impact on CVs trajectory are set, this allows us to take steps to prevent interference in control process.

When you configure the controller the model of process in the form of matrix of connections between the variables (influence matrix) is built. Next, the model is adjusted online in the control process.

The main feature of the proposed technology is the fact that some of the controlled variables cannot be measured on the real object because of the impossibility or difficulty of such measurements and are calculated by analytical modeling. These are so-called "virtual sensors”

Currently, a commercial product - Profit Suite is a family of products designed to set up and operate an APC system in various technological objects. In particular it includes such packages as Profit Max a special development for non-linear processes, allowing us to linearize the process near the operating point and calculate the input data for linear regulators Profit Controller и Profit Optimizer. Profit Optimizer calculates in real time based on linear models the optimal consistent values of the controlled variables for units involved in the process. Profit Controller is a basic element of APC application that implements a multiple control of the unit, giving control actions on MVs variables, for example, when defining setpoints for PID controllers. Currently, the autonomous Profit Controller is widely used for multiple control of a separate unit to retain the values of the controlled variables in the feasible region defined by the operator.

4. The structure of the integrated training complex

The purpose of the work - to create on the basis of the above mentioned products by Honeywell a single complex, which combines the functions of a computer simulation of the process, the design and configuration of automation and process control systems, based on the latest generation of distributed control system with the use of advanced control (APC) to select and maintain optimum operating modes for process plants. The system is designed for students and training and retraining of specialists in the oil and gas industry.

Integrated complex of modeling and control is built on the basis of four modules, as shown in Figure 2

Figure 2. ***The basic structure of the complex.***

Here:

- UniSim Design – is a described above powerful emulator of technological processes in static and dynamic modes, which allows to synthesize a set of technological units with means of automation and their work in real time.
- ExpPKS – latest generation DCS Experion PKS by Honeywell with a wide variety of utilities (control, safety, diagnostics, reporting etc.)
- UniSim Operation implements a computing environment which allows DCS Experion PKS to cooperate in real time with models produced by UniSim Design.
- APC (Advanced Process Control) – described above software package Profit Suite that implements multiple control and optimization of technological units performance based on constructing of the mathematical models of technological processes with forecast of object’s reaction to control signal.

Working with the complex offers the following integrated features for the student or researcher of the process: modeling the process of automation, control settings, manage real-time process with the implementation of the different modes, depending on the input conditions and ambient conditions, process optimization with a choice of operating points and their maintenance by the means of APC.

5. Conclusion

Based on the integrated training complex learning spaces can be created for engineers and operators and engineers in the automation process. As part of work on the use of the complex in the learning process it is expected to expand the library of models of oil and gas industry and the development of training materials for the training of students and professionals enrolled in refresher courses.

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THE SYSTEM OF TRANSMITTED TEXT INFORMATION ON THE BASIS OF IDENTIFICATION OF GENETIC ALGORITHMS

I.I. Jumanov, S.A. Tishlikov

Department of Information Technologies, Samarkand State University
Samarkand, 15, University blvd., 140104, Uzbekistan,
Phone: +998662206881, e-mail: akmalar@rambler.ru, a-axatov@samdu.uz

Keywords: *authenticity, textual information, units of data input, mistakes of data transfer, checking, text element image, neural network, fuzzy set, fuzzy rule, data base, knowledge base, function of membership.*

1. Introduction

The key tasks in the design of interactive systems for monitoring the authenticity of transfer and processing of the text elements images, intended for detection and correction of mistakes in the electronic documents are the identification and approximation of dynamic characteristics of signals and of nonlinear dependences "inputs-output" in conditions of the incomplete information. Moreover, efficient approximator of multidimensional nonlinear functions is carried out by the synthesis of fuzzy logic and neural networks (NN) models [1,2]. However, the synthesis of neuro-fuzzy systems (NFS) brings to difficulties such as the large dimension of the fuzzy model parameters vector and of feature search space, the difficulty of the mathematical description and presentation of the text elements images, the extremity of aim function of NSC learning error, complete dependence of identification function of signal characteristics on size of the training sample, which is changing with each new tact transmission of information.

Development of methods for monitoring of authenticity of transmitted text information based on the approaches to create the new methods and algorithms for adaptive data processing by the synthesis of NN learning and fuzzy logic models, models of approximation and recognition, algorithms of monitoring based on the use of dynamic characteristics of the image signals and ways of optimize and parallel processing of information. Moreover, the realization of these approaches involve the use of concepts and properties of the learning in recognition, self-regulatory and self-organization of NN [3,4].

In this paper the authors state results of designing the methods and algorithms of NFS which control the authenticity of text element images transfer and processing, constructed on the basis of synthesis of fuzzy rules and adaptive models of fuzzy logic inference.

2. Designing of fuzzy logic inference model

To assess the quality of the text element image we suggest to use the fuzzy model with aim function:

$$\Phi(P) = \frac{1}{n}\sum_{j=1}^{n}[F(X_j, P) - y_j]^2 \Rightarrow \min_P \, , \qquad (1)$$

which minimizes mean-squared deviation between actual value of output y_j and value, received on the basis of fuzzy approximation and dot rating by $F(X_j, P)$. The vector P represents a vector of fuzzy model parameters for logic inference.

As a basic model of fuzzy logic inference is proposed to use the Takagi-Sugeno first-order model with the rules of the form:

$$\Pi_i : \text{IF } x_1 \text{ is } A_{i1} \text{ and } \dots \text{and } x_j \text{ is } A_{ij} \text{ and } \dots \text{and } x_m \text{ is } A_i$$

Then $y = k_{i1}x_1 + ... + k_{ij}x_j + ... + k_{im}x_m + k_{i0}$, $\qquad i = 1,..., n$,

where A_i are the fuzzy sets and matching membership function (MF), constructed in space of input data x_i; k_{ij} $(j = 0,..., m)$ are the coefficient of function arguments.

For accepted model is typically to use of Gauss membership function

$$\mu(x) = \exp\left[-\left(\frac{x-c}{\sigma}\right)^2\right], \tag{2}$$

where c is the centre of fuzzy set; σ is a steepness of function.

We assume that when you configure the NFS, it's used the signal characteristics of the text element image from the database (DB) and the knowledge base (KB), which represent collection of information and sets of linguistic variables, corresponding MF, set of fuzzy inference rules.

Let's present model of adaptive NFS as a train:

$$A = \langle \{X_i, y_i\},\ BR,\ DB,\ I,\ G(BR),\ L(DB),\ F \rangle,$$

where $\{X_i y_i\}$, $(i = \overline{1,n})$ is a training sample; BR is base of rules; DB is database; I is a mechanism of fuzzy inference; $G(BR)$ is generation and optimization of BR; $L(DB)$ is generation and optimization of DB (parameters of MF); F is function estimating efficiency of fuzzy model.

Refinement of NFS model is made by solutions of structural identification of fuzzy rules, search for a rational set of terms of linguistic variables, rules of inference and determine the coefficients of the fuzzy rules.

3. Structural identification of rule of fuzzy logic inference

To form the fuzzy knowledge base is provided a method, which is a consistent procedure for the identification of observations results on the training set. Stated NFS has ergonomic character and effectiveness of decisions largely depends on energy of human-expert in making decisions about the accuracy of information. However, in real conditions is required to carry out the correction of errors at a distance and with constraints on time of transmission and processing.

We offer variant of automated solution-making process based of synthesis of models, rules and properties of genetic self-organizing systems for the operative control and correction of mistakes on the basis of NFS [5].

Note that in traditional systems of spell-checking main point is to form a training set for visual detection and correction of errors in the texts.

In the studied interactive system the text elements are presented as images signals. It is believed that a training set has the genetic of natural language, represented by statistical, correlation and linguistic characteristics of texts.

Controlled signals of the text elements are exposed to distortions by various reasons, characterized by different degrees of error, and it reflects the penetration of foreign objects into the body. The system, based on existing sets of antibodies (n-programmatic model) generates antigenic system - rules, models, algorithms for fuzzy control of text elements image signal to detect and correct errors. Hence, the antigen system for mistakes checking and correction based on the NFS is synthesized by algorithms which performance the statistics of multiple errors, generate the encoding rules, find and correct the mistakes on the basis of n-gram models and on the dictionary of word forms.

Now, let us state basic moments of algorithms for automated expert control of authenticity of the textual information.

Let's designate examples of training sample through word-forms, submitted for parsing based coding and recognition as n-grams. During processing such objects we can show evidently the use of properties of self-regulation and network organization of NFS.

It is considered, that everyone monogram codes one rule of KB. The quantity of rules for formation word-forms in KB corresponds to quantity of examples in training sample.

The rules of NB are coded by real quantity representing an index fuzzy input data sets and coefficient of fuzzy rules, i.e.

$$Ab = < IFS_1, IFS_2, \ldots, IFS_n, k_0, k_1, \ldots, k_n >,$$

where $IFS_1, IFS_2, \ldots, IFS_n$ are indexes of fuzzy set for n input variables; $k_0, k_1, \ldots, k_n$ are coefficients of fuzzy rules.

We construct algorithm of formation most suitable n-gramm word-forms on the basis of set of fuzzy rules as in genetic algorithms:

$$R_1: \begin{array}{l} IF\ \ x_1\ is\ IFS_{11}\ \ ...AND...\ \ x_n\ \ is\ \ IFS_{1n}\ \ THEN \\ y = k_{10} + k_{11}x_1 + ... + k_{1n}x_n; \end{array}$$

$$R_2: \begin{array}{l} IF\ \ x_1\ is\ IFS_{21}\ \ ...AND...\ \ x_n\ \ is\ \ IFS_{2n}\ \ THEN \\ y = k_{20} + k_{21}x_1 + ... + k_{2n}x_n; \end{array}$$

$$\dots$$

$$R_q: \begin{array}{l} IF\ \ x_1\ is\ IFS_{q1}\ \ ...AND...\ \ x_n\ \ is\ \ IFS_{qn}\ \ THEN \\ y = k_{q0} + k_{q1}x_1 + ... + k_{qn}x_n. \end{array}$$

Note, that the complete set of rules of algorithm with fuzzy logic inference for real tasks can be great enough, so for example, if for the description of supervision are used n variable, each of which has m of terms, than the top rating of number of rules is m^n.

At structural identification for each object the training sample is formed as

$$\left(x_1^{(k)}, x_2^{(k)}, \ldots, x_n^{(k)}, y^{(k)}\right), \qquad k = \overline{1, K},$$

where $x_1^{(k)}, x_2^{(k)}, \ldots, x_n^{(k)}, y^{(k)}$ are the value of input variable $x_1, x_2, \ldots, x_n$ and output variable y at k-th example; K is total number of examples in training sample.

The domain of input variable is divided into segments, on each of which is set of Gauss MF, and the minimal and maximal values of input variable are established.

Further at a stage of structural adaptation is formed *N* of sets of fuzzy rules.

The bases of inference rules are formed and on the basis of them the parametrical adaptation is carried out.

Now we present an algorithm of parametric identification, which is iteratively repeated the concrete number of times.

4. Algorithm of parametrical identification of fuzzy logic inference model

The purpose of parametrical identification is the search of such fuzzy model of NFS with set of parameters, for which the quality of identification will be best. The parametrical identification includes procedure of optimization of MF's parameters primary values, where MF is the change of terms parameters for all linguistic variable.

In a task of NFS parametrical identification the examples of NN's training sample are also submitted as n-grams; and for word-forms which is an input variable the MF are determined.

The word-form on a basis of n-gram represents a line with fixed length:

$$Ab = \left\langle c_{11}, ..., c_{1m},\ ...,\ c_{n1}, ..., c_{nm},\ \sigma_{11}, ..., \sigma_{m1},\ ...,\ \sigma_{n1}, ..., \sigma_{nm} \right\rangle,$$

where c_{ij}, σ_{ij}, $i = \overline{1, n}$; $j = \overline{1, m}$ are parameters of Gauss MF in a view (2) for n input variables, each of which has m terms. Each of MF is set in the range $X = [x_{\min}, x_{\max}]$, which is chosen as a closed interval of real numbers.

In a task of NFS learning everyone word-form is represented as

$$Ab = < c_{11}, ..., c_{1m}, ..., c_{n1}, ..., c_{nm}; \sigma_{11}, ..., \sigma_{1m}, ..., \sigma_{n1}, ... \sigma_{nm}; k_{10}, ..., k_{1n}, ..., k_{q0}, ..., k_{qn} >,$$

where $k_{i0}, \ldots, k_{in}$, $i = \overline{1, q}$ are coefficients of q fuzzy rules.

The developed algorithm of parametrical identification for fuzzy model of NFS which control the authenticity of transfer and processing of the text elements images synthesizes following procedures: formations of training sample; choice the MF for parameters taken from antibodies; generation of rules base; structural identification and performance the fuzzy inference; calculation of affinity for each antibody with all antigens from population according to (1); search of function (1) minimum in allowable set of change input variable x_i, $x_i^{\min} \le x_i \le x_i^{\max}$, $i = \overline{1,n}$.

As a result of algorithm the n-grams with best affinity are stored in memory for the further processing (mutation), and n-grams with the worse value of affinity are removed from set and replaced with new one. DB is formed on most suitable word-form.

The algorithm of MF formation for NFS on the basis of parametrical identification is represented by the following steps.

Step 1. Initialization of initial n-gram Ab and start cycle for word-forms Ab_i.

Step 2. In system of fuzzy inference with base of fuzzy rules received at a stage of structural adaptation, the parameters MF for Ab_i are substituted and affinity is calculated for n-gram from set of word-form Ag.

Step 3. Choice most suitable n-grams.

Step 4. Formation of word-forms set C.

Step 5. Updating of set C, formation of set C^*.

Step 6. Calculation of affinity set C^* to set Ag.

Step 7. Editing of word-forms set.

Step 8. Replacement d worse word-forms by new word-forms with n-grams models on a basis Ab.

Step 9. Check of stop criterion. If criterion do not reach then go to step 2, else go to step 4. The result is the word form with best affinity, which contains the parameters of MF.

5. Comparison of effectiveness of the developed algorithms

To evaluate an efficiency of the offered algorithms, experiments were conducted using test functions listed in table 1, where the function 1 is an unimodal and function 2 is multimodal.

Table 1

	Test function	The domain of function
1	$F_1(x_1, x_2) = x_1^2 + x_2^2$	$x_1,\ x_2 \in [-3,3]$
2	$F_2(x_1, x_2) = 3(1-x_1)^2 \exp(-x_1^2 - (x_2+1)^2) - -10\left(\frac{x_1}{5} - x_1^3 - x_2^5\right)\exp(-x_1^2 - x_2^2) - \frac{1}{3}\exp(-(x_1+1)^2 - x_2^2)$	$x_1,\ x_2 \in [-3,3]$

The training sample makes 121 examples. Each test function is restored on the data of training sample.

The initial values of MF parameters are installed so that the MF was evenly distributed throughout the domain of the function.

It is established that the algorithm of fuzzy logic inference requires significant temporary expenses for calculation, and it is connected to length of a line of optimized parameters submitted in an antibody. Thus, when for a linguistic estimation of input variable we used 3 terms, length of a line of an antibody makes 39 parameters, in case of 5 terms - 95 parameters, in case of 7 terms - 175 parameters.

At the same time, NFS which was built based on the synthesis of fuzzy logic inference models not only change the coefficients of the fuzzy rules, but they change the number of fuzzy inference rules too. If the algorithms of fuzzy logic inference quantity of rules for two input variables with five MF were 25 for both test functions 1&2, then for the synthesized algorithms of NFS number of rules is reduced to 19 for a test function 1, and up to 23 for test function 2. The synthesis of NFS algorithms can also achieve better results by simultaneously setting both the parameters of fuzzy rules and parameters of MF.

In Table 3 we compared the effectiveness of adaptive fuzzy inference systems with adaptive NFS by the criterion of mean-squared deviation for the test functions 1 and 2.

Table 2

Quantity of linguistic terms	Test function 1	Test function 2
System of fuzzy inference		
3	0,2	0,69
5	0,051	0,082
7	0,012	0,05
Fuzzy neural network		
3	0,27	0,501
5	0,035	0,057
7	0,024	0,047

Results from table 3 shows, that use of NFS allows to increase the accuracy of function restoration.

Thus, the solutions of problems show an opportunity of identification and approximating for the nonlinear dependence and dynamic characteristics of the text element images signal on the basis of NFS. The synthesized algorithms of structural and parametrical identification of objects are realized as adaptive NFS. Experimental studies were carried out on two test functions. The parameters of efficiency are established for using the NFS on the basis of synthesis of fuzzy logic inference algorithms and NN when it is necessary to identify and interpret the nonlinear dependences.

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TO THE ISSUE OF FORMING INFORMATION MODELS OF NATURAL-ANTHROPOGENIC OBJECTS ON THE BASES OF FUZZY-SET APPROACH

F.B.Abutaliyev, R.N. Usmanov, K.K. Seitnazarov

Tashkent, Uzbekistan, Tashkent University of Information Technologies
rishat.tuit@mail.ru

Abstract: *Principles and algorithms of projecting of information models of research object and subject are offered and matters of interrelation between hydrogeological object and its numbered model in process of computing experiments holding are regarded.*

Key words: *Complex objects, characteristics and parameters of object, fuzzy information, information models, membership functions*

Process of complex natural-anthropogenic objects modeling in dominance conditions of fuzzy information includes the following stages [1,2]:

– Problem situation analysis;

– Structuration of subject range and construction of fuzzy model of hydrogeological object and process;

– Holding of computing experiments (CE) with model;
– Use of CE results;
– Correction and completion of fuzzy model.

Analysis of problem situation, structure, characteristics and parameters of filtration range (FR) and process of geofiltration and range is made by means of their formalization on the bases of fuzzy sets theory (FST) principles, particularly, on the example of membership functions (MF) construction of fuzzy parameter К= $\tilde{K}$ (x,y), where x, y – point coordinates of filtration range (FR). For this trapezoidal fuzzy numbers $\tilde{K}$ defined with expression [1] are used:

$$\tilde{K} = \left(\underline{K}_0, \overline{K}_0, \underline{K}_1, \overline{K}_1\right) \tag{1}$$

where $\underline{K}_0$ $(\overline{K}_0)$ – lower (upper) bound of fuzzy number $\tilde{K}$ on zero $\alpha-$level; $\underline{K}_1$ $(\overline{K}_1)$ lower (upper) bound of fuzzy number $\tilde{K}$ on one $\alpha-$level; Interval $[\underline{K}_1, \overline{K}_1]$ is called optimistic estimation of K parameter, and interval $[\underline{K}_0, \overline{K}_0]$ is called pessimistic estimation of K value.

Analytically trapezoidal form of fuzzy number $\tilde{K}$ is expressed as:

$$\mu_{\tilde{K}}(K) = \begin{cases} 0 \quad , & K < \underline{K}_0 \\ \dfrac{K - \underline{K}_0}{\underline{K}_1 - \underline{K}_0} \quad , & \underline{K}_0 \le K < K_1 \\ 1 \quad , & K_1 \le K < \overline{K}_1 \\ \dfrac{\overline{K}_1 - K}{\overline{K}_0 - K_1} \quad , & \overline{K}_1 \le K \le \overline{K}_0 \\ 0 \quad , & K > \overline{K}_0 \end{cases} \tag{2}$$

The carrier of fuzzy number $\ddot{K}$ will be interval $[\underline{K}_0, \overline{K}_0]$, and core - $[\underline{K}_1, \overline{K}_1]$ Transition of fuzzy number from trapezoidal form $\tilde{K} = <\underline{K}_0, \overline{K}_0, \underline{K}_1, \overline{K}_1>$, to $\alpha-$level description, i.e. $\tilde{q} = \bigcup_{a \in [0,1]} [\underline{K}_a, \overline{K}_a]$ is made according to formulas:

$$\underline{K}_a = \underline{K}_0 + (\underline{K}_1 - \underline{K}_0)\alpha \tag{3}$$

$$\overline{K}_a = \overline{K}_0 - (\overline{K}_0 - \overline{K}_1) \tag{4}$$

l - form of indefinite K parameter is called triplet

$$K = (\underline{K}, \overline{K}, l) \tag{5}$$

where $\underline{K}$ $(\overline{K})$ - lower (upper) bound of K parameter change:

l - linguistic estimation of K parameter in diapason $[\underline{K}, \overline{K}]$, though $l \in L = \{l_1, l_2, ..., l_m\}$. L- linearly-ordered on principle from “least” to “greatest” set of linguistic terms. Further information model of FR is projected, main purpose of which is establishment interconnection between hydrogeological object and its numeric model, and also organization of computing experiments (CE) in order to parallel computing process and possibility provision of variety boundary conditions in process of numeric modeling.

Process of RF information model construction is done in following order [3,4]: SR → CM → IMFR → FIM FP → PMM

The following explanations are used here:

SR – subject range, hydrogeological object.

CM – conceptual model – knowledge base, reflecting specialist knowledge about hydrogeological object, its interconnections, main processes, factors represented in the form of graphics, tables, graphs and etc.

IMFR– information model of filtration range is for organization of computing process

FIM FP – fuzzy information model of filtration process.

PMM – productional mathematic model of object

On the first stage FR is replaced by net domain, further for each point information in five-digit number of integer type $i_1\, i_2\, i_3\, i_4\, i_5$ is prepared, and digit positions mean following information: i_1- information about boundaries, where i_1= 0 inner boundary, i_1= 1,2,3,- boundaries of 1,2 and 3rd types, prepared when $i_1>0$; $i_2\, i_3$ –information about underground hydrosphere nutrition (infiltration from channels, rivers), prepared when $i_2\, i_3>0$; $i_4\, i_5$- information about flow item of expenditures (recovery wells, drainage systems, drop-ins and etc.). All information, prepared this way is formed in two-dimensional array of integer type INF2.

Special interest from the viewpoint of decision strategy choice organization and realization of concrete technological schemes are algorithms IMFR and FIM FP. That is why, we will stop on these issues with more details.

Algorithm of decision strategy choice organization in process of numeric modling is represented as:

1. Beginning;
2. Input n, m – quantity of lines and columns;
3. Cycle on j = $\overline{1,n}$;
4. Cycle on $i=\overline{1,m}$;
5. Input of values inf 2[c, j];
6. inf [i] =inf 2[i, j] ;
7. Sorting procedure: in=0; in_1=0; in_2=0;
8. in =inf [i] ;
9. If in< 10000 then go to point 10, otherwise in = in-10000, in_1 = in_1+1; go to point 9;
10. If in < 100 then go to point 12;
11. in = in – 100; in_2+1 go to point 10;
12. in_3 =inf [i].

2. Construction of FIM FP is meant for fuzzy presentation of filtration process and medium parameters. For every point of net domain seven-digit number of integer type - $i_1\, i_2\, i_3\, i_4\, i_5\, i_6\, i_7$ is put, digit positions of which hold the following information:

i_1 – number of heterogeneity zone;

$i_2\, i_3$ – input of MF (triangular, trapezoidal);

$i_4\, i_5$ – total number of therms;

$i_6\, i_7$ – number of therm;

FIM FP is formed on the bases of following principle:

– filtration range is divided into zones of heterogeneity with highlighting of transitional zones;

– For each point of filtration range on the bases of expert information MF of medium parameters are projected;

– For each point of FR fuzzy values of filtration coefficient are defined.

FIM FP sorting algorithm:

1.Input of values n – number of columns and m – number of lines of net domain, ℓ_1 - total number of heterogeneity zones.

2.Input of boundaries values of filtration coefficients on zones: tl[i], tp[i], i = $\overline{1,\ell_1}$; tl, tp – arrays of left and right filtration coefficient values.

3.Input of FIM FP array values – inf 2t [i,j]: [($i=\overline{1,n}$), ($j=\overline{1,m}$)].

4. $in11=0; in12=0; \underline{in13}=0;\ in14=0;$

Cycle:

i = 1,n – outer;

j = 1,m – inner;

in = inf 2t [i,j];

5. Address to sorting procedure:

sort(in, in11, in12, in13, in14)

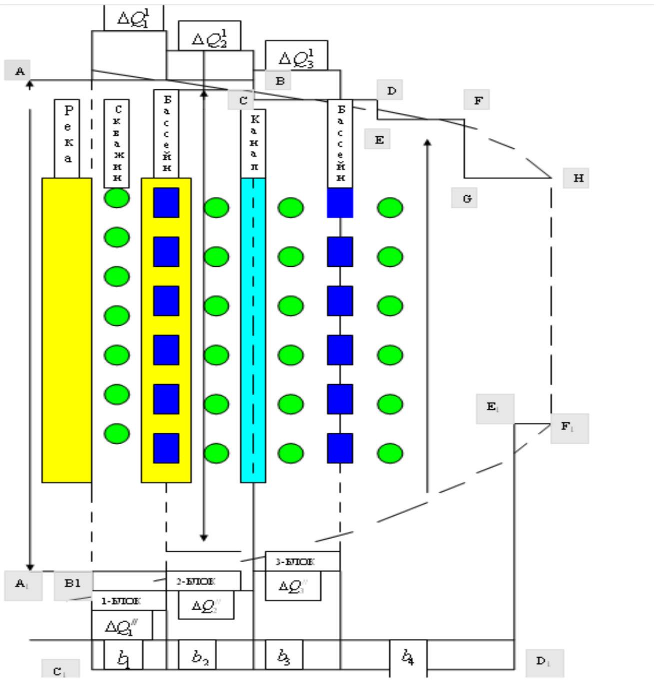
6. If $in11 \geq 1$ then appropriate: 1, 2, 3, 4, 5, 6, 7 zones are defined.

Depending on indicator in11 value, verbal messages as HC (1), M(3) and etc. are printed, that means possessiveness of the parameter to definite zone.

7. Fuzzy values of coefficient filtration are counted on all points of net domain in triangular or trapezoidal forms.

The offered algorithms of information model forming provide interrelation between object model and geofiltration process, representing in the form of two-dimensional (quasi three-dimensional) non-linear differential equations of filtration and salt transition and allow to organize CE on grounds of object model and studying processes with account of different parameters and factors.

As an example we consider process of information modeling of water intake of underground waters presented in gif.1.



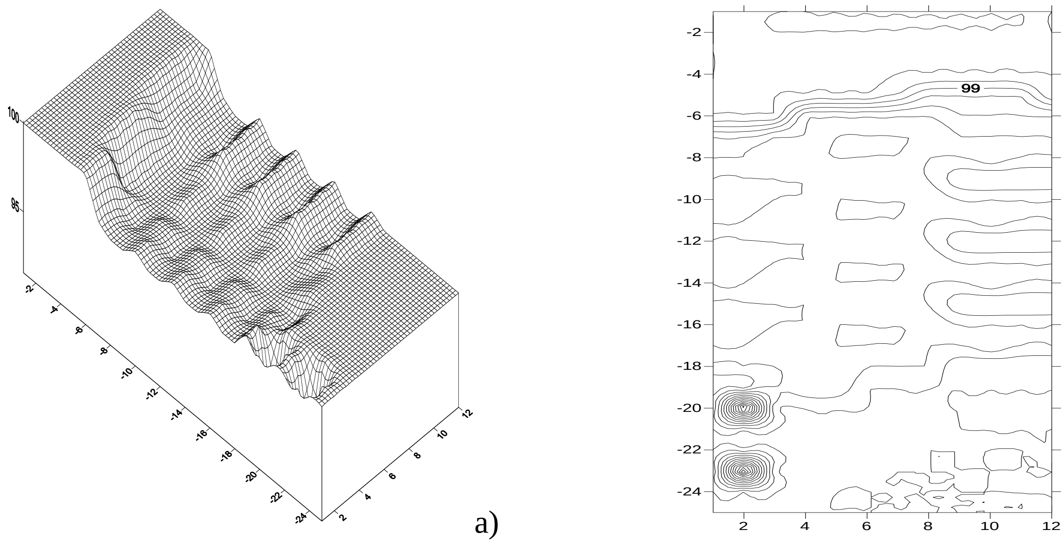
Gif.1. ***Water intake of underground waters.***

10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
10000	0	0	0	0	0	0	0	10000	10000	10000	10000
10000	0	0	0	0	0	100	1	0	10000	10000	10000
10000	0	0	200	0	0	100	0	0	0	10000	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	0	0	100	1	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	300	0	100	0	0	0	0	10000
10000	0	0	0	0	0	100	1	0	200	0	10000
10000	0	0	200	300	0	100	0	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	300	0	100	1	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	300	0	100	0	0	0	0	10000
10000	0	0	0	0	0	100	1	0	200	0	10000
10000	0	0	200	300	0	100	0	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	300	0	100	1	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	0	10000
10000	0	0	200	300	0	100	0	0	0	0	10000
10000	0	0	0	0	0	100	0	0	200	10000	10000
10000	0	0	200	300	0	100	1	0	10000	10000	10000
10000	0	0	0	0	0	10000	10000	10000	10000	10000	10000
10000	0	0	0	0	10000	10000	10000	10000	10000	10000	10000
10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000

Gif. 2. ***Information model of water intake of underground waters.***

```
*   *   *   *   *    *   *   *    *   *   *   *
*   .   .   .   .    .   .   .    *   *   *   *
*   .   .   .   .    .   ch  w    .   *   *   *
*   .   .   p   .    .   ch  .    .   .   *   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   .    .   ch  w    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   ich  .   ch  .    .   .   .   *
*   .   .   .   .    .   ch  w    .   p   .   *
*   .   .   p   ich  .   ch  .    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   ich  .   ch  w    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   ich  .   ch  .    .   .   .   *
*   .   .   .   .    .   ch  w    .   p   .   *
*   .   .   p   ich  .   ch  .    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   ich  .   ch  w    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   .   *
*   .   .   p   ich  .   ch  .    .   .   .   *
*   .   .   .   .    .   ch  .    .   p   *   *
*   .   .   p   ich  .   ch  w    .   *   *   *
*   .   .   .   .    .   *   *    *   *   *   *
*   .   .   .   .    *   *   *    *   *   *   *
*   *   *   *   *    *   *   *    *   *   *   *
```

Gif.3. ***Symbolic representation of water intake of underground waters in plan:***
** - FR boundaries; p-infiltration pool; ich – infiltration channels; ch – channels; w- water intake well.*



a) b)

Gif.2. ***Results of CE: a) Solid model b) results of CE in plan.***

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TO THE ISSUE OF COMPLEX RESEARCH OF HYDROGEOLOGICAL OBJECTS IN CONDITIONS OF FUZZY INFORMATION DOMINANCE

F.B.Abutaliyev, R.N.Usmanov, R.I.Oteniyazov

Tashkent, Uzbekistan. Tashkent University of Information Technologies
Chairman of department of "Multimedia technology"
100084, Str. Amir Temur 108, e-mail: rishat.tuit@mail.ru

Abstract: *Problems of complex research of hydrogeological objects' condition on the base of integration principles theory of fuzzy sets are considered.*

Key words*: hydrogeological object, heterogeneity, feature space, conditions diagnostics, knowledge base, fuzzy situation, membership function.*

In conditions of anthropogenic impact intensifications on natural-anthropogenic objects, including underground hydrosphere the most typical are:

- Qualitative (fuzzy) feature of significant part of information;
- Uncertainty in output conditions and targets assessment;
- Absence of impossibility to construct the determinate model of research object;
- Impossibility of direct use of fuzzy information in traditional modeling methods.

Hydrogeological objects of natural-anthropogenic type (HHO NA) are characterized with heterogeneity features, i.e. object parameters have different feature space. Combining of these processes into unique feature space in purpose of their correlation can lead to loss of research sense.

HHO NA conditions diagnostics is the process when on the base of existing observations data and research systems several more significant but not available for direct measure system indicators are defined, fully characterizing it from definite target position and allowing constantly to observe system transition from primary condition into condition we are interested in[6,7].

Nowadays distinct experience of HHO NA conditions diagnostics is built up based on statistic and determinate approaches, and also on ideas of image recognition and creation of more completed mathematic model of researching object. The following characterized moments to widely use of these methods for HHO NA conditions diagnostics impede:

- Their limitation, explained by orientation of these methods for processing mainly information of digital type;
- Impossibility of constant control of dynamic system transition from one state to another;
- Not always reached in practice requirements to information capacity (statistic method);
- Subjectivity in system analysis and weak ability to generalization (determinate approach);
- Complexity to describe process structure (image recognition method);
- Impossibility to create complete object model.

The perspective method of complex research of hydrogeological objects, in our opinion, is fuzzy-set approach, characterized by high level of generalization and semantics, heuristics addition in the process of their identification. Such kind of approach does not exclude existing methods of HHO NA diagnostics and control, but will allow rationally combine these methods on unique system-methodological bases.

Solution of fuzzy modeling of HHO NA condition assessment consists of following stages [6,7,8]:

- Construction of membership function parameters;
- Fuzzy knowledge base projecting;
- Construction of fuzzy logical models of condition diagnostics;
- Construction of fuzzy system model of hydro chemical condition changes of HHO NA on the base of FLT system of Matlab environment.

Definite features in the process regarding the quality of HHC are knowledge, experience, and qualification of specialists-hydrogeologists, hydrologists-irrigators, soil scientists and others, that are called expert information. Condition of HHO is defined by following levels:

S_0 – favorable state;

S_1 – waterlogging of irrigated lands;

S_2 – salinization of soil and sorts of aeration zones;

S_3 – SW quality degradation;

S_4 – engineering geological conditions degradation.

Counted above HHO conditions are interrelated and put in order according to heaviness extent, i.e. each current condition, beginning from S_1, is derivative from the previous one, i.e. $S_1 \Rightarrow S_2 \Rightarrow S_3 \Rightarrow S_4 \Rightarrow \ldots$.

Ellipsis means that further degradation of hydrologic, land, soil resources can lead to ecological, economic, social and other problems [5,6].

In the process of S_0 , S_1 , S_2 , S_3 , S_4 conditions diagnostics the distinct ones are following parameters (qualitative or quantitative type), possible changes diapasons are pointed in brackets:

X_1 – depth of UW level bedding ($0 \div 20$ m);

X_2 – UW mineralization level ($0 \div 30$ and more gr/l);

X_3 – area drainage degree ($0 \div 2{,}5$ c.u. – conventional unit);

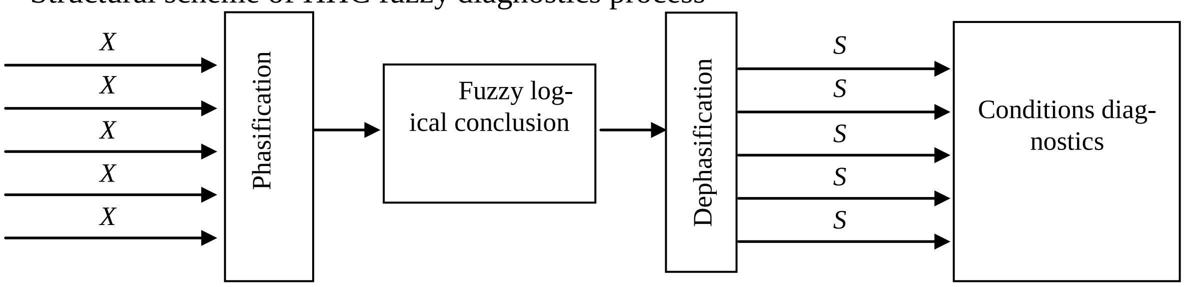
X_4 – correlation of underground and pressured water levels (-3; 3 m);

X_5 – air temperature ($10 \div 40\ ^0$ C and more).

In this situation, as the base of fuzzy modeling structure of HHO hydro chemical changes in arid conditions it is reasonable to take pattern of layered assignment and temperature changeability, water and salt cycle, based on the principle of SW vertical zoning [5]. In the process of diagnostics organization $X_{1,}X_2$ parameters are defined on the bases of field research data or results of numbered modeling of geofiltered and hydro chemical processes with account fuzziness classification of filtered and physical chemical features of water-bearing horizon. It is necessary to define concrete condition of S_j (j = 1,4) HHC depending on values (numeric, non-numeric) of X_1 , X_2 , X_3 , X_4 , X_5 parameters, that can be defined on the bases of regime observations data, results of water-salt process modeling, verbal assessment (knowledge) of specialists-experts.

Next X_1, X2, X3, X4, X5 parameters are regarded as linguistic. Structure of differential diagnostics of HHC is represented in gif.1

Structural scheme of HHC fuzzy diagnostics process



Gif. 1.

For values evaluation of linguistic variables (LV) X_1 , X_2 , X_3 , X_4, X_5 we will use unified scale of qualitative terms: L – the least, BA – below the average, A – average, AA – above the average, G – the greatest. Particularly, for x_3 parameter the term “low” (L) corresponds to intensive drainage, other terms are following: high (H), average (A), below the average (BA), above the average (AA);

For construction of membership function parameters let’s use traditional form with account α - level adjustment [1,2,5]:

$$\tilde{q} = U\left(\underline{q}_\alpha, \overline{q_\alpha}\right), \quad \alpha \in [0,1], \qquad (1)$$

where $\underline{q}_\alpha\ (\overline{q}_\alpha)$ – lower (upper) bound of fuzzy number $\tilde{q}$ on α-level.

Thus, α-levels of transition from pessimistic assessments of fuzzy number $\tilde{q}$ to optimistic one are defined from equation:

$$\mu_{\tilde{q}}(\underline{q}_{\alpha}) = \mu_{\tilde{q}}(\overline{q}_{\alpha}) = \alpha \quad (2)$$

For complex research of hydrogeological objects conditions it is necessary to analyze big amount of information, regarding the changes of filtered, capacitive features and power of water-bearing horizon; to study hydrological and hydrogeological conditions – duration of surface flow, mineralization level of surface and underground waters, content of general pollutants (bacterial, organic, oil) in surface and underground waters. The necessary condition of righteousness of management decision making is reliable estimate of conditions where the research object (RO) is. As RO let's consider HHO.

The condition of RO, particularly HHO is characterized according to such features as SW level changes dynamics (Δh), level changes of mineralization (ΔC) and reserves (Δz) SW [5, 6, 7].

Set of features values, describing condition of RO at some moment is called situation and defined as:

$$\tilde{S} = \{<\mu_S(y_i)/y_i>\}, \; y_i \in Y.$$

Let's enter following LV: $\Delta\tilde{H}$ - recession of SW level, $\tilde{C}$ - change of salt concentration level in SW, $\Delta\tilde{Q}$ - change of water well productivity. In this case we will use constructions such as $<\Delta\tilde{H}$, X, $\tilde{C}_{(1)}>$, $<\tilde{C}$,Y, $\tilde{C}_{(2)}>$, $<\Delta\tilde{Q}$, Z, $\tilde{C}_{(3)}>$, $<\tilde{f}$, S, $\tilde{C}_{(4)}>$, where $\tilde{C}_{(1)}$, $\tilde{C}_{(2)}$, $\tilde{C}_{(3)}$, $\tilde{C}_{(4)}$ - MF – fuzzy variables $\Delta\tilde{H}$, $\tilde{C}$, $\Delta\tilde{Q}$, $\tilde{f}$:

$$\tilde{C}_{(1)} = \{\mu_{C_1}(\Delta H)/x\}, \qquad \tilde{C}_{(2)} = \{\mu_{C_2}(C)/y\},$$

$$\tilde{C}_{(3)} = \{\mu_{C_3}(\Delta Q)/z\}, \qquad \tilde{C}_{(4)} = \{\mu_{C_4}(f)/s\},$$

where $x \in X, y \in Y, z \in Z, f \in S,$ X,Y,Z,S – области значений $\Delta\tilde{H}$, $\tilde{C}$, $\Delta\tilde{Q}$, $\tilde{f}$. And,

$$\tilde{C}_{(1)} = \{\alpha_1/T_1^1, \quad \beta_1/T_2^1, \quad \gamma_1/T_3^1\}$$

$$\tilde{C}_{(2)} = \{\alpha_2/T_1^2, \quad \beta_2/T_2^2, \quad \gamma_2/T_3^2\}$$

$$\tilde{C}_{(3)} = \{\alpha_3/T_1^3, \quad \beta_3/T_2^3, \quad \gamma_3/T_3^3\}$$

$$\tilde{C}_{(4)} = \{\alpha_4/T_1^4, \quad \beta_4/T_2^4, \quad \gamma_4/T_3^4\},$$

where

$$T_1 = \{T_1^1, \quad T_2^1, \quad T_3^1\}, \quad T_2 = \{T_1^2, \quad T_2^2, \quad T_3^2\}$$

$$T_3 = \{T_1^3, \quad T_2^3, \quad T_3^3\},$$

$T_1 = \{T_1^1, \quad T_1^2, \quad T_1^3, \quad T_1^4\}$ - «lower», $T_1 = \{T_1^1, \quad T_2^1, \quad T_3^1\}$ - «average»,

$T_1 = \{T_1^1, \quad T_2^1, \quad T_3^1\}$ - «great».

Coefficients $\alpha_i^j, \beta_i^j, \gamma_i^j, \quad i, j = \overline{1,4},$ are defined by means of expert poll. Accordingly [6], concepts of situations are entered: common situation, typical, reference, and target.

Common situation is defined on the bases of value features, particularly, by values Δh, ΔC, Δz in every node of network filtration sphere, if tsk is solved. Expert or face, which decides problem during situation analysis, will be interested in typical situations, total number of which is significantly less than total number of situation. For typical situations description verbal, linguistic feature marks are used.

Condition definition of object of managing is made by means of correlation of input fuzzy situation $\tilde{S}_0$ with every fuzzy situation from some set of typical fuzzy situations $\tilde{S} = \{\tilde{S}_1, \tilde{S}_2, ..., \tilde{S}_N\}$.

As measure for proximity degree definition of fuzzy situation $\tilde{s}_0$ with fuzzy situation $\tilde{S}_i \in S, (i = 1,2,...,n)$ degree of fuzzy equation $\tilde{S}_0$ and $\tilde{S}_i$; degree of fuzzy generality $\tilde{S}_0$ and $\tilde{S}_i$ and other proximity measures are used. Principles of situations proximity degree definition are described in detail in work [4].

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DEVELOPMENT OF SOFTWARE FOR ADAPTING SYSTEM OF DISTANCE EDUCATION

R.N.Usmanov[1], V.S.Khamidov[2], S.Abduhakimov[3]

[1]. Professor, Tashkent University of Information Technologies, Tashkent, Republic of Uzbekistan,
e-mail: rishat.tuit@mail.ru
[2]. Master of Science, Tashkent University of Information Technologies, Tashkent, Republic of Uzbekistan,
e-mail: vkhamidov@gmail.com
[3]. Bachelor of Science, Tashkent University of Information Technologies, Tashkent, Republic of Uzbekistan,
e-mail: sarvar.abduhakimov@gmail.com

***Keywords**: fuzzy set, database, intellectual, educational mode, adaptive knowledge.*

Analysis of research and development experiences of European, American and Russian counterparts reveal, that technologies have developed in numerous countries for many years, which allow using internet for educating various categories of the population.

At the present time some well-known commercial and non-commercial companies develop quality software for educational purposes from the point of view of technical, software, economic requirements. However, there are some reasons which are obstacles for wide application of such kind of products. The most fundamental root is lack of sufficient accurate evaluation of knowledge level and skills of educated people. This relates mostly to low adaptivity of both educational systems and means of their development for individual particularities of educated people, subject sphere, implemented tasks and developers skills.

New research direction in the sphere of distance education on web platform is adaptive and intellectual technologies in education. The task of this research direction is to include individualization possibilities in distance education. The educational system by means of adaptive and intellectual technologies takes into consideration individual skills of a student and his previous knowledge and skills. On the basis of these data about the student the educational process is on optimum way. All this contributes to the fact, that today there is an issue for provision of individualized education in distance education, which is characterized by the methods, technologies and software for creation of adaptive systems of distance education on the basis of intellectual internet technologies.

Taking this into consideration, the development of educational and informational software, taking into account individual skills of a student, is emergency timely scientific task.

The review of well-known systems, applying widely classical approaches in the modern distance education, such as ANGEL, BlackBoard, Desire2Learn, ILIAS, Lotus Learning Space, Moodle, WebCT, eFront, revealed that as a rule the educational course, presented in the distance education system environment, shows the set of statistical hyper textual documents. All the students get the same material for studying without consideration of their individual particularities.

Informational and educational environment of distance education, presented in figure 1, includes the subsystems, designed for provision of efficient work of structural components of an organization and accompanying of educational process and their collaboration within the frame of single system of support for decision making.

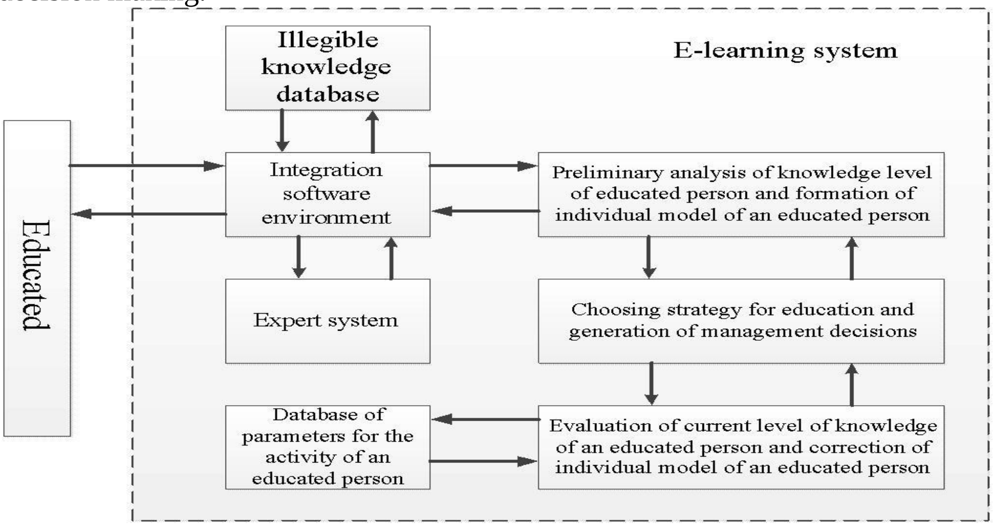

Figure 1. ***Structure of intellectual system of distance education.***

The perspective method for decision making in pedagogical systems is the integration of principles of fuzzy sets theory, allowing applying all accessible information for defining decisions in the real time, which is at the same time perspective method for formalization of pedagogical concepts and processes by means of natural language.

Created models and concept of system formation allow executing automatic generation of educational trajectory for each educated person on the basis of fuzzy sets theory derived from test answers and coherence of educational material.

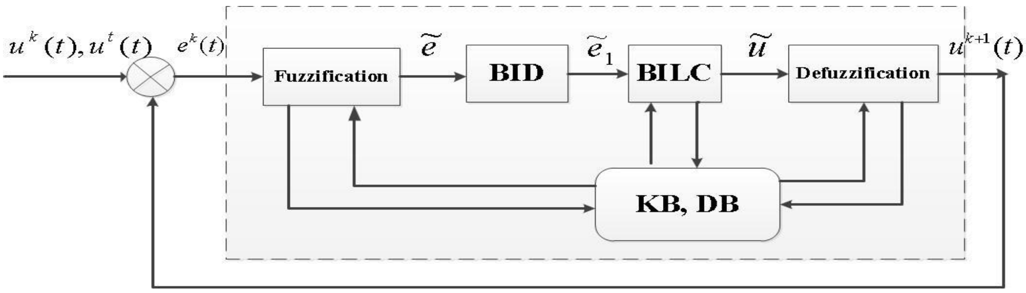

Figure 2. ***Principal scheme of illegible adaptive management in distance educational system. (BID) block of illegible diagnosis-(BILC) block of illegible logical conclusion-(KB) knowledge base-(DB) database.***

The basis of this system is the block of illegible logical conclusion, database and knowledge for complex evaluation of knowledge quality of an educated person, customized for implementation of the following illegible model:

$$Y = \widetilde{f}(x_1, x_2, x_3)\ , \tag{1}$$

where $x_1, x_2, x_3, y-$parameters, defining the educational process, accepted as linguistic alterations:

x_1 -<the level of preparation of an educated person>; x_2 - <the level of organizing the process of education in distance education system>; x_3 - <ways of developing learning material (LM) available in distant education system>; y - <evaluation of knowledge of an educated person >.

Implementation of illegible logical model of complex evaluation of quality of knowledge of an educated person (1) implemented on the basis of designing of productional rules – the set of management rules of illegible logic, connecting system inputs with its output. And they use accepted above linguistic alterations (LA) and their derivatives– thermae, including their illegible values. On the basis of entered LA and their thermae, illegible model of quality evaluation of an educated person in distant education system can be presented in the following way:

If *the preparation level of an educated person* (x_1) = (**L,M,H**),
And *the level of organizing the educational process* (x_2) = (**L,M,H**),
And the ways of development UM (x_3) = (**L,M,H**),
THEN *knowledge quality* (У) = (**L,M,H**),

where L-low, M-mean, H-high.

Numerical evaluation of knowledge quality of an educated person (y^*) for concrete values (numerical, linguistic) parameters x_1^*, x_2^*, x_3^* in quantitative correlation is defined by means of defuzzification on the principle of gravitation.

All the information delivered to the input system ($e^k(t)$) is fuzzified and numerous typical situations are defined, which are understood as numerous typical situations, including numerous purpose situations. Delivered fuzzified information to input block of diagnostics is presented as illegible current situation, which is matched with purpose situation, as a result it defines the condition of management object, management decisions are taken, which are implemented on the block of illegible logic output. At the same time the most important issues are expressed by appeared situations related to identity, similarity, inclusion degree, etc.

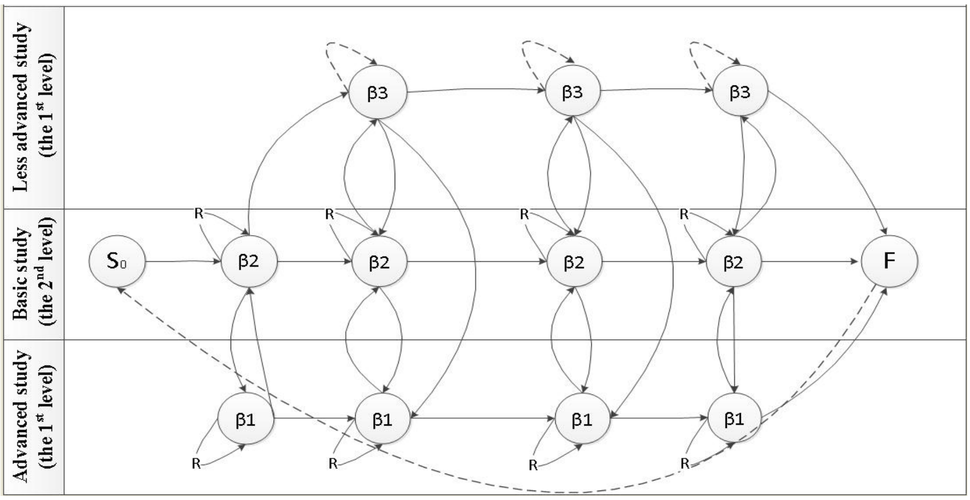

Figure 3. ***Graph presentation of educational process on the basis of individual curriculum.***

Developed by us distance education system eStudy.uz is based on above mathematical model FST(Fuzzy Sets Theory) and meets all these requirements and is technologically implemented in the form of web-application. The system is written in PHP programming language with usage of object designed programming. The system is working under the management of Apache web server, and it also uses DBMS MySQL for storage and processing data. The work with system is implemented by means of web-browser, by means of addressing to site, where the system itself is located.

The system is built on the basis of Code Igniter framework, providing object customized approach for writing the system, and allowing to fully implement MVC architecture (Model-Viewer-Controller), which were used for building system modules. In Figure 1 there are separate parts of complex: operational system, database system management, databases, program modules, web-server and browsers on customer's side.

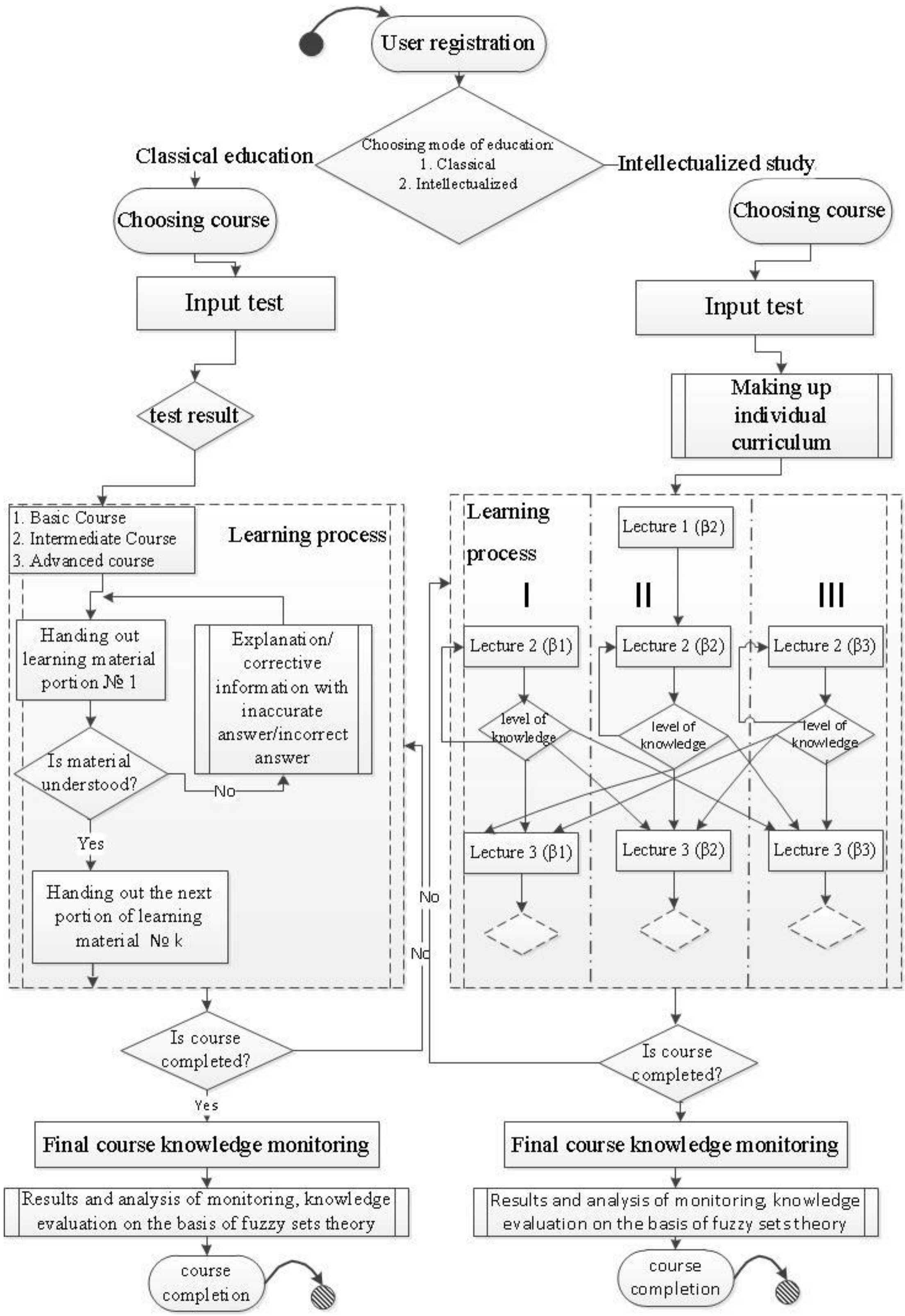

Figure 4. ***Learning process in E-learning system.***

In the system there are two educational modes, one of which can be chosen during the registration in the system: Classical education; Intellectualized education.

Classical educational mode is based on testing knowledge for defining the level of newly registered user and automatic record of a user for a course based on test results.

Intellectualized educational mode is based on adaptive knowledge testing, which allows to define not only knowledge level of a student as a whole, but to define the knowledge level of each concrete topic separately. Based on these results the system generates individual educational trajectory, which is used for educational purposes consequentially.

Individualized educational mode (Figure 3) can be presented in the form of graph, where each unit of the graph sets one step of education comprised of presenting (quantum) portions of educational material and it is finalized with checking of educational material understanding.

Presented customized graph in Figure consists of three levels:

- 1st level – the level of advanced studying
- 2st level - the level of basic studying
- 3rd level – the level of elementary studying.

Advanced, less difficult advanced and basic studying topics on the graph match different points. Graph curves define educational trajectory on the basis of monitoring results after the completion of the next step and defining new level of educational scenario (choosing a strategy), such as the first level and second level and third level or stationary level.

In graph representation of educational process on the basis of individual curriculum there are some possible transitions:

- For learning of the next portion of learning material at the same level (curve N), that is to say it is chosen the strategy not to alter the educational process;
- Repetitive presentation of just presented portion of learning material (curve R);
- Transitional the third level that is to say it is chosen the strategy of slow educational process.
- Repetitive presentation of the previous studied material (curve B).

Finally we shall point out, that efficiency of computer educational systems is mostly defined by development of methodological aspects of evaluation rate of understanding by an educated person of studying subject, timely diagnostics of detection, weakness elements prevention, including adaptive solution for their elimination. This is explained by perspective of suggested adaptive management system in the present article, based on the situation analysis of educational process within the frame of single system of decision making support. In this regard the perspective of principles integration of fuzzy sets theory for intellectualization of educational process in distance education system is obvious.

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DEVELOPMENT OF MICROPROCESSOR SHAPER CODES FOR SUPPLY CHAIN RAIL CODE AUTOLOCK, EC AND ALSN

A.R. Azizov, M.N. Xamraxanov

Tashkent institute of railway engineers, Department of Avtomatization and telemechanics
Adilhodjaev str. 100125, Tashkent, Uzbekistan
Ph. +99893-568-99-70. muzaffar.hamrahanov@mail.ru

***Keywords**: Transmitters, microprocessor shaper codes, KPTSH, AUTOLOCK, EC and ALSN, KPTSH.*

1. Introduction

Improvement and introduction of new technologies is one of the most important areas of technical progress in rail transport. The application for a new rail traffic control technology ensures better use of capacity of railway lines, reducing maintenance costs of railways by speeding trains, and promote better use of locomotives and wagons, as well as increasing productivity railroad.

The rapid growth of traffic and complexity in connection with the working conditions of the railways made a number of new requirements for devices to encode the code auto-lock track circuits, power centralization and ALSN on the other hand, new scientific and technological advances which make it possible to meet the increased requirements of railways in coding region track circuits. [1]

These achievements include the rapid advances in microprocessor technology.

Microprocessors and microcontrollers are implemented in almost all spheres of human life, in various branches of science and technology.

2. The wording of the general problem

Device developed by its functions coincides with the work of the existing code track transmitter. However, it will be replaced the most energy intensive part of the device microcontroller. The mass of the transmitter code track down a few times and energy consumption in the dozens, many of the improved specifications. There will be a function of self-control and diagnostics.

Transmitters types KPTSH KPTSH-5 and-7 are used in auto-lock device with a numeric code from the AC frequency of 50 Hz.

Transmitters types KPTSH KPTSH-8-9 are designed to work on the AC frequency of 75 Hz, 110/220V in track circuits in areas with electric traction, and the type KPTSH-10 - in the railway station chains with a pulsed power supply current at a frequency of 75 Hz. [2,3,4]

Code track transmitter type KPTSH-11 code is used in devices with auto-lock pulses broadcast at AC frequency of 50 Hz, 110/220V.

Transmitter type KPTSH-13 operates in rail station chains with a pulsed power supply current at a frequency of 50 Hz.

KPTSH transmitters are asynchronous AC motors with worm gear, the output shaft gear washer planted the code, having protrusions and depressions. In the code washers are moving contacts which are closed during rotation washers and opens with the fixed contacts.

The duration of opening and closing depending on engine speed, gear reducer, Profile washers and adjust the contact system.

Transmitters used in single-phase asynchronous AC motor type ACOM-48 with cage rotor on the operating voltage of 110 V. The minimum rotor speed motor no-load supply current at a frequency of 50 Hz is 982, and the supply current at a frequency of 75 Hz - 1473.

In the transmitter gear bearings are used in the contact system - ball bearings with brass cage.

Insulation of live parts KPTSH transmitter relative to the housing must withstand for 1 minute ± 5 seconds without breakdown, or overlap with an air temperature of +20 ° C and relative humidity up to 70% of the test voltage of 1000 V AC, 50 Hz at a power of the test is not less than 0, 5 kV A.

Coded transmitters KPTSH type manufactured for use in the following conditions:

- Ambient temperature from - 50 to +60 ° C;
- Relative humidity up to 70%;
- Vibration of the mounting with a frequency of 20-30 Hz with acceleration up to 1 g;
- Working position - plug and socket contacts connected up;
- Operation - long.

Transmitters should be stored in a dry heated room, in the absence of acid and other corrosive substances. Transmitters in stock for long term storage should be located only in the inner packaging (in boxes). Store in a transport container no more than three months.

Overall dimensions 224x180x210 mm, weight 8,0 kg.

Electrical and timing characteristics.

The power supply voltage, input current and frequency for different types of transmitters KPTSH in the table. A. [2]

Pick-up voltage transmitter, measured directly at the terminals of motor shall not exceed 60 V.

When applied to the terminals 0 -220 autotransformers rated voltage of 220V at the terminals should be 0-110 voltage of 110 V ± 5%, at times 0-90 - 90V ± 5%. At the same transmitters must provide contact closure (pulse) and the opening of the contacts (intervals).

Table 1

The electrical characteristics

Type of Transmitter	Frequency, Hz	Rated Voltage	Current consumption is not more than, A			
			at 50 Hz		at 75 Hz	
			110V	220 V	110V	220 V
KPTSH −5	50	110/220	0,13	0,10	0,25	0,15
KPTSH −7						
KPTSH −11						
KPTSH −13						
KPTSH −8	75					
KPTSH −9						
KPTSH −10						

Tolerances and short pulse duration of the interval 0.12 should not exceed ± 0,01 s, and long intervals of ± 0,02 p.

3. Conclusion

Contact KPTSH transmitter shall withstand one year of continuous operation at a load of 150 mA and a voltage of 12 V DC at (20 ± 5) ° C without a control and cleaning contacts. [4]

In drawing up the functioning of the algorithm code track transmitter has the task to determine how the measure pulse intervals. In the beginning, has been proposed algorithm, in which intervals are used to determine the time delay (cycles).

The meaning of the algorithm code track transmitter consists of the following figure. A. At the beginning of the program in three port pins of the microcontroller logic levels are fed units after 230 ms, the output port of the code designating the QL logic level zero is applied at the other ports do not change. Further, when prosledovanii another 120 ms, the output of the code indicates the level of N applied zero, the findings indicate the code of M, and QOL remain unchanged. The rest of the work is doing is analogous to the formation of the above codes. The main problem of the functioning of the algorithm lies in the fact that the routine use timer for 10 ms (time delay), which allows for continuous operation of the deviation signal, as is the addition of time delay subroutine itself and the time the main program. Calculate the delay for the universal cycle of the code track transmitter, which would have prevented the distortions in the transmission of signals, a task not feasible.

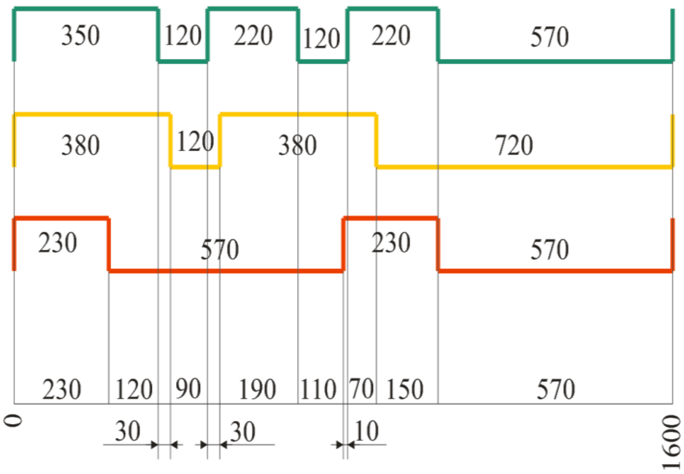

Fig. 1. ***The principle of the algorithm code to track the transmitter encoder example KPTSH - 5, 8.***

The next step was to develop a new algorithm of the code transmitter uses a fundamentally different method of determining the duration of the signal, which is based on timer interrupts. The accuracy of the timer sets the quartz resonator, which are of high quality clock.

The work begins with a code of generator installation on codes indicating the findings of microcontrollers QL, F, G, and logic level units of Figure 1. At the end of 230 ms, the output port of the code designating the QL logic level zero is applied at the other ports do not change. Next, using a timer and a scratch register is counted 350ms, the output of the code indicates the level of N applied zero, the findings indicate the code of M, and QOL remain unchanged. After 380ms, and is measured at the output code F indicates the output logic level zero, the findings indicate the microcontroller code W and QL are the same. Subsequent work done by the above algorithm works. The simplified algorithm is shown in Fig. 2.

It should be noted that shown in Fig.2. operation of the algorithm code track transmitter is characterized by its simplicity of execution. Use a timer interrupt gives no distortion to the signal formation, since the time of the main program does not depend on the time of program termination.

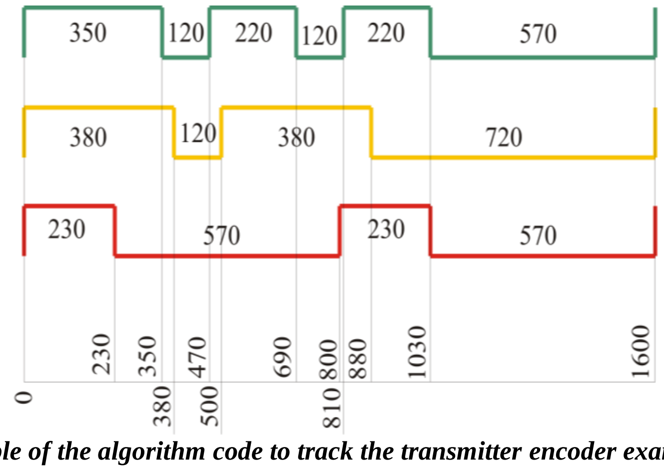

Fig. 2. ***The principle of the algorithm code to track the transmitter encoder example KPTSH - 5, 8., Using a timer interrupt.***

This algorithm was selected for the operation of a working basis for the algorithm of the code track transmitter. As can be seen from the algorithm it is composed of two code-shapers, KPTSH - 5 and KPTSH - 7. The choice of code depends on the encryption logic level on the corresponding output of the microcontroller.

To power the transmitter track code, as mentioned above, are applied voltage of 110 V and 220 V, 50 Hz. To ensure these conditions, it was decided to use the power supply module, where the primary converter transformer chosen, with the findings in the primary winding 110 and 220, as it has sufficient durability of work, as a static element.

As you know, in order to improve the reliability of the device, it must be duplicated and each module is compared with the reference value. In our case, the dimensions of the microcontroller can not only duplicate, but the check box and enter the generated signals.

Produced an analytical overview of the existing code track transmitter, the technical and electrical characteristics, a description of the algorithm and shows the technical and operational standards. The analysis of possible options for the use of microprocessor-based controllers.

For the rectification of alternating voltage is selected standard diode bridge. The filter capacitor is a low frequency is selected with a sufficiently high capacity (1,000 uF), and to filter out pulses of high frequency capacitor of low capacitance (100 nF). And to stabilize the output voltage is selected KR142EN5 chip, which provides a stable output voltage of 5 V and supports the load current to 2A. schematic diagram of the power supply is shown in Fig. 3.

Based on the reduced functional scheme was drawn up algorithm decrypts the device with the functions of inspection and permit transmission of codes.

Became the task of synthesizing decrypts the device, which allows to determine the efficiency of the code track transmitter and choose which of the two modules, encryption, at the moment, is intact. Also, the block decoding and checking should signal about the health unit serving his mechanics, and BL signaling. Functional diagram of the device shown in Fig. 4.

As a shaper device codes used microcontroller ATTINY2313 of AVR. [5,6]

The algorithms of the functioning of the shaper codes with two kinds of measuring time, and from them selected algorithm is optimal and does not cause distortion of signals in the process of forming codes.

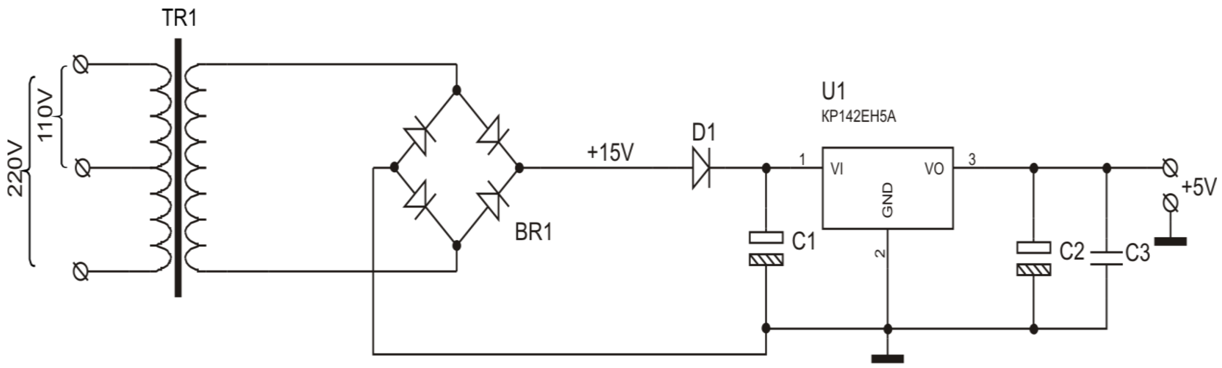

Fig.3. ***Schematic diagram of the power supply unit.***

Table 2

Specification of the elements shown in Table 2

№	Designation of the scheme	Name
1	TR1	Power transformer (pins in the primary winding 110 and 220, the secondary windings 15 V)
2	BR1	Diode bridge - 2W005G
3	D1	Diod – 1N4007
4	C1	Electrolytic Capacitor 1000uFx16V
5	U1	Stabilizer KP142EH5A
6	C2	Electrolytic Capacitor 220uFx16V
7	C3	Ceramic Capacitor 100 nF

The same algorithm functioning shaper device codes are deciphered with the functions of inspection and permission to transfer codes. Concepts developed power supply device, the shaper device codes are deciphered, as well as opto-pack (galvanic) isolation. For the formation of the device codes and decodes the device was chosen microcontroller AVR ATTINY2313 family can be replaced for PIC 16F84. Program was written based on the functioning of the algorithm decrypts the device with the functions of inspection and permission to transfer codes. [7]

Figure 4. shown:

- GTI1, GTI2, GTI3 - clock generator;
- FI1, FI2 - coded transmitter pulse shapers;
- D - the decoder to verify that the function of the encoder;
- BR1, BR2 - block permission to transmit signals.
- C – block conjunction.

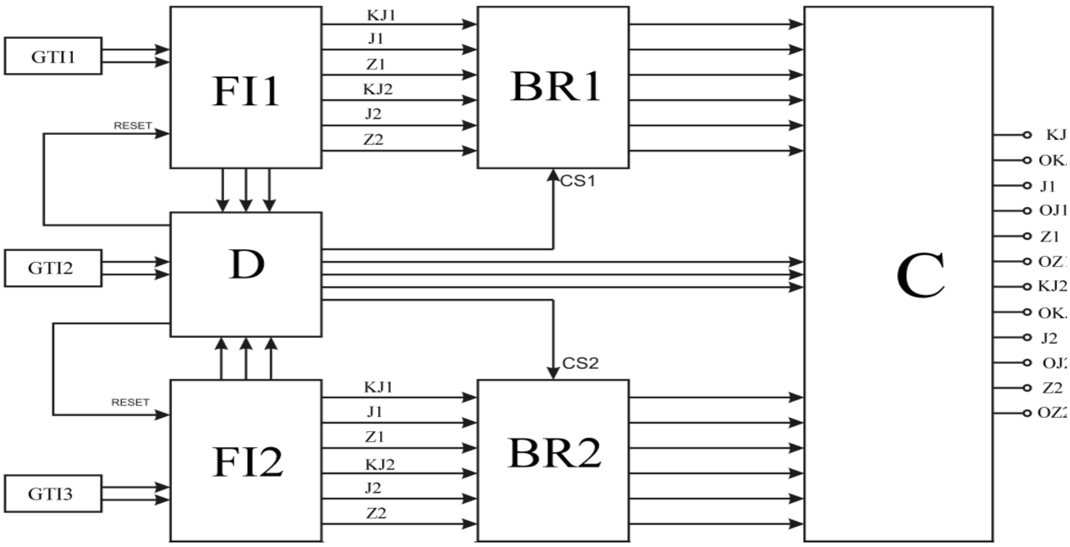

Fig. 4. ***Functional diagram of the device with the duplicate number of encoders and block decoding, and verification.***

Installation of devices implemented in the relay cabinet for subsequent testing of the prototype and determine its efficiency, reliability and fault tolerance. Trial operation of the device is held in the Republic of Uzbekistan Railways.

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MATHEMATICAL MODELLING AND SHARING THE HEAT IN SOLAR HEATED HOTHOUSE GROUND

Af. Vardiyashvili

Karshi State University, 17 str. Kuchabog, 180103, Karshi city, Republic of Uzbekistan
Phone: (8-375)-225-28-43. (+99893)- 525-14-41 e-mail: vardi73@mail.ru

***Keywords**: Modeling, heat-mass-exchange, convection, radiations, hothouse ground, factors of heat-temperature-conductivity.*

The Production of vegetables in climatic condition of Central Asia requires great expenses of energy on heating and is found on comparatively low level. Because of increasing prices of oil-products and natural gas many enterprises spare big attention to use waste heats of industrial enterprises for heating hothouses [1,3,4].

It is known that the use in hothouses can save the much of solar energy, but anyway he it is not enough for full heat provision.

So multifunctional use of solar energy and waste energy of an industrial enterprise and heat-generating installation in hothouse allow to raise the possibility of the full exception direct and indirect consumption fossilized fuel [1,3,4].

In given work for decision of the problem of heat-exchange in hothouse ground is used the method, as more simple on mathematical device and physically approximate to the object of the study –a helio-hothouse.

In study [1,2] the method of equivalent heat-conduction considers ground as quasi-homogeneous body, carrying the heat in which is described by one equation of heat-conductivity, complicated action of the internal sources and, first of all, presence of the variable heat features. It is known that changeable nature of the heat features reflects the equivalent influence of all possible phenomenas in ground, aside from heat-conductivity such as convection, radiation and mass-exchange. As a result, for description non-stationary process of heat-conductivity in ground turns out to be sufficient for only one differential equation in quotient derived, but with equivalent feature i.e univariate note for vicinity of the crossing the axis of the hothouse under even irradiation of surfaces of ground.

$$C_{pЭ} \cdot \frac{\partial T}{\partial \tau} = \frac{\partial}{\partial x}(\lambda_{Э} \frac{\partial T}{\partial x}) \tag{1}$$

where $C_{pЭ} = C_p(x,\tau,T), \lambda_Э = \lambda\,(x,\tau,T)$, accordingly equivalent heat-capacity and factor of heat-conductivity of the ground. For univariate problem of the sharing the heat in ground is used equation (1) for conclusion of the analytical dependency of the sharing the heat in heated hothouse ground with provision for features $C_{pÝ}$, $\lambda_Ý$ and written as:

$$C\,(x,\tau,T)\frac{\partial T(x,\tau)}{\partial \tau} = \frac{\partial}{\partial x}[\lambda\,(x,\tau,T)\frac{\partial T}{\partial x}], \tag{2}$$

or

$$C\,(x,\tau)\cdot\gamma_{об}\,(x,\tau)\,\frac{\partial T(x,\tau)}{\partial \tau} = \frac{\partial}{\partial x}[\lambda\,(x,\tau)\frac{\partial T}{\partial x}], \tag{3}$$

under given initial sharing the temperature on depth of hothouse ground.

Marginal conditions of the condition heated hothouse ground under known value of the specific flow of the heat in ground $q_П$ they were defined from equation of the heat balance on surfaces of ground with provision for shielding dug the plants and correspond to expressions:

$$T\,(\infty,\tau) = 0, \tag{4}$$

$$T(x,0) = T_0, \tag{5}$$

$$\lambda\,(0,\tau)\frac{\partial T}{\partial x} + q_n = 0, \tag{6}$$

$$T(x,\tau) = T_0 + \theta\,(x,\tau), \tag{7}$$

where θ - surplus against initial temperature of the ground.

For simplification of analytical calculation equations (3-7) are written in importances of the surplus temperature:

$$C(x,\tau)\cdot\gamma_{об}(x,\tau)\frac{\partial\theta(x,\tau)}{\partial\tau}=\frac{\partial}{\partial x}[\lambda(x,\tau)\frac{\partial\theta}{\partial x}], \tag{8}$$

$$\theta(\infty,\tau)=0, \tag{9}$$

$$\theta(x,0)=0, \tag{10}$$

$$\lambda(0,\tau)\frac{\partial\theta}{\partial x}+q_n=0, \tag{11}$$

System of the equations (8-11) is solved by method of the introduction additional variable

$$dƶ=\frac{dx}{\lambda(x)}, \tag{12}$$

$$dy_{Ý}=\sqrt{q(ƶ)}\cdot dƶ, \tag{13}$$

where

$$q(ƶ)=c(x)\cdot\gamma_{об}(x)\cdot\lambda(x), \tag{14}$$

Then equation (8) gets type

$$\frac{\partial\theta(ƶ,\tau)}{\partial\tau}=\frac{1}{q(ƶ)}\cdot\frac{\partial^2\theta}{\partial ƶ^2}, \tag{15}$$

and after transformations is reduced to standard equation of heat-conductivity of deep stream with variable heat-conduction and heat-capacity, but constant, single heat-conductivity a,

$$\frac{\partial\theta}{\partial\tau}=\frac{\partial^2\theta}{\partial ó_{Ý}^2} \tag{16}$$

under $\tau>0,\ 0\le y_{Ý}<\infty$.

Marginal conditions for new variable are written as

$$\theta(\infty,\tau)=0, \tag{17}$$

$$\theta(y_{Ý},0)=0, \tag{18}$$

$$\lambda(0)\frac{\partial\theta}{\partial ó_{Ý}}+q_n=0, \tag{19}$$

decision of the equation (16) at condition (19) will be expressed by the following equations

$$\theta(y_{Э},\tau)=\frac{q_n}{\lambda_{y_{Э}=0}}\int erfc\frac{y_{Э}}{2\sqrt{a\tau}}\alpha\, y_{Э}, \tag{20}$$

or

$$\theta(y_{Э},\tau)=\frac{2q_n}{\lambda_{y_{Э}=0}}\cdot\sqrt{a\tau}\cdot ierfc\frac{y_{Э}}{2\sqrt{a\tau}}, \tag{21}$$

and with provision for characteristic of equivalent deep stream.

$$\theta(y_{Ý},\tau)=\frac{0{,}02\,q_n}{\lambda_{ó_{Ý}=0}}\cdot\sqrt{\tau}\cdot ierfc\frac{y_{Ý}}{2\sqrt{\tau}}, \tag{22}$$

where function $ierf\,L\left(L=\frac{Ó_{Ý}}{2\sqrt{\tau}}\right)$ tabulated.

Using equation (22), it is possible easily to define surplus temperature θ in any points of the soil array under given value of the heat flow in ground q_{Π} and time of functioning(working) the system τ. For determination of this correlation it is necessary to know value $q(ƶ)$, i.e. the change of heat-physical features on depth of ground.

From equations (12) and (13) follows:

$$ƶ=\int_0^x\frac{dx}{\lambda(x)}, \tag{23}$$

$$dy_Э = \sqrt{q(x)} \cdot \frac{dx}{\lambda(x)} = \sqrt{\frac{c(x) \cdot \gamma_{об}(x)}{\lambda(x)}} dx, \tag{24}$$

$$y_Э = \int \sqrt{\frac{c(x) \cdot \gamma_{об}(x)}{\lambda(x)}} dx. \tag{25}$$

Consequently, defining dependency

$$u_1(x) = \frac{c(x) \cdot \gamma_{îá}(\tilde{o})}{\lambda(x)}, \tag{26}$$

it is possible to get correlation ($y_Э - x$)and hereunder to provide the realization of the equation (22) for decision of direct and inverse problems of the heat condition of the hothouse premises of cultivated buildings.

Change of heat-physical features on depth of hothouse ground hitherto fundamentally was not studied, but analytical calculation of the specified features in view of difficulty of the processes, running in capillary-porous poli-phase ambience-ground, inadvisable so dependency (26) is installed by practical consideration.

In this connection is determined the whole heat-physical complex and features of ground of the hothouses that has provided certainty when spreading of got importances on the other types of ground and soil.

It is known that in helio-hothouses solar energy accumulates in upper and accumulating layer of ground. For finding the amount of accumulated energy it is necessary to have a data, characterizing heat-physical characteristics of the ground. It was organized series of measurements of heat-conductivity of heavy loamy ground in helio-hothouse depending on moisture and density [1,5].

It is shown that average weighing moisture of ground varies within $16 < \omega < 18\%$, on depth is changed linear, also as density ρ ground, but specific heat-capacity within 0,71 $< c_\rho < 0{,}8$ kj/kg·K. Three-dementional heat-capacity of the ground was at the depth defined on formula [1,2].

$$C_V = \left(C_\rho + \frac{\omega_0}{100} \right) (\rho_0 + 510x) \ . \tag{27}$$

Under ω_0=16%, C_ρ=0,75 kj/кг·K, ρ=1065 кg/м^3, for upper layer of ground C_V=970 kj/м^3·K; for depth x=0,5 м C_V=1201 kj/m^3·K.

Thereby, heat-physical features of heavy loamy ground are bound dependency between itself: $\alpha = \lambda / c_v; c_v = c_\rho \cdot \rho; Q = \sqrt{\lambda \cdot c_v}$ where c_ρ и c_v - specific and three-dementional heat-capacity, ρ - density Q, λ, α - the factors of heat assimilability, heat-and heat-conductivity.

It is installed that in energetic surfaces of helio-hothouse flow of the heat in ground and heat-accumulation can be escalated by increase of radiation balance, heat-conductivity of the ground and reduction of the expenses of the heat on turbulent heat-exchange and evaporations, and gained information about heat-physical features of ground can be used at determination of heat-accumulating features, consequently and warm-up mode of hothouse ground both on surfaces, and on depth.

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MATHEMATICAL MODELING AND CALCULATION OF HELIOSDESALTER – A BOILER WITH A PARABOLA-CYLINDRICAL REFLECTOR

Asf.A. Vardiyashvili, A.A. Abdurahmonov

Karshi State University, 17 str. Kuchabog, 180103, Karshi city, Republic of Uzbekistan
Phone: (8-375)-225-28-43. (+99893)- 525-14-41. E-mail: vardi41@mail.ru

Keywords: *Modeling desalinization of water, heat mass-exchange, processes of the evaporation and condensation, factors of diffusions, mass giving.*

It was shown by researchers that for some regions of Central Asia desalinization of water with use of solar energy is more profitable, than the desalinization on the base of imported fuel [1, 2, 3, 4, 6, 7].

Results of the perennial work domestic and foreign researchers [2, 3, 4, 6, 7] show that hotbed type solar water desalters with two sloping surfaces are not firm to external meteorological factor, since the installation with all sides covered by windowpanes has low capacity because of great convectional and radiant heat losses and main inconvenience in exploitation consequence of which is less economical.

It must be noted that at increasing heating of water and air with 50 before 70^{0}C Coefficient of Efficiency of low potential solar installation within working period decreases at the expense of increase of convectional and radiant heat losses [2,4,5,7]. Actually at differences of temperature inwardly solar installation and surrounding air $\Delta t = 20^0 C - 25^0 C$ and at the average factor of heat feedbacks from 1 м^2 surfaces of the installation in surrounding ambience - $\alpha = 8 \div 12$ Vt/m^2 ^{0}C, heat losses will form 250 Vt that forms $\frac{1}{3}$ parts of falling solar radiation in summer term on 1 m^2 surfaces of the land of the south region of the Republic.

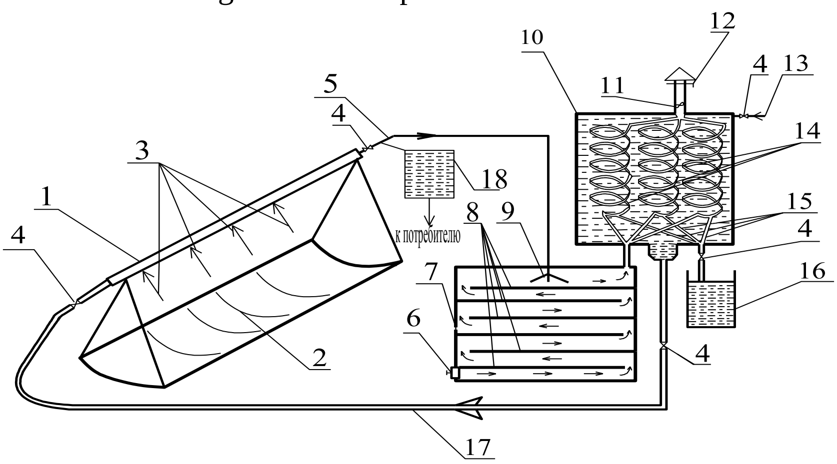

Fig.2. ***The Scheme solar desalter-boiler with parabola-cylindrical reflector:***

1-caldron-boiler; 2-solar parabola-cylindrical reflector; 3-reflected sunbeams; 4-valve; 5-hot water; 6-manhole for entering the air; 7-evaporating camera; 8-moistened surfaces of the vaporizer; 9-injector; 10-capacitor camera; 11-ventilator suction;12-exhaust channel with valve; 13-entry of salty water; 14-screw coils for condensation of the water vapour (pair)s; 15-distillatecollections; 16-measured container for distillate; 17-pipe line beforehand heated nourishing water; 18-storage tank.

Taking into account these considerations, we made a pilot model solar desalter - boiler with parabola -cylindrical reflector by capacity 6,5-7,4 L/ a day distillate

and 80-100 L / a day of hot water with temperature 80°C, the principle of the action which is submitted in fig.2.

For efficient desalinization mineralized water we constructed and explored solar desalter with parabola-cylindrical reflector 2, working with compelled convection, consisting of vaporating camera 7, capacitor 10 and ventilator 11, exhaust 12 and circulating pipe line 17.

Caldron - boiler 1 of solar desalter consists of parabola-cylindrical reflector 2 made from electro polished aluminum, with useful area of the reflection $1m^2$, and shaped iron pipe, which enters on pipe line 17 salty water, beforehand warming in capacitor 10, to account of the condensations of the water vapours in screw coils 14.

The Reflected sunbeams 3, falling on solar reflector -a mirror 2, are reflected from it and concentrate on blackened bottom caldron- boiler 1.

Boiler -a caldron 1, hard attached to reflector 2 and revolving together with it, presents itself steel pipe by length 1 m with internal diameter 55 mm. In the bilge of caldron two carbines are attached -a valve 4, lower - for admission of cool water, upper- for issue of hot water. Outside of the caldron 1 is covered with layer of insulation from cotton wool slag, placed in cover from roofing ferric. Non-isolated remains only slot for focal of the band, on which directly fall the reflected rays of the sun 3.

The Pressure tank- capacitor camera 10 serves for sending cool water 13 in lower part caldron 4, afterwards warming in caldron-boiler 1 water enters storage tank 18, which is intended for gathering hot water, then from storage tank water is withdrawn by consumer.

In our case evaporating part of parabola-cylindrical desalter presents itself a camera, which is filled with adjutage i.e. developed surface by 8 spongy material, moistened by salted water enterring from 5 collectors-heat-receiver with temperature 70-100°C [3], it is moistened by jet device 9, and presenting of water is regulated by the valve 4. From evaporating of camera steam-air mixture moved into experimental coil 14, the temperature mixture before and after the experiment area was measured by the thermocouple, pressure-mercury diphmonometres, and the temperature wall of each whorl coil was defined by thermocouple on section of the tube in four points.

Incoming into evaporating camera the atmospheric air is sated through manhole 6 with water vapour(air), washing upper and lower surface of the adjudge 8, which is moistened by hot water of jet device 9.

The External dry air gets sucked by the ventilator in evaporating camera and in capacitor afterwards, then depending on given conditions is thrown through exhaust pipe line 12 in atmosphere. For checking parameters of the air in evaporating camera there are installed dry and wet mercury thermometers. Steam-air mixture with given temperature and moisture enters the capacitor, where occurs its cooling, drainage and conditioning moreover cool condensate enters measured container 16.

The Autumn 2010 and the summer 2011 in experimental base of helios laboratories in

Karshi SU there organized tests of the pilot model of helios desalter. During the tests significance of direct solar radiation, temperature of entering water and temperature of leaving water (last within 70-100^0) were changed. Before every test the reflector was cleaned from dust and, consequently, the degree of dust contents of mirrors was the same for all tests.

The Velocity and direction of winds at different days changed; the velocity of winds in all test was insignificant (at the average 0,3-0,5 m/sec) and could not render the essential influence upon fluctuations of the heat losses.

Intensity of solar radiation was measured by actinometer of Savinov-Yanishevski.

Coefficient of Efficiency of rhe installation of the helios desalter - boiler with parabola - cylindrical reflector was defined on formula and has formed $\eta = 0{,}64 \div 0{,}7;$.

$$\eta = \frac{(100 - t_{\text{H}}) \cdot G \cdot c_p}{S_{cp} \cdot F \cdot \tau} . \qquad (3)$$

where S_{cp} - average intensity of solar radiation; $\frac{Вт}{м^2}$; c_p - heat-capacity of water, $kj/kg \cdot {}^{O}C$, F - surface of the reflector, η; τ -time, sec., G - amount of water, kg; t_H - initial temperature of water in container, ${}^{O}C$.

Useful heat used on heating of water defined on formula and forms - $4600 \div 4800\, kkal/day$ at year term

$$Q_{пол} = q_{рез} \cdot f_D - q_1\, f_B; \tag{4}$$

where $q_{рез}$ - density of the resulting heat flow on bilge, $\frac{VT}{м^2}$; f_D- surface bilge, $м^2$; f_B- external surface of the container, with the exclusion of bilge, $м^2$. -a heat, sent from external wall to external air, $\frac{VT}{м^2}$.

It is known that in bent pipe (the coils) factors of heat irradiation are observed to be much higher, than in direct pipe. This is explained by additional transference of steam-air mixture in consequence of twirls of the flow and secondary currents. For this purpose it is used effect so named circulations in cross-sections of the pipe and the calculation of heat irradiation in curved pipe can be produced on formula

$$\varepsilon = 1 + 1{,}77\, d/R, \tag{5}$$

where R - average radius coil; d - internal diameter of the pipe.

The condensation of water pair from moving steam-air mixture was realized on internal surface screw coils 14.

The Results of the study and gained estimated heat technical features of the heliosdesalter - boiler with parabola -cylindrical reflector on base of new technology intended for reception hot and fresh water shows that it may be used for drinking and hot water-supply of small in number and dispersed consumers.

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APPLICATION OF THE PRINCIPLES OF FINITE PUMPED FOR ELECTRIC CARS CHEMICAL INDUSTRY WORKING IN THE LONG LINES

N.M. Aripov, Sh.Yu. Usmonov

Tashkent, Uzbekistan. Tashkent institute of engineer rail-freight traffic, Adilxodjayev str. – 1.
Ph.: +99871-235-23-16, +99891-673-84-92, e-mail: usshyu@mail.ru

Keywords: *electric drive, pumping machines, long pipeline, automatic control system, finite control, supply, wave, gate.*

The application of controlled electric drives (ED) for the pumping machinery (PM), pumps, compressors and fans at a number of chemical facilities productions requires a special approach because of water hammer and pressure fluctuations in a long line (LT) in regulating the speed turbo machinery, changing the operating parameters of piping systems [1].

The appearance of oscillations in the ED-PM-LT is conditioned by the fact that long lines are objects with distributed parameters [2]. A change in pressure at any point in the system causes a pressure wave propagating through the pipeline at a rate determined by the speed of sound in the medium pipe stiffness of the pipe material, its thickness, etc.

The pressure fluctuations also occur in the presence of the piping system of closed contours or objects that reflect the pressure wave. As such it may be masked or a closed valve check valve, pressure regulator, or the open end of the pipe. In this arrangement, the pipeline system for automatic control system (ACS), ED, stabilizing the pressure at a specific point of the pipeline, and the leakage contributes to the oscillatory process along the entire length of the pipeline.

To study the dynamical regimes pipeline is represented as a linear tube with valve at the end (Fig. 1). Wave propagates from one end of the pipeline to another in a time τ and is reflected from the valve by a factor reflection k_r. Hydraulic losses are taken into account the linearized coefficient a [3].

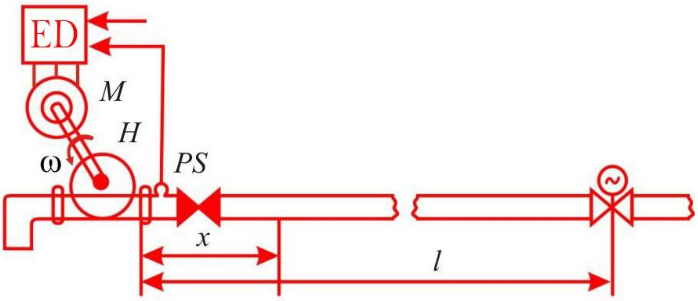

Figure 1. ***Functional diagram of the system "Electric drives-pumping machinery-long line".***

Here we consider two cases of oscillations: Start the pump at the closed valve and stop the pump working on a column of liquid. Such a representation of the problem reflects the typical cases of pressure fluctuations on the length of the pipeline.

Unsteady motion of a real fluid with subsonic velocity in a long line (Fig. 1) is characterized by the relation [4]:

$$\left.\begin{aligned} \frac{\partial H}{\partial x} &= \frac{\rho}{s}\left(\frac{\partial Q}{\partial t} + 2aQ\right) \\ -\frac{\partial H}{\partial t} &= \frac{\rho c^2}{x} - \frac{\partial Q}{\partial x} \end{aligned}\right\} \qquad (1)$$

where x – coordinate of the current length l ($0<x<l$), m; $Q(x,t)$ – the liquid flow rate through the cross section of the pipe, m^3/s; s – cross sectional area of pipe, m^2; ρ – density of the medium, kg /m^3, c – speed of sound in the medium, m/s, H – the pressure in the pipeline, Pa.

The transfer function of pressure at the end of the pipeline and feed in the early pipeline on its head in the beginning, starting from (1) has the form [3]:

$$W_н(p) = \frac{H_{x=1}(p)}{H_{x=0}(p)} = \frac{(1+k_0)e^{-\tau p}}{1+k_0 e^{-2\tau p}} \tag{2}$$

$$W_Q(p) = \frac{H_{x=0}(p)}{H_{x=0}(p)} = \frac{s}{\rho c}\,\frac{1+k_0 e^{-2\tau p}}{1+k_0 e^{-2\tau p}} \tag{3}$$

where $k_0 = (ks/\rho c-1)/(ks/\rho c+1)$ – the coefficient of wave reflection from the end of the pipeline; k – the linearized coefficient taking into account the degree of closure of the valve, $H_{x=l}$, $Q_{x=l}$ –the pressure and flow at the end of the pipeline; $H_{x=l} = kQ_{x=l}$;, $\tau = l/c$ – time propagation of pressure in one end of the pipeline.

The equations of the pipeline are a model of a long pipeline downtime, which can be realized by using delay elements. I mean the Dual beam with the PI speed and current regulators, given the characteristics of $H(Q)$ and $N(Q)$ pump, and also taking into account (2) and (3), we obtain the block diagram of the automatic control PM-ED-LT (Fig. 2).

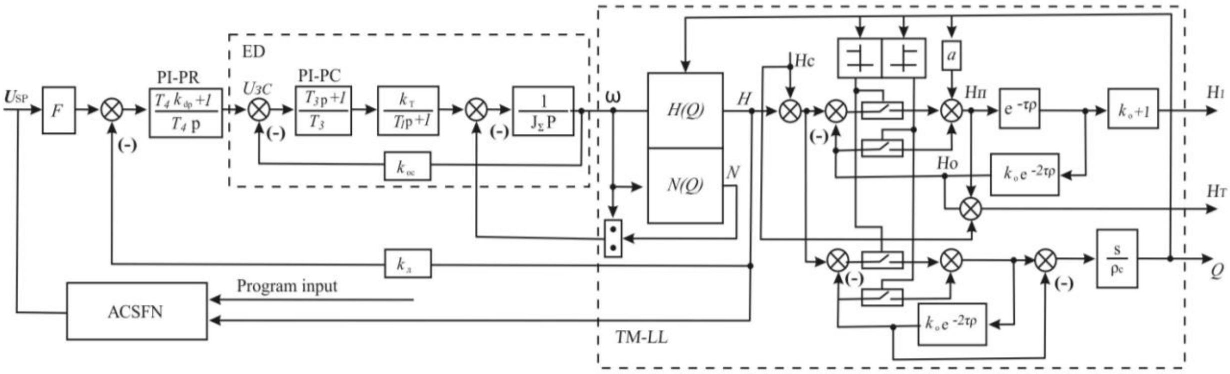

Figure 2. ***Block diagram of autopilot "PM-ED-LT".***

On the basis of the model can be judged on the parameters of the oscillations in different systems of the pipeline, the impact of pipeline parameters (length, diameter, wall thickness and tiffness of the pipeline material and the density of the liquid inside of it) on the temporal characteristics and magnitude of fluctuations.

As a result of linearization of the pressure characteristics turbo machinery taking into account the transfer function of the pipeline can write the linearized transfer function of the PM-LT (head H and Q at the beginning of the supply pipe) on the speed of rotation turbo machinery ω_{dv}:

$$W_{Hn}(p) = \frac{H(p)}{\omega_{дв}(p)} = k_н\,\frac{1+k_0 e^{-2\tau p}}{1+\lambda k_0 e^{-2\tau p}} \tag{4}$$

$$W_{Qn}(p) = \frac{Q(p)}{\omega_{дв}(p)} = k_н\,\frac{s}{\rho c}\,\frac{1-k_0 e^{-2\tau p}}{1+\lambda k_0 e^{-2\tau p}} \tag{5}$$

where k_n – coefficient of the linearization of the curve on the rate of pressure turbo machinery; $\lambda = 1\text{-}2k_{xn}s/\rho s$ – coefficient of the degree of oscillation of the system, depending on the stiffness characteristics of turbo machinery ($\lambda \approx 0{,}6$); k_{xn} – stiffness characteristics of the pump in the vicinity of the operating point.

In many practical cases, the ACS pressure in the pipeline is used to maintain a given pressure in the pipeline and process of perturbing influences coming from the pipeline in different operation modes.

For the synthesis of ACS rather than frequency methods to ensure the desired quality of transient processes in the unit step exposure, appropriate to apply the method of optimizing regulators by ACS maximum damping in the system from the disturbing effects in the maximum system performance.

Having the information on the forward and backward waves, we can construct a system automatic control for any pipeline on the basis of the principle of finite control [1,2]. Functional diagram of the system is shown in Figure 3.

The object of regulation is a regulated electric ED, resulting in the pump *N*, which in turn pumps the pressure of fluid in a long line with uncertain parameters. Automatic control of pressure control system provides the pressure in the pipeline (CSPP), giving a speed reference REP.

Feedback signal to the pressure coming from the pressure sensor PS optimal Wiener filter is filtered (WF), which allows you to allocate useful signal of the controlled pressure and avoid the occurrence in the system oscillations. Knot formation feedback (SFBL) generates signals proportional to the forward and backward waves.

The main unit is CSPP GIS, which forms the reference signal pressure in accordance with the form of a finite control [2] for constant feedback and support continuous wave direct wave when you change back to the accordance with the principle of finite control. The node identification and configuration (SIC) identifies the parameters of the pipeline and the setting of GIS and taxiways in accordance with these parameters. Managing the entire system of automatic regulation is carried out by an external control system in accordance with technological requirements.

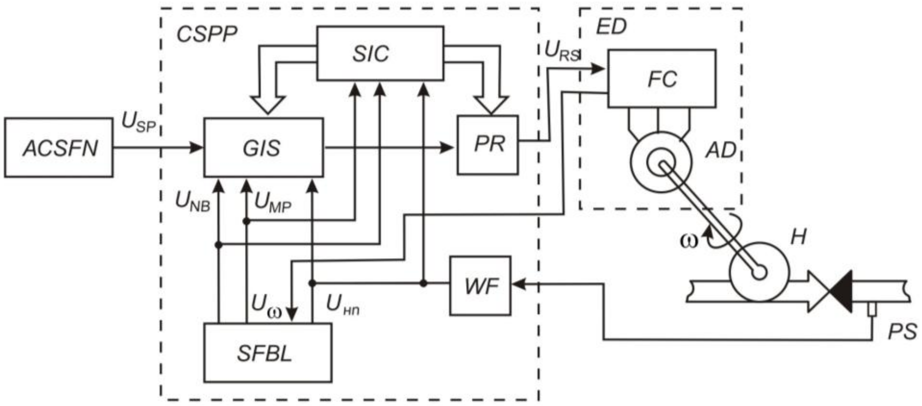

Figure 3. ***Functional diagram of the automatic control system pump working on the pipeline.***

The simulation results of the ED-PM-LT, for example, ostonova pump operating at the liquid column (Fig. 4), show that the ACS, based on the principle of finite control, to avoid large pressure surges.

In practice the principles of the finite control is implemented in a block of digital pressure regulator (BDPR), developed on the basis of the microcontroller. This BDPR provides automatic maintenance of pressure on the discharge manifold pump station by changing the speed of the two variable speed ETA1-03, electric motors with a A112-4M (320 kW, 1500 rev/min), pump SE 1250-70-11. Replacing the conventional PI pressure BDPR was to avoid pressure fluctuations of demand.

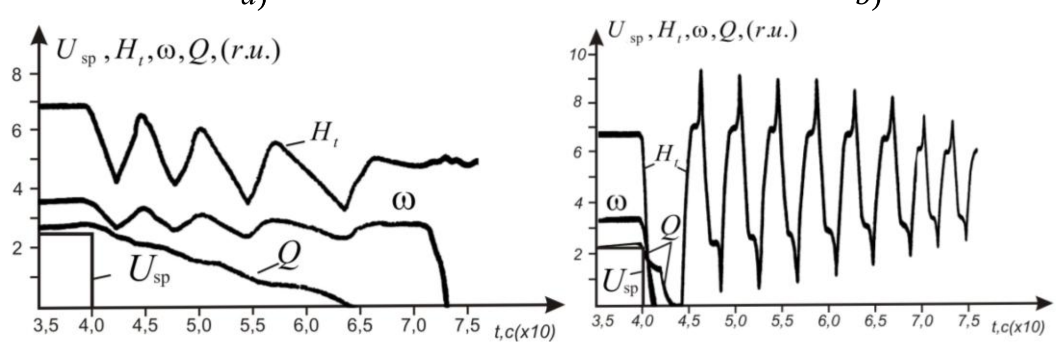

Figure 4. ***The curves of the transients in the ED-PM-LT when stopping the pump working on a column of fluid: a – during the rapid discharge pressure of the pump; b – in the finite control pressure; U_{zd} – set pressure, N_1 - the pressure in the pipeline for the pump; ω – rotational speed of the pump, Q – flow pump.***

The block diagram is shown in Figure 5 BDPR. The controller provides three modes of operation:

- Mode of finite control pressure in the pipeline;
- Mode of proportional-integral pressure regulator (PIPR) with variable time constant control;
- Shutdown mode the regulator pressure.

The principle of its operation, the finite control is in maintaining a constant pressure of the direct wave in the pipe when the backward-wave and the formation of a pressure control during times 4τ.

BDPR consists of a proportional-integral pressure regulator PR, unit switch modes USM and two channels of the signal at the input of the error of PR. USM is calculated from the signals of pressure and pump speed (U_n, U_ω), the values of forward and backward waves. Backward-wave signal is filtered by the filter F. U_{no}.

If the change U_{no} exceeds a certain value (threshold), a signal, and U_{ro} – enables the backward wave (RM). In this mode, the value of the direct wave is kept constant, since the error at the input of the PR is formed as the difference recorded when you turn the RA and the current values of the direct wave U_{np}.

If the change does not exceed U_{no} threshold, a signal U_{rp} and finite-enables the formation of the direct wave (RP). The error signal is formed as the difference in signal intensity of a finite set point (SIF) and the pump pressure signal U_n.

Rate of increase of the output signal SIF is constant throughout the RP mode and is determined by the value of fixed pressure difference between the reference signals U_{zd} and the pump pressure U_n. The time constant of the SIF chosen such, that the recorded difference was reduced to zero during a multiple of 4τ.

A new, different from the traditional, self-tuning regulator, the structure has a high speed and does not depend on the work of the spatial parameters of the pipeline, its scheme and its possible changes.

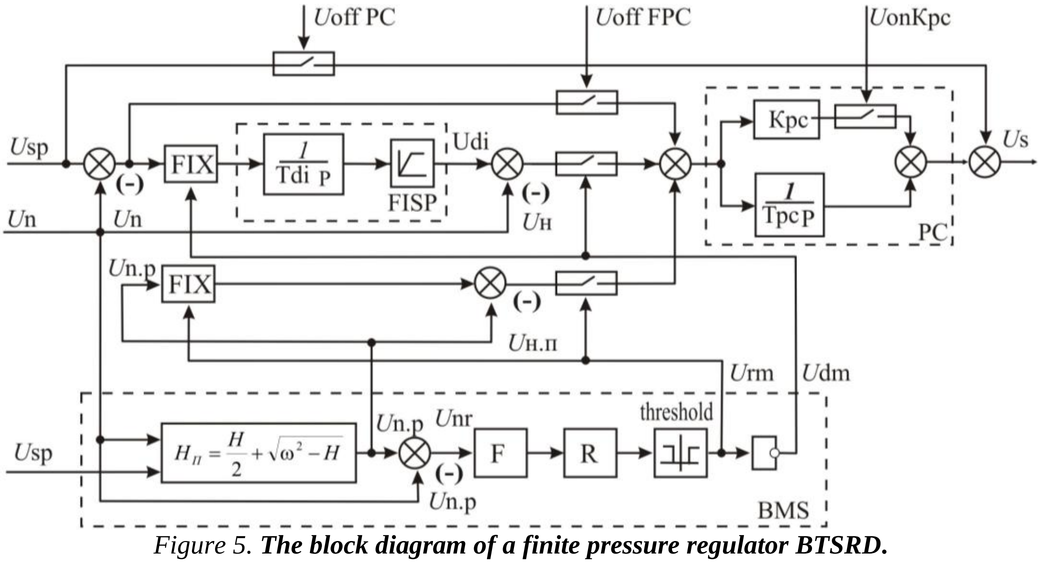

Figure 5. ***The block diagram of a finite pressure regulator BTSRD.***

The simulation results show that the system automatically control of electric pumping machinery, built on the principle of finite control, to avoid pressure surges, and absorb vibrations to practice in all cases.

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RECONSTRUCTION STRATEGY OF THE SERVICING THE SYSTEMS OF THE RAILWAY AUTOMATION AND TELEMEHANIKI ON BASE DEVICE COUNT OF THE AXISES

N.M. Aripov, D.H. Baratov, S.T. Boltayev

Tashkent, Uzbekistan
Tashkentskiy institute engineer rail-freight traffic
Ph.: (+998 90) 957-10-88, sunnat_3112@mail.ru

Keywords: *systems of the railway automation and telemechanics, device of the count of the axises, technical diagnose, safety of the motion, reconstruction strategy of the service, itselfcheckability tester, boolean functions, interpretting program.*

At system device usages of the railway automation and telemechanics on base device count of the axises decision problems technical diagnose has paramount importance. Their refusal can cause the delays a train and, in worse the event, condition the breach to safety of the motion [1, 2].

At usages modern microelectronics and computer systems such as device of the count of the axises expedient transition to reconstruction strategy of the service. These systems on order сложнее, than relay-type so necessary using intolerant and easy diagnosed device that can be marketed with the help of corresponding to mathematical device.

We shall consider the results of the study protected from error interpreting program realization itselfcheckability tester for codes with constant weight. The logical functions tester introduce by means of parentheses-free postfix writing the system boolean function [3].

Under program realization discrete automaton with finding refusal of quality of the built-in program checking are used program itselfcheckability tester (ICHT). In this case the main program blocks compute the boolean function y1, y2, … yn for internal variable automaton, herewith necessary to check the number m variable y, equal unit (the weight of the internal condition). This is realized program block, computing m/n-ICHT.

Experimental is shown that exist the program realizations ICHT in microprocessor system, possessing high degree itselfcheckability. The studies were conducted for class single error - a distortion of one bit in word of the code of the program or in word data.

The Studies have shown that characteristic itselfcheckability is greatly provided beside that program realization, which reflect the structure boolean function (BF), describing ICHT. However best method (with standpoint itselfcheckability) - a method of the direct calculation BF is complementary. So if in system of the programs, in her different checkpoints, is required compute different ICHT, necessary to form and debug different programmy. in this connection suitable to have united interpretting program (IP), to which possible was address as to subroutine at calculation any m/n-ICHT.

The interpretting methods to program realizations BF do not take into account the structure molded and so have low protected from mistake. We shall consider the interpretting method of the calculations postfix parentheses-free record molded. This method takes into account the structure BF and allows to calculate any arithmetical or logical expression. Is it Hereinafter considered method applicable to controlling program, realizing systems BF in basis {AND, OR, NOT}. They are analysed classical method (incoherent) and method with keeping of information intermediate variable (coherent). It is shown that at calculation ICHT second method provides best protected from error.

The symbol variable their own operand always follow in postfix parentheses-free record BF statement symbols. This does the parentheses excessive. The operations are executed consecutively, in order of the viewing the array of the description. For temporary keeping input, intermediate and output variable is used stack.

We shall carry this characteristic on program realization of the system BF. Herewith, the alike fragments molded in system BF are calculated once, but at calculation following BF fragments are changed by their importance, computable earlier. We shall name the intermediate variable result of the calculation of a certain fragment of the formula. In general event order calculations and substitutions intermediate variable can be free so often does not manage to organize keeping intermediate variable in stack. For their keeping necessary to organize the separate random access array.

Herewith in postfix parentheses-free writing the system BF are in addition entered official symbols $\uparrow Yj$ and $\downarrow Yj$, meaning accordingly record and reading intermediate variable Yj. The array of the system definition BF in liason program realization contains four groups symbol: 1) symbols sending input variable; 2) statement symbols and symbol of the completion of the array; 3) symbols record intermediate variable; 4) symbols reading intermediate variable.

For their distinguishing is used identifying sign (IDP), which is situated in three senior bits of the word of the array opisaniya. for the reason provision protected from single error codes IDP have a code distance not less dvuh. in remaining portion of the word of the array encoding as follows: a) for input variable - a relative address *i* variable X*i* in array input variable; b) for intermediate variable - a relative address j variable Yj in array intermediate variable; v) for statement symbol - an operations AND, OR, NOT, N and Z symbols.

The way of the assotiative coding variable for protection from error, bring about change one variable on another, concluding in that that word variable is split on information and assotiative part is offered in [4]. Each input, intermediate and output variable have different importance of the assotiative part. For ensuring characteristic itselfcheckability interpretting program realization by method postfix parentheses-free record array input variable is coded associatively. On fig.1 is shown algorithmic scheme liason interpretting program, executed in the manner of subroutines.

Characteristic itselfcheckability is provided itselfcheckability of the system BF for distortion her molded, assotiative coding variable and coherence to program realization.

For testing of each elementary boolean operation, realized by microprocessor, is required have four input set. In scheme m/n-ICHT on word of the code "m from n" is guaranteed check of each logical element and and OR on three sets of the shortened test since they are considered constant to faults, which can not bring about transformations of the logical function of the element. However in program realization of such transformations possible, for instance, command transformation ORA→XRA.

The analysis all ICHT from catalogue [4] has shown that at least for one logical element of each type (AND, OR) is provided presenting on entering the trivial test from four sets in IP all boolean operation of each type executes one block (the blocks 6, 8, 10), which, consequently, is checked by trivial test at least at calculation ICHT once. The transformations statement symbol in array of the description BF come to light since change to operations to conjunctions on operation of the disjunctions conversely comes to light on shortened test. The other transformation statement symbol, not breaking mechanism to addressing the stack, in program does not exist.

Results of the studies liason and incoherent program realizations 1/6-ICHT is presented in tabl. 1. The analysis result studies IP (the indicator panel. 1) shows that coding by variable assotiative code gives get fat protected from single error, since number wrong two-rail result is a zero. The type of the coding input variable in tabl. 1 is accepted such, either as in(to;at) functioning [4].

The characteristic itselftestable is not provided completely, but number undetectable error small: 25 errors (4,81 %) beside incoherent program and 29 (3,9 %) beside liason. Analysis these error has revealled two reasons of their existence:

- a command system of the microprocessor is surplus and one command can have a different codes;

- some distortion IP bring about such error, which do not come to light in hardware realization ICHT.

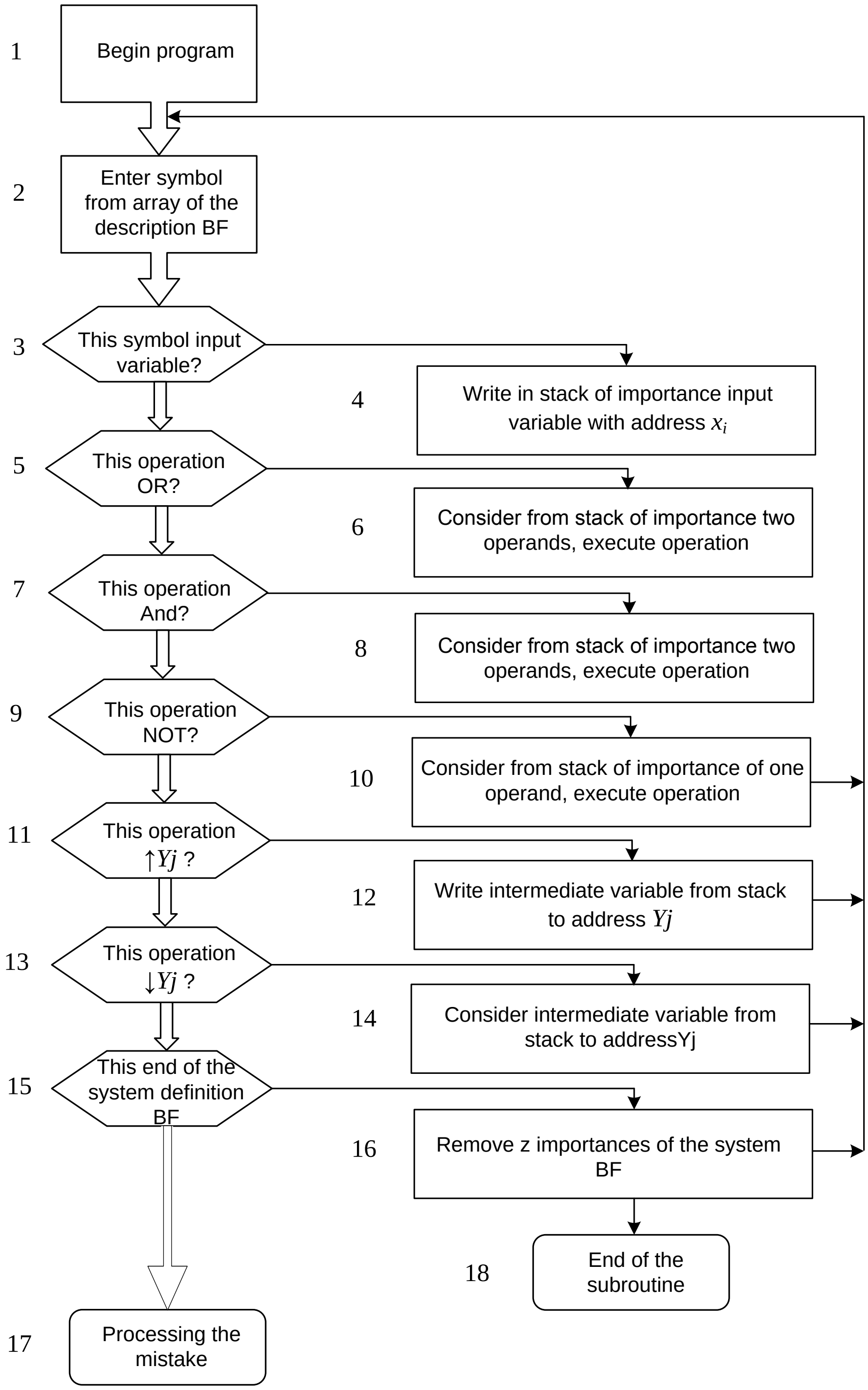

Fig.1. ***Algorithmic scheme liason interpretting program.***

Results of the studies of the array of the description 1/6-ICHT are received. The data show that liason realization gives get fat itselfcheckability from single error regardless of way of the coding variable (the number wrong result and undetected error is a zero).

Results of the studies liason and incoherent program realizations 1/6-ICHT is presented in table 1.

The studies of the program have shown high secured and when contributing multiple error in word IP and array of the description BF. The number multiple error word of the program is $2^p – 1$, where p - class word (for eightclass of the word - 255 all multiple errors).

The interpretting program realization has one-hundred-percent secured from mistake any degree multiple. The characteristic itselftestable is provided only beside array of the description to liason program realization.

Table 1

Results of the study when contributing error in interpretting program

Type of the coding input variable	(00, 01)		(55, *AA)*	
	Type IP			
Amount:	incoherent	liason	incoherent	liason
studies	3120	4944	3120	4944
mistake	520	824	520	824
correct result	337 10,80 %	411 8,31 %	186 5,65 %	238 4,81 %
wrong two-rail result	31 0,99 %	53 1,07 %	3 0,01 %	7 0,015 %
defensive result	2752 88,21 %	4480 90,62 %	2931 93,34 %	4699 95,17 %
undetected mistake	23 4,42 %	26 3,16 %	26 5,00 %	28 3,39 %

The results of the studies of the array input variable show that regardless of way of the coding variable is provided full secured and itselftestable program from single and multiple error.

The length array descriptions BF for incoherent (Lнс) and liason (Lс) program realization are defined on formula:

$$L_{\text{нс}} = 2C - z + I + 1, \tag{1}$$

$$L_{\text{с}} = 2G - S - z + I + 1, \tag{2}$$

where with - a number of the letters in system BF, recorded in right part equality; z - a number BF in system; I - a number inversion in system BF; G - a number of the letters in system BF, including intermediate variable, recorded in right part all inequality; S - a number substitutions intermediate variable in system BF.

Running time of the programs is found

$$T_{\text{нс}} = A_1 + A_2C + A_3D + A_4K + A_5I, \tag{3}$$

$$T_{\text{с}} = A_1 + A_2C + A_3D + A_4K + A_5I + A_6M + A_7S, \tag{4}$$

where D, K, I - a number sign to disjunctions, conjunctions and negations accordingly; M - a number intermediate variable.

The Factors A1, A7 can be calculated for each concrete program realization and

Completion table 1

Results of the study when contributing error in interpretting program

Type of the coding input variable	$\{4K_1, 8K_1\}$		$\{0K_2, 1K_2\}$	
	Type IP			
Amount:	incoherent	Amount:	incoherent	Amount:
studies	3120	4944	3120	4944
mistake	520	824	520	824
correct result	250 4,81 %	177 3,58 %	150 4,81 %	193 3,91 %
wrong two-rail result	0 0 %	0 0 %	0 0 %	0 0 %
defensive result	2970 95,19 %	4767 96,42 %	2970 95,19 %	4751 96,09 %
undetected mistake	25 4,81 %	28 3,39 %	25 4,81 %	29 3,52 %

concrete type computing device. In considered event at realization micro-COMPUTER c clock rate fт = 2,0 MHZ have: A1 = 49,5 мкс; A2 = 28,0 мкс; A3 = 68,5 мкс; A4 = 77,0 мкс; A5 = 78,0 мкс; A6 = 73,0 мкс; A7 = 77,0 мкс.

The experiments have shown that time of the calculation m/n-ICHT interpreting program in 1,5 3 times more, than time of the calculation of the similar program of the direct calculation BF.

Thereby, designed interpreting program realization of the system BF is a generalized facilities of the built-in program checking in program system and is used in program system, realizing algorithms of control with finding failure device of the systems of the railway automation and telemechanics built on base device count of the axises.

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STRUCTURAL COMPLEX CONFIGURATION PLATE MATHEMATICAL MODELING AND OPTIMIZATION

Sh.A.Nazirov, S.H.Yakubov

Tashkent University of information technologies, Karshi State University

Abstract: *This paper examines the optimization problem of lamellar complex configuration structures. The results of a complex configuration plate structures' weight optimization calculation.*

Keywords: *Mathematical modeling, optimization, plate design, a complex form, methods of solution, R-function, various methods, numerical experiments, software package.*

1. Introduction

In the design of various engineering structures, namely the construction of facilities, aircraft, missile, ship, etc. - there are problems of complex configuration (not rectangular plate shape, with cut-outs, multiply, etc.) lamellar structural elements calculation and optimization. The mathematical complexity of the calculation of these arbitrary shape plate elements, especially their optimization, resulted in a significant research and publications backlog on these issues from the calculation and optimization of the "traditional" types of structural elements.

2. Statement of the Problem

The problem of engineering design optimizing will be put as mathematical programming problem: it is necessary to determine the vector $X(x_1, x_2, \ldots, x_n)$ optimized parameters x_i $(i=1,\overline{n})$, giving the objective function F(x) extreme (for definiteness, we take min), keeping restrictions on the parameters $a_i \le x_i \le b_i$, $(i=1,\overline{n})$ and functional limitations $f_j(x) \le 0$ $(j=1,\overline{m})$. This problem can be written

$$\begin{gathered} F(X) \to \min, \\ f_j(X) < 0 \quad (j=1,\overline{m}), \\ a_i \le x \le b_i \quad (i=1,\overline{n}). \end{gathered} \tag{1}$$

We shall consider equation (1) in details. The most commonly accepted parameters to be optimized in the structural elements are geometric (plate thickness h, curvature radius R_1, external and internal edges, cutouts, etc.) and physical (elastic modulus E, etc.). The lower a_i and upper b_i meanings of x_i limits of parameters are defined on the basis of design and technological, operational, etc. requirements. For the objective function F(X) the most commonly accepted parameters are: weight, materials consumption, the cost of construction.

The main functional constraints $f_j(X) \le 0$ $(j=1,\overline{m})$ for engineering structures, subjected to various external influences, optimization, are the following.

1. Stress state restrictions :

$$\max \sigma^{(\psi)}{}_{экв}(X) \le [\sigma]^{\psi} \qquad (\psi = 1, n). \tag{2}$$

Here ψ is the number of variants of the design impact; $\max \sigma^{(\psi)}{}_{eq}(X)$ - the maximum equivalent structural stress, defined according to the accepted hypothesis, or theory of strength, with

ψ - м version of the impact, $[\sigma]^{\psi}$ - the allowable stress for the material of construction in the - m option exposure.

To the canonical form (1) restrictions (2) come as follows:

$$F_1(X) = \max \sigma^{(\psi)}_{eq}(X) - [\sigma]_{\psi} \le 0.$$

2. Deformed state restrictions :

$$\max\left|u^{(\psi)}(X)\right| \le [u]^{\psi},$$

where $\max\left|u^{(\psi)}(X)\right|$ - the maximum the surface structure displacement with m -option impact, $[u]^{\psi}$ - allowable surface structure displacement.

In the canonical form:

$$F_2(X) = \max\left| u^{(\psi)}(X)\right| - [u]^{\psi} \le 0.$$

3. Stability conditions:

$$P^{\psi} \le P_{cr,}$$

where P^{ψ} - compressive force with ψ -effect, P_{cr} - the critical force on the structure.

In the canonical form:

$F_3(X) = P^{\psi} - P_c \le 0.$

4. Restrictions on the natural oscillations frequency. The variable (periodic) loads activity at a certain frequency demands to analyze natural frequency constraints :

$$\min\left\{w_i^{(\psi)}(X)\right\} \ge [w]^{\psi} \quad (i = 1,2,\ldots),$$

where the $\min\{w_i^{(\psi)}(X)\}$ is the lowest natural ψ -x oscillation frequency, $[w]^{\psi}$ -the lowest allowed natural ψ -x oscillation frequency, appointed as the calculated value of the compelled ψ vibrations.

In the canonical form:

$$F_4(X)=[w]^{\psi} - \min\{w_i^{(\psi)}(X)\} \le 0$$

5. Mechanical vibrations amplitude constraints:

$$a_0^{(\psi)}(X,w_i) \le [a_0(w_i)^{\psi}],$$

where $a_0^{(\psi)}(X,w_i)$ is the maximum forced ψ x- oscillations amplitude with the w_i frequency; and $[a_0(w_i)^{\psi}]$ is the permissible amplitude.

The above mentioned restrictions are most common in the structures ‘ optimization, but the certain structures optimization solving tasks may require additional structural, technological, operational and other constraints.

Problem (1) of complex configuration structures engineering optimization is non-linear programming problem, which has a number of specific features. First, the calculation of the objective function (weight, cost) needs much less time than to check the restrictions, which require the construction calculation direct task solving, Second, the global minimum will always be at a border or at their junction, otherwise we will have a stockpile of material, that can be removed without violating the conditions of strength, stiffness, stability, etc. Third, the form of the σ(X), u(X), P_c(X) etc. functions are a priori unknown and can only be determined numerically. Thus, to solve the problem (1) we shall apply the algorithms described in [2-15] taking into account the above features. The algorithm has high convergence speed and reliability.

3. Calculation methods.

Let us consider the methods for solving the direct problem of calculation.

It is known that the equations of equilibrium, fluctuations and the stability of anisotropic plates, according to the moments are [1]:

$$\frac{\partial^2 M_1}{\partial x^2} + 2\frac{\partial^2 M_{12}}{\partial x \partial y} + \frac{\partial^2 M_2}{\partial y^2} = q_1(x,y), \tag{3}$$

$$\frac{\partial^2 M_1}{\partial x^2} + 2\frac{\partial^2 M_{12}}{\partial x \partial y} + \frac{\partial^2 M_2}{\partial y^2} + h(\sigma_x \frac{\partial^2 W}{\partial x^2} + \sigma_y \frac{\partial^2 W}{\partial y^2} + 2\sigma_{xy}\frac{\partial^2 W}{\partial x \partial y}) = 0, \tag{4}$$

$$\frac{\partial^2 M_1}{\partial x^2} + 2\frac{\partial^2 M_{12}}{\partial x \partial y} + \frac{\partial^2 M_2}{\partial y^2} + m\frac{\partial^2 W}{\partial t^2} = q_2(x,y,t)\,. \tag{5}$$

Here, W- plate deflection, M1, M12, M2 - the bending and tensional moments, m $=\gamma$ h $/$ g, γ - the volume weight per unit, g - plate gravity acceleration, h - thickness.

Relations for the M1, M12, M2, when the plate is isotropic, orthotropic and anisotropic, are given in [1].

Substituting in (3), (4) the ratio of M1, M12, M2, when the plate is isotropic, orthotropic, or in other cases of anisotropy, it is possible to obtain the corresponding equations. These equations are given in many textbooks on the theory of elasticity [1-2].

Equations (3), (4) are supplied with the boundary conditions, and equation (5) –with both boundary and initial conditions.

Here are the types of encountered boundary conditions frequencies [1]:

a) rigidly clamped-edge

$$W\big|_{\Gamma=0}\ \Gamma=0,\ \frac{\partial W}{\partial n}\Big|_{\Gamma}=0$$

b) free-simply supported edge

$$W\big|_{\Gamma=0}\,,\ M_n\big|_{\Gamma}=(M_1\cos^2\alpha + M_{12}\cos\alpha\sin\alpha + M_2\sin^2\alpha)\big|_{\Gamma}=0$$

where $\alpha=(n\wedge ox)$ and $\beta=(n\wedge oy)$ are the angles between the normals, relatively the axis Ox, Oy;

c) the free edge

$$M_n\big|_{\Gamma=0}\,,\ (\theta_n + \frac{\partial}{\partial S}M_{n\tau})\big|_{\Gamma}=0$$

where

$$\theta_n = M_1\cos\alpha + M_2\cos\beta\,,\ M_\tau = (M_2 - M_1)\cos\alpha\cos\beta + M_{12}(\cos^2\alpha - \cos^2\beta).$$

In addition, there are possible combinations of these boundary conditions, depending on the plates edges fixing method.

The initial conditions for equations (5) have the form

$$W(x,y,t)\big|_{t=t_0} = W_0(x,y)\,,\ \dot{W}(x,y,t)\Big|_{i=t_0} = \dot{W}_0(x,y)\,.$$

The formation of the matrix to solve the above problems is carried out by V.L.Rvachev‘s R function [12] and Bubnov-Galerkin ‘s [3-4] method s combination.

It should be noted that the direct application of the Bubnov-Galerkin method to solve equations (3), (4), (5) leads to computational difficulties. In this work further for the formation of resolving equations elements we shall use the method proposed in [12].

Here the application of the R – functions method is associated with the coordinate sequences construction, that will satisfy the boundary conditions without any approximations.

Coordinate sequences that satisfy the boundary conditions can be represented as an expansion

$$W = \sum_{i=1}^{n} T_i(t)B(\omega,\phi_i) = \sum_{i=1}^{n} T_i(t)W_i(x,y\ )\,, \tag{6}$$

where Ti (t) are unknown function of time, to be determined;{W_i(x,y)} - a complete, linearly independent system of functions, which we will build, using V.L.Rvachev’s R - functions method [12].

Note that in the case of static’s in the representation (5) instead of $T_i(t)$ function the unknown coefficients C_i will occure.

Substituting (6) to (3) - (5) and performing the usual procedure of the Bubnov-Galerkin method, we obtain the following equation:

$$AC=B, \tag{7}$$

$$A-\lambda B=0, \tag{8}$$

$$M\ddot{T} + AT = F\,, \qquad (9)$$

$$T(t_0) = T_0\,,\ \dot{T}(t_0) = \dot{T}_0\,,$$

where

$$b = \{b_{ij}\} = \frac{1}{S}\left\{\iint_\Omega q_1 W_i d\Omega\right\},\ \{a_{ij}\} = \frac{1}{S}\left\{\iint_\Omega f_{ij} d\Omega\right\}, \text{A=}$$

$$\text{B=}\ \{b_{ij}\} = \frac{1}{S}\left\{\iint_\Omega \varphi_{ij} d\Omega\right\},\ F = \{f_i\} = \frac{1}{S}\left\{\iint_\Omega q_2 W_i d\Omega\right\},$$

$$M = \{m_{ij}\} = \frac{1}{S}\left\{\iint_\Omega m W_i W_j d\Omega\right\},\ T(0) = \mu^{-1} T_1(t_0), \dot{T}(0) = \mu^{-1} T_2(t_0)$$

$$T_1(t_0) = \frac{1}{S}\left\{\iint_\Omega W_0 W_i d\Omega\right\},\ T_2(t_0) = \frac{1}{S}\left\{\iint_\Omega \dot{W}_0\, W_i d\Omega\right\},$$

$$f_{ij} = \left(\frac{\partial^2 W_i}{\partial x^2} + \nu\frac{\partial^2 W_i}{\partial y^2}\right)\frac{\partial^2 W_j}{\partial x^2} + \left(\frac{\partial^2 W_i}{\partial y^2} + \nu\frac{\partial^2 W_i}{\partial x^2}\right)\frac{\partial^2 W_j}{\partial y^2} + \frac{\partial^2 W_i}{\partial x \partial y}\cdot\frac{\partial^2 W_j}{\partial x \partial y}$$

$$\varphi_{ij} = \left(\sigma_x \frac{\partial^2 W_j}{\partial x^2} + \sigma_{xy}\frac{\partial^2 W_j}{\partial x \partial y} + \sigma_y \frac{\partial^2 W_j}{\partial y^2}\right) W_i\,,$$

To solve the system of equations (7) Gaussian elimination or the method of least squares and other methods depending on the properties of the matrix are applied. To determine the critical load the QL – method is applied.

We find the solution of equation (8) under condition (9) with the help of a variety of numerical methods: for example, by the central difference method or the Newmark method, or the method of quadrature sums or,others [4].

It should be noted that in the formation of the matrix, computation of the coordinate functions and their the n-th order derivatives' values, is carried out by the card operations [5, 12]. Here the integrals are computed by the n-point Gauss formula [4].

The above-described numerical algorithm allows to optimize the plate-like structure s of both constant and variable thickness.

Thus, the computational algorithm of plate structures optimization consists of the following steps:

1. Objective function formation.
2. Functional limitations formation.
3. The parameters restrictions formation.
4. The direct calculation.
5. Strength, stiffness, stability and other conditions checking.

In its turn, the direct phase calculation consists of:

- Constructing a sequence of coordinate functions, satisfying the boundary conditions of the problem;
- The solving equation matrix elements formation;
- The equation calculation.

It should be noted that the resolving equations can be algebraic or differential, depending on the problems considered in the static or dynamic formulation.

As mentioned above, the problem of engineering design optimizing will be put as a problem of mathematical programming. Starting from the equation (1), we consider the optimization of weight plates, where $F(X)$ is the weight of a plate of isotropic material under the action of the external load q. Functional limitations, taking into account in the engineering designs optimization , as well as a numerical optimization algorithm of complex configuration lamellar structures are described in detail in [4-9,11,14,15]. As the optimized option we take the plate thickness, constant in the plate range.

4. Experimental calculations.

Task 1. The tightly clamped round the whole contour plate under uniform external pressure q = 10 kg. weight optimization. The radius of the plate is R = 100 cm, elastic modulus is $E = 2^{10} \cdot 6\,кг/см^2$, Poisson's ratio is $\nu = 0.3$,permitted deflection is $[W] = 1\,см$ cm and equivalent stress is $[\sigma_{экв}] = 2550\,кг/см^2$, the gravity (specific weight) is $\gamma = 7 \cdot 8\,г/см^3$, $G(h) = \pi R^2 \gamma h \to \min,\ W_{\max} \le [W],\ \sigma^{экв}_{\max} \le [\sigma_{экв}],\ 1см \le h \le 10\,см.$

Optimization was carried out up to $\varepsilon = 0.01$. We obtained the following results:

$$G_{\min} = 1141.19\,кг, \quad h = 4.6571\ см,$$

$$W_{\max} = 0.8206\,см, \quad \sigma^{экв}_{\max} = 2549.99\,кг/см^2.$$

This problem has an exact solution:

$$W_{\max} = \frac{qR^4 12(1-\nu^2)}{64Eh^3}.$$

With the calculated value of h, we have :

$$W_{\max} = 0.8446\,см.$$

The accuracy of the obtained approximate solution is satisfactory.

Task 2. Optimization of the entire ring rigidly clamped at both the contours plate under uniform external pressure intensity $q = 10\ кг/см^2$.

The outer radius of the plate R = 100 cm, inner - r = 50 cm. The other parameters are the same as in Task 1:

$$G(h) = \pi \gamma h \left(R^2 - r^2\right) \to \min$$

The results are :

$$G_{\min} = 382.95\,кг,\ h = 2.0837\ см,\ \sigma^{экв}_{\max} = 2549.82\ кг/см^2$$

Task 3. Optimization round the whole ring (Fig. 1). All parameters are the same as in Task 2. We obtained the following results:

. $G_{\min} = 134.48\,кг,\ h = 1.126\,см,\ \sigma^{экв}_{\max} = 2549.99\,кг/см^2$

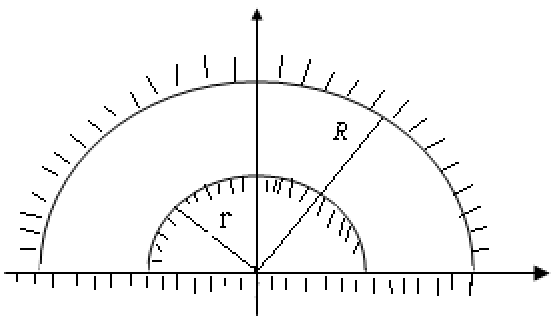

Fig. 1.

Task 4. A square with round neck weight optimization (Fig. 2).

Initial data for the square with a round neck weight optimization calculation:

$$G(h) = (ab - \pi r^2)\gamma h,\ a = 200\,см,\ b = 200\,см,\ r = 50\ см,\ q = 10\ кг/см^2,$$

$$W_{\max} = [W],\ \sigma^{экв}_{\max} \le [\sigma_{экв}], 1см \le h \le 10\,см.$$

The results of the calculation: $G_{\min} = 296.07\,кг,\ h = 3.9767\,см,\ \sigma^{экв}_{\max} = 2546.07\,кг/см^2.$

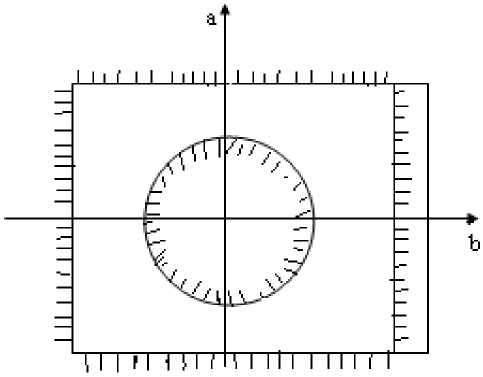

Fig.2.

Task 5. Weight optimization of the figure shown in Fig. 3 Baseline data:

$$G(h) = (ab - 3\pi r^2)\gamma h,\ a = 200\,см,\ b = 200\,см,\ r = 20\,см,$$

$$W_{\max} \le [W],\ \sigma_{\max}^{экв} \le [\sigma_{экв}], 1см \le h \le 10\,см.$$

We obtained the following results:

$$G_{\min} = 725.96\,кг,\ h = 2.5689\,см,\ W_{\max} = 0.1262\,см,\ \sigma_{\max}^{экв} = 2549.9998\,кг/см^2.$$

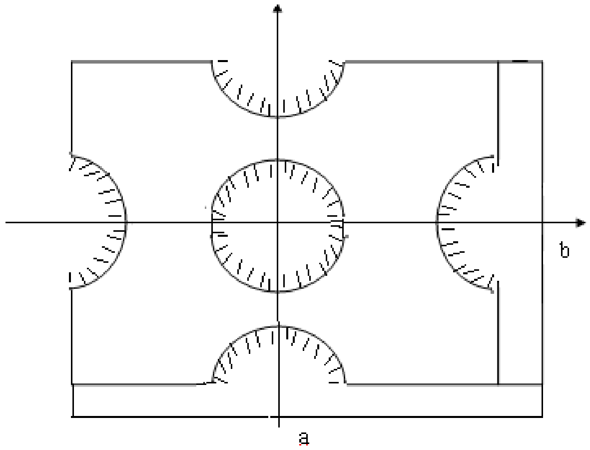

Fig. 3.

Tasks 1 and 2 have the exact solutions and are given only for the algorithm [5] performance monitoring possibility. According to the solved problems, the main limitation (with the taken values $[\sigma_{экв}],\ [\sigma]\ u\ [W]$) is the strength limitation, and the algorithm provided a high degree approximation to the boundary. A variety of forms of plates indicates wide opportunity of applying the algorithm to solve optimization problems of plates of complex configuration [4, 15].

5. Conclusion

Thus, the proposed technique allows to optimize on the weight the calculation experiments of complex configuration design plates.

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STRUCTURE OF COMPLIANCE MODELS OF OPTIONAL ALTERNATIVES IN INFORMATION SERVICE SYSTEM

T.S. Nusratov

Centre for the development of software and hardware-program complexes of Tashkent University of Information technologies Phone: 263 39 39, e-mail: nusratov@inbox.ru

Keywords: *automated information system, central cross-connect, communication switcher, compliance model system, table of functions.*

1. Introduction

It is considered structure of the system to big dimensionality for group decision making. The stated description of the information processes in automated information system (AIS) on base of the models mathematical correspondence to; recommendations are made on possible expansion function AIS.

This article is imbued with the algorithmization ideas of V.K.Kabulov and some recommendations on generalization of development and use of the “Rada-Majlis” information service system for the members of RU Oliy Majlis(Parliament) put into operation in June 1991. The system was developed by cybernetists of the Ukraine by participation of their Uzbekistan colleagues [1]. The analysis of the “Rada-Majlis” automated information system (AIS) shows that it represented a new stage of development of automation that allows adoption of resolutions in complicated situations [2]. The diversity of matters related to development of the system can be classified by means of a systemic approach and the direction of algorithmization being developed by us aimed at elaboration of the “Table of Functions” which V.K. Kabulov took as the basis for research and development of any management system. The architecture of algorithm and of the whole system, like the architecture of any system objects, are expressed by such concepts as component, integrity, link(compliance) and is determined by three factors: component count, their quality as well as by how they are made up into the general architectonics of the system, i.e. by the architecture [3].

Fig. 1 provides the AIS system architecture. The dotted lines indicate potentials for expanding the system. CCC: the central cross-connect; CS: the communication switcher to other local or regional networks.

The architecture model of a quite complicated system cannot be the only one model as it is certainly impossible to identify its architecture, the criteria of assessment of its components. Therefore, let us view the matter more formally from the point of view of its information supply. In order to formalize the synthesis of the AIS system, a graphic model of conformance can be used. In such a case, the information system model will be represented by a multi-level conformance multi-graph

$$\Gamma_{Df} = \langle G, X, Y \rangle \quad (1)$$

where $Y = \{Y_k; k = 1; k_0\}$ is the set of files; $X = \{X_j; j = 1; j_0\}$ is the set of procedures; $G = \|X_{kl}\|$ is the compliance matrix, reflecting architecture of interrelation of files and procedures as:

$$\begin{cases} \lambda_{kl} = 1, \text{ if the file } Y_k \text{ is required for formation of the file} \\ Y_l(Y_k, Y_l \in Y_l) \text{ by procedure } X_{jl}; \\ \lambda_{kl} = 0, \text{ otherwise} \end{cases}$$

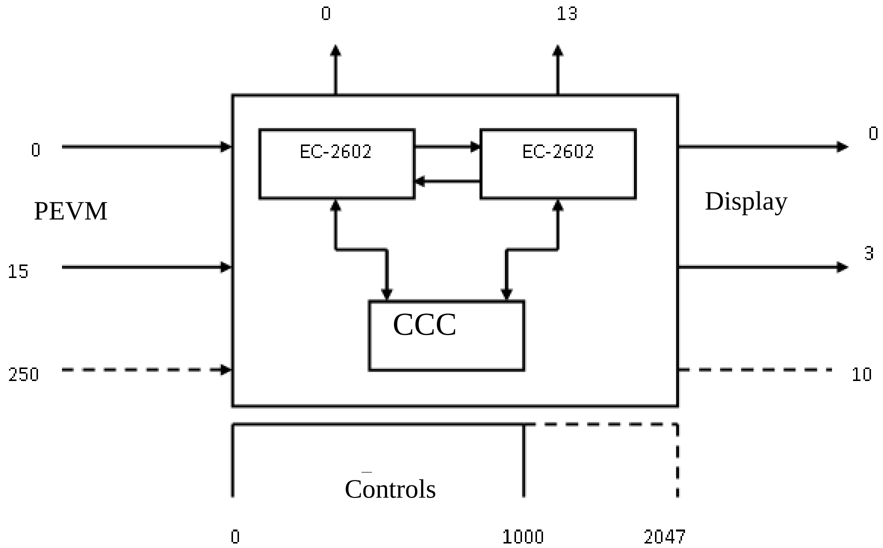

Fig.1. ***AIS architecture.***

Files Y_k will be placed according to apexes, while procedures X_j arc bundles (clusters) that create individual apexes of graph Γ(G). The arrays and their features will be determined:

1) array meaning content;
2) by means of organization slots in records, by means of records from information slots and array of records;
3) by media type;
4) strategy of access to the array while searching for required information and recording the newly received information.

The procedure of transformation of arrays of one type into another and its features will be set up by selecting operators sufficient for performing the required transformation, by the procedure of performance of operators in this selection, by appointment of means of implementation for each operator of the procedure. The features of application of procedure X_j for formation of array Y_k depend on the relevant features of the initial set of arrays $\{Y_k / \lambda_{kl}^{\vee} = 1\}$, procedures X_j and array Y_k being created.

The formalized model of potential options of information system $\Gamma_f = \langle G_f, X_f, Y_f \rangle$ is provided in fig. 2. Here, P is the respondents (sources), while Π is the information users.

Accordingly, $Y_P = \{Y_{Pn}, n = 1, n_0\}$ is the respondents' information arrays and $Y_{\Pi} = \{Y_{\Pi n}, m = 1, m_0\}$ of the information users. The main (basic) arrays are $Y_D = \{Y_{Dv}, v = 1, v_0\}$, intermediate arrays: $Y_{\pi} = \{Y_{\pi r}, r = 1, r_0\}$. The system inputs and outputs, respectively

$$Y_{input} = \{Y_{np\eta}, \eta = 1, \eta_0\}; \quad (2)$$

$$Y_{input} = \{Y_{np\mu v}, \mu = 1, \mu_0\}. \quad (3)$$

Input formation subsystems:

$$X_{P-input};\ Y_P \to Y_{input}, \tag{4}$$

of intermediate arrays from input

$$X_{input-\pi};\ Y_{input} \to Y_{\pi}, \tag{5}$$

of main arrays from input

$$X_{input-D};\ Y_{input} \to Y_{D}, \tag{6}$$

And from intermediate arrays

$$X_{\pi-D};\ Y_{\pi} \to Y_{D}, \tag{7}$$

of intermediate arrays from main

$$X_{D-\pi};\ Y_{D} \to Y_{output}, \tag{8}$$

Of required output from main arrays

$$X_{D-output};\ Y_{D} \to Y_{output}, \tag{9}$$

and directly from system output

$$X_{input-output};\ Y_{input} \to Y_{output}, \tag{10}$$

As well as with use of intermediate arrays

$$X_{\pi-output};\ Y_{\pi} \to Y_{output}. \tag{11}$$

In the formalized model of potential options of the information system $\Gamma_f = \langle G_f, X_f, Y_f \rangle$ for each information array $Y_k \subset Y_f$ it is possible to select various options of procedures $X_\xi \in X_f$; set Y_f contains potential options of organization of information arrays, while to each option of procedure X_ξ correspond arc bundles λ_{kl}^{ξ}.

If users' set $\{\Pi_j\}$ is set and possibly respondents of information $\{P\}$, as well as sets of information arrays corresponding to them:

$$Y_P = \{Y_{Pn}, n = 1, n_0\}; \tag{12}$$

$$Y_\Pi = \{Y_{\Pi n}, m = 1, m_0\}, \tag{13}$$

then, it is possible that a general task of information synthesis will be set: select optimal option of implementation of the whole system from the graph of potential implementations Γ_f

$$\Gamma^* = \langle G^*, X^*, Y^* \rangle \subset \Gamma_f \tag{14}$$

Taking into account the requirements of the preset quality characteristics, i.e. as per preset optimality criteria.

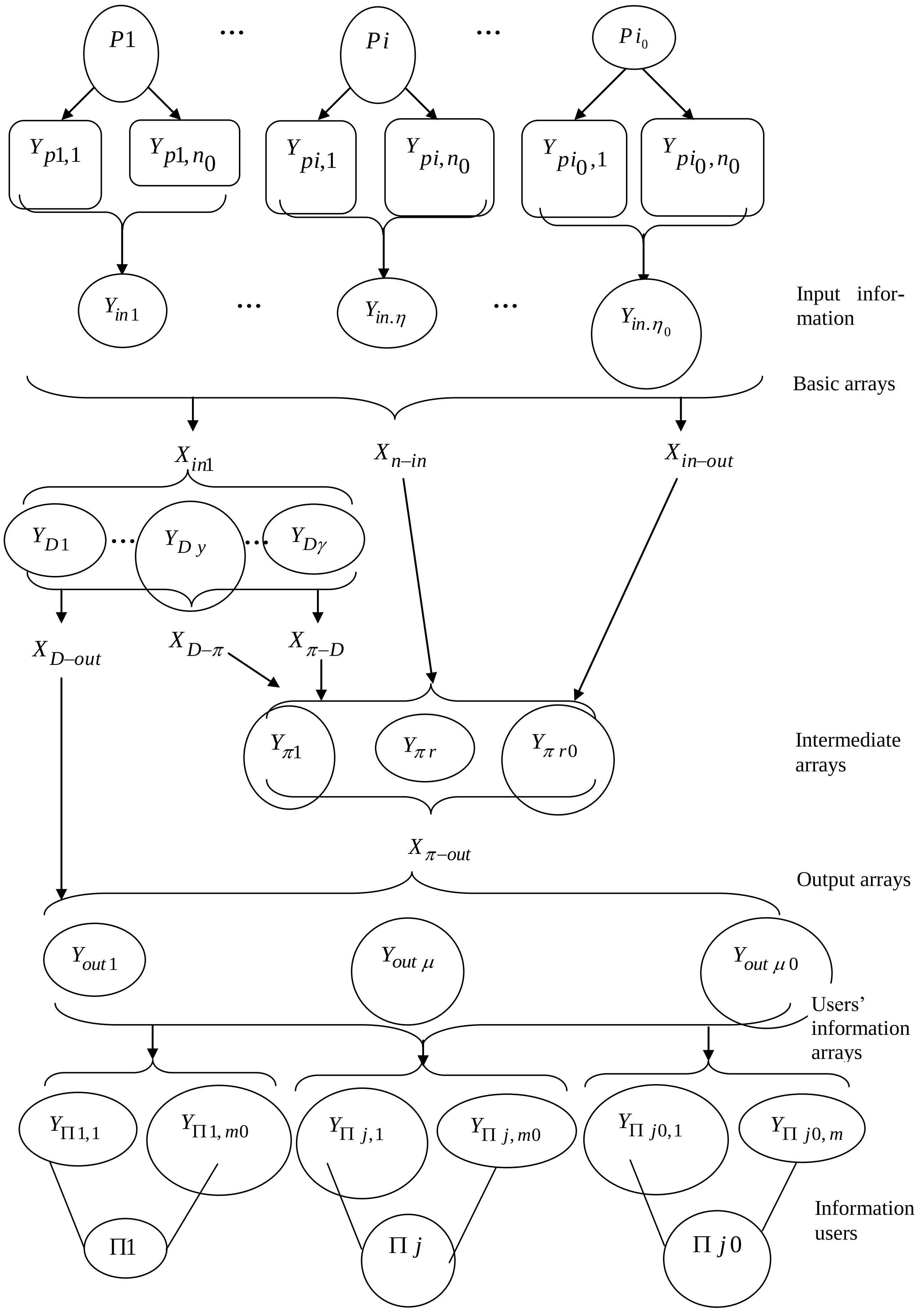

Fig.2. ***Compliance model system.***

At the same time, it has to be noted that the important component system is the database. Therefore, heuristics or aggregated procedures of organization of basic (main) arrays [5] and the model parts related to them can be input on the formal model. Depending on such modular principle, typical and standard programs can be used or typical parts of ready-made designs from which options of expansion of the system can be then built.

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AUTOMATION ENGINEERING DESIGN OF STRUCTURES AND FACILITIES

S.H. Yakubov, Sh.A. Nazirov

Karshi State University, Tashkent University of Information Technologies, Republic of Uzbekistan
E-mail: shnazirov@mail.ru

Abstract: *The basic features of design optimization problems of engineering structures and buildings. The requirements for mathematical models optimization. It is shown that the process of optimal structures and facilities designing is a process of feedback control, which can be represented as a hierarchy of decision making. The main organization and functioning of a software program and CAD principles are developed.*

Keywords*: optimization, system analysis, design automation, mathematical model, mathematical and software, mathematical programming.*

In the formulation of optimization problems in the engineering structures and buildings design an ambiguous interpretation (understanding) of Systems Analysis (approach) can be found): on one hand - this is really an analysis of any existing system, on the other - the formation of the system parameters to achieve the goals. In reality, the two positions go hand-in-hand, because you cannot create a system, that provides goals, without analyzing the contents and determining the actual processes, that lead to the desired result. Systems analysis provides the conditions for joint optimization both structural parts of the system (subsystems) and the system as a whole, as well as computer software. The ultimate goal of systems analysis in the design is an actual design of the system, its subsystems and components for optimum efficiency and economy. Despite the fact that there are no well-defined rules in systematic analysis, the basic features are adequately disclosed in [1].

1. Main design processes of engineering structures and facilities

Taking into account the specifics of the design process of engineering design and construction tasks , the main features of our approach can be displayed in the following :.

1. As an optimized projected engineering design or construction, we take determined appropriate performance of the functions, the complex elements, endowed with specified properties and having links to the abstract and the external environment systems [1-3].

In this complex in the research process we can attached to each element the desired properties without regard to actual performance, to identify the possible contribution of these properties in the studied process and, therefore, justify the requirements for the prospective deal with this item. In practical optimization problems it is assumed that the properties of elements and their functional and technical specifications are known and therefore the functioning of the processes is considered in the field of permissible (taking into account the accepted limit) solutions of the systems. Both in first and second, as well as in the case of the software (development of algorithmic systems) evaluation of the complex is considered with taking into account the totality of known processes and phenomena and the relationship between them. All this highlights such features of the model of designed engineering structures and buildings, that contribute to the elucidation of the functioning of this complex in order to select the least weight or cost.

The most significant is that in all cases, the system includes the concept of a whole consisting of interrelated, interacting and interdependent parts. The properties of these parts depend on the system as a whole, and the properties of the system – on the properties of its parts.

2. The place for specific design and engineering projected construction should be determined in the overall structure of the other systems. The systems approach requires a reasonable allocation of the designed system in general systems structure to maintain the normalizing parameters, dividing it into subsystems.

The design or construction is considered as an independent object of study and optimization, but with the necessary information exchange with the adjacent and external systems, and within it, between the subsystems.

The chosen general structure of systems should clearly delineate the boundaries of the system and contribute to selection (structuring) of its subsystems, which in size are available for research and homogeneous in the description. This provides links to the organization on each successive level, the descent of the system to the individual elements from the top - down with the subsequent transfer of the resulting aggregated data to the top (bottom-up).

Both the overall structure of compensation systems and subsystems of structures and facilities must have inherent properties of integrity: the changes that have arisen in any of their parts, impact on other parts, and on their entirety.

3. Engineering design or construction are presented in the form of the model. Complex systems designing, that the engineering designs and constructions are, requires knowledge of the quantitative and qualitative patterns of the system and its individual elements behavior , depending on the nature of the changes of multiple factors (parameters).

The model should be similar to the original, but differ from it. Its distinctive features are manifested in the fact that it is subjected to such transformations in the right direction, which is not possible in the direct study of the original.

Ultimately, the choice of method is determined by taking into account many considerations, the latter role of which belongs to the convenience of the treatment algorithm, the duration of the account, etc. It is also clear that the tasks require informal activities, opportunities to intervene in the process of counting and to obtain interim results for the implementation of a dialog mode.

4. To assess the quality of designed structures and buildings solutions .a set of indicators is selected. As a rule, the purpose of system analysis is, that for all possible characteristics of external relations, to achieve the best possible (optimal) solutions of designed structures and buildings according to their structural, economic and other indicators. However, the optimum and optimality is not an absolute concept, they require a precise definition of optimality criteria, i.e. the main features on which the effectiveness of different solutions are compared. Solution, the best in one setting and one criteria, may be far worse in other circumstances and other criteria. Optimizing on one criterion (sub optimization), mostly for technical systems is aimed at reducing the cost (in this study the objective function is the weight of the structure).

5. The analysis of the model structures and buildings should be transferred to the real systems. To transfer the solutions to the real object requires confidence in the adequacy of the solution. The adequacy is estimated by the analogy of a real object and the model properties according their main characteristics. Adequacy is achieved if the model fully reflects the stress-deformed state (VAT) of actual projected structures and facilities.

Listed and taken to the execution, the main provisions of the systems approach are characterized by a basic framework of the method, but the efficiency of its use depends entirely on the way of their implementation. In order to systematize and generalize the information about the main symptoms of systemic analysis that contribute to the representation of disparate data in an orderly manner with a smaller number of significant variables, you must:

- systemize relationship between the systems ,designed to maintain the normalized parameters;
- analyze multiple baselines, to find a form of generalization ,suitable for determining the VAT system conditions classification;
- identify the classification structure or structures, contributing to a focused selection of competing options;
- determine the principles of decomposition of systems ,based on the analysis of their aggregate as a whole;
- formulate a basic framework for constructing a mathematical model of the design or construction;
- classify optimization problems ,arising in practice, research and design.

The purpose of the design process is to develop technical documentation, required for the production of design objects and based on both priori (the original) and posteriori (additional) information, obtained in the design .Thus, the design is the process of creating a prototype of an object, indispensable for the object manufacture. Design is essentially a process of feedback control (Fig. 1). Terms of Reference (TOR) produce inputs or outputs, which are compared with the results of the design, and if they do not match, the design cycle repeats itself as long as the error (deviation from the set of technical requirements) is not within limits.

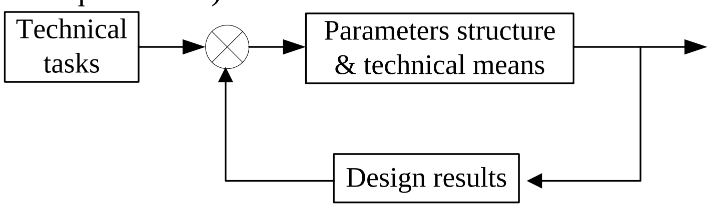

Fig. 1. ***The scheme design.***

The design process is system design, i.e. a set of interacting with each other designers and means, required for the hardware. In essence, the system design can be considered as a complex man-machine multi-loop, multi-dimensional control systems with feedback, requiring the collection, transmission, processing and using information to achieve the design objectives. They should be subject to one or another criterion of optimization, for example, the criterion of minimum length or maximum performance on a limited budget, or the fastest designed system payback criterion, etc. To reduce design time it is necessary to increase the speed of transmission of useful signals, and to prevent interference, i.e. signals, not carrying useful information. The incorrect or inaccurate intermediate results, or an unfortunate choice of the structure of the system design, when the signals, necessary for making decisions on any low level , get to the upper levels, where they can be not only useless but harmful, may give such interference. On this basis, we can conclude that a systematic approach, principles and methods of control theory are of great interest for the rational organization of the design.

"Computer-Aided Design" (CAD) was used in all cases where a computer was used for calculations, related to the design. Currently Apr for engineering structures and buildings is associated with the new stage of development - the creation of computer-aided design (CAD), primarily designed to meet the challenges of scientific research and conceptual, partly technical, design. CAD can be considered as a system of feedback control. Therefore, we can give the following definition, emphasizing the "management" aspect of CAD. CAD is a man-machine or an automated process control system design of engineering structures and buildings and technical documentation, required for the manufacture of the designed object. Common to all CAD systems is that they are, as already was indicated above, regardless of the design object, may themselves be regarded as the automated process control system for the production of technical documentation.

Therefore, the development of a general theory of automated control systems is at the same time the development of theoretical foundations of any CAD objects.

2. Steps to create automated design of optimal structures and facilities

Thus, the essence of computer-aided design of optimal engineering structures and buildings comprises:

1. The development of the optimized mathematical model of the object (the projected design and construction) and the external environment on the a priori available information and the results of the identification of existing facilities or physical models.
2. Structural synthesis on the basis of analysis of the design projected features and construction, determination of the necessary information flows, taking into account the possibility of decomposition of the system and distribution management functions to appropriate levels.
3. Structural synthesis of algorithmic (automated) optimization of engineering structures and buildings system.
4. Definition of the computer interaction modes.
5. Analysis of the results of computer simulation.
6. Clarifying and making amendments to the TOR.
7. Documentation.

Let's call computer-aided design of engineering structures and buildings, carrying out the first five of the above points, a system of automated synthesis.

Certainly the development of CAD engineering structures and buildings must be guided by standard operating system.

One of the most important base to create CAD software application for optimization of engineering structures and buildings, is the method of computational mathematics. However, the "adaptation" of these methods to a form that is possible and convenient for implementation of the computing means, is a complex and laborious process, that represents the life cycle of a software product. The most important step in this process is the development of algorithmic software [2].

Once you made up the algorithm of solutions of a problem, the programming process, i.e. coding algorithm in terms of selected high-level language, or directly in terms of machine instructions starts.

Created (designed) software package (RFP) for the optimization of engineering structures and buildings should have the following features:

- be built in a modular (sub systems) principle;
- have some flexibility in the ratio of hardware and software operating environment;
- availability for poorly prepared in the field of computer science professionals;
- have friendly means of advanced problem-oriented dialogue;
- allow interface with tool support systems: databases, graphics systems, databases;
- allow modification and expansion.

3. The scheme for obtaining the optimal solution

Let’s consider the integrated scheme for optimal solutions. To create a calculation model, taking full account of all the properties of a real object (the deformed system) is fundamentally impossible. The art of choosing the computational model is to identify the basic properties of a real object. After selecting a design model, a mathematical model for describing the strain and stress states, the dynamic processes, etc., connecting the incoming parameters should be composed. Availability and preliminary analysis of a mathematical model, describing the state of a deformable system, allows to give the task of the problem optimization and find an effective mathematical tool optimization. To estimate the received solution (project) it is necessary to define an optimality criterion (the criterion of excellence, quality criteria, the criterion of efficiency, etc.). The objective function $C(x)$ is a mathematical account of the criterion of optimality. Using of the criterion of optimality ,limitations of the mathematical model describing the state, the mathematical apparatus of optimization (optimization techniques) allows you to find the optimal solution, which describes the projected structure (object model).

4. A mathematical model of optimization of cylindrical shells by weight

The problem of optimizing the design put a mathematical programming problem: it is necessary to determine the vector X (x_1, x_2, ...,x_n) of x_i $(i=1,\overline{n})$ optimized parameters, giving the objective function F (x) extreme (for definiteness, we take min), subject to restrictions on the parameters $a_i \le x_i \le b_i$, $(i=1,\overline{n})$; and functional limitations f_j (x)≤ 0 $(j=1,\overline{m})$ [3]. This problem can be written as

$$\left.\begin{aligned} &F(X) \to \min \\ &f_i(X) \le 0 \ (j=1,\overline{m}) \\ &a_i \le x \le b_i \quad (i=1,\overline{n}) \end{aligned}\right\} \tag{1}$$

For example, let's consider the problem of optimization of cylindrical shells by weight. We assume the objective function as

$$F(x) = \int_{\alpha}\int_{\beta} h(\alpha,\beta) R d\alpha d\beta \tag{2}$$

For open shell type codes are given:

a) the boundary conditions;

b) the length of the overlap- a;

c) the width of the overlap;

d) the material of the shell:

E modulus of allowable elasticity; σ - allowable stress; γ - gravity; ν - Poisson's ratio; [U] - allowable transfer (if required limitations on the stress; implementation of strength and stiffness);

e) - a system of external loads;

e) - other restrictions (such as design, technological, etc., if you want to meet them.).

Optimizable parameters are parameters that determine the variation of shell thickness, angle of the shell, which determines the degree of its steepness.

5. The results of computer simulation

At present we have developed the engineering constructions optimization software on the base of global search [3]. It is realized in visual program system Delphi 7.

Task 1. Optimizing of cylinder shell, of rectangular shape, the whole shape hinge supported, under uniform average load of q intensity.

The shell thickness is constant $h = const$.

The physical parameters of shell material: $E = 2\cdot 10^6 \, кг/см^2$; $[\sigma] = 2000 \, кг/см^2; \nu = 0{,}5$ The shell geometrical parameters:

a=150sb=100sm

Load q=1 kg\sm^2.

Optimized parameters h, β_0.

Parameters restrictions :

$$\frac{\pi}{10} \le \beta_0 \le \pi;$$

$$0{,}1см \le h \le 3см$$

Minimized function is the cross–section aria

$$S = R \cdot h \cdot \beta_0$$

Construction restrictions:

$$\sigma_i \le [\sigma],$$

Where σ_1-stress intensity is calculated according to:

$$\sigma_i = \sqrt{(\sigma_{11}-\sigma_{12})^2 + (\sigma_{22}-\sigma_{33})^2 + (\sigma_{33}-\sigma_{11})^2 + 6\tau_{23}^2} \tag{3}$$

Stress values σ_{11}, σ_{22}, σ_{33}, σ_{23},τ_{23} were determined after solution of equations (3), solved according to Ritz method. AS co-ordinate functions were selected beam functions ,which in case of shell hinge support, look like:

$$U_{nm} = \cos\frac{n\pi\alpha}{\alpha_0}\sin\frac{m\pi\beta}{\beta_0};$$
$$V_{nm} = \sin\frac{n\pi\alpha}{\alpha_0}\cos\frac{m\pi\beta}{\beta_0}; \qquad (4)$$
$$W_{nm} = \sin\frac{n\pi\alpha}{\alpha_0}\cos\frac{m\pi\beta}{\beta_0}$$

The optimizing was performed with the help of global search algorithm to within $\varepsilon \approx 2\%$. Calculation results are given in Table 1.

Table 1

Local min	**S sm^3**	**h sm**	**β_0 rad**	**σ_i kg\sm^2**	**Steps**
1	125,0179	0,956369	2,467197	1990	52
2	126,6418	1,125607	1,662033	1977	28
3	114,072	0,8343	2,6613	1989	39
4	165,1633	1,53425	1,320312	1993	42

Figure 2 shows curves $\sigma_i\ (\alpha,\beta)$, corresponding to received minimums.

Task 2. Optimizing of cylinder shell, of rectangular shape, free-supported along edges under uniform load of q intensity.

The shell thickness is variable and is determined according to

$$h = h_0 + h_1 \cdot \sin\frac{\pi\beta}{\beta_0}.$$

Optimized parameters: h_0, h_1, β_0.

$$\frac{\pi}{10} \le \beta_0 \le \pi$$
$$0{,}5\text{см} \le h_0 \le 3\text{см}$$
$$-0{,}5\text{см} \le h_1 \le 0{,}5$$

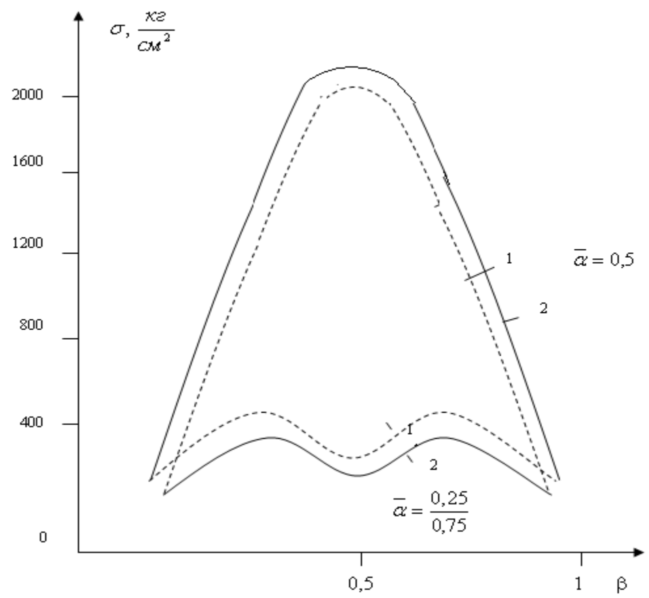

Fig. 2.

The rest parameters are the same as in task 1.

Optimization was performed with the help of global search algorithm to within $\varepsilon \approx 2\%$.

Calculation results are shown in table 2.

Table 2

In. loc. min	S sm^2	h_0 sm	h_1 sm	β_0 rad	$\sigma_{i\,max}$ kg\\sm^2	Steps
1	81,7348	0,38713	0,48340	1,9416	1998,7	57
2	97,8944	0,53173	0,38432	2,3025	1965	24
3	110,0278	1,2699	-0,4740	1,7447	1952	27
4	126,6314	1,0333	-0,1104	2,4939	1946	13
5	114,899	1,0548	-0,21962	2,2839	1936	23
6	106,003	1,0408	-0,0763	1,2513	1999,3	54

Figure 3 shows curves $\sigma_i(\alpha,\beta)$, related to 1-st and 4-th minimums

As we can see from tasks' 1 and 2 solutions results, the usage of cylinder shells of different thickness gives the opportunity to reduce a construction weight by about 14%. Tables 1 and 2 show the effectiveness of global search algorithm use in construction optimization, according to strength criterion.

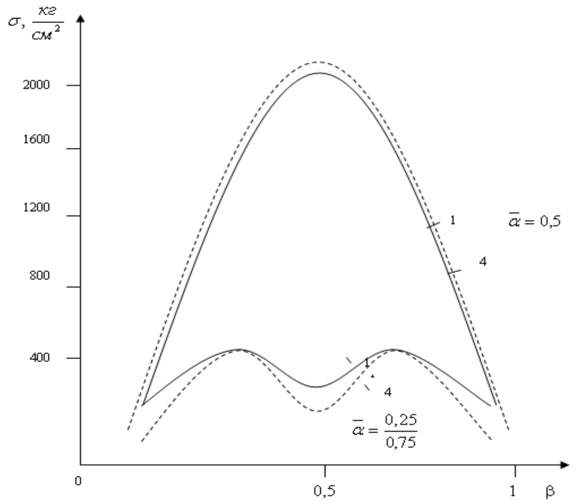

Fig. 3.

If the shell was optimized with the help of global search algorithm with constant step, 22-52 steps were necessary to determine one minimum. The difference of time expenses is essential.

We have studied the specific of engineering construction design process and determined the essence and content of engineering constructions design automation. We have developed engineering constructions optimizing software, based on global search method and worked out the calculation of cylinder shells optimization according to their weight.

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FUZZY ALGORITHM FOR PREDICTION OF THE FORMATION OF QUALITY CERAMIC BRICKS DURING FIRING IN A TUNNEL KILN

T.U. Dzhuraev, S.M. Isaev

Karshi Engineering-Economic Institute, Tashkent information Technologies University, Karshi branch
juraev15@mail.ru

One question that arises in the analysis and automation of technological process of ceramic bricks is to determine the influence of process parameters on the quality of products produced [1]. We found that the quality of ceramic bricks, we can estimate the measure of the density of the finished product [2]. This indicator is closely linked with the quality of accurate indicators of quality, appearance, strength, and frost water absorption finished ceramic bricks.

On the basis of experimental data and performed statistical analysis of input and output signals revealed the most significant factors affecting the quality index of ceramic bricks. They were the maximum temperature zone heating and firing zones of tunnel kiln, as well as the area under the curve of temperature distribution in the heating zone and firing zone. Thus it informative as variables characterize the state of the system, selected the maximum temperature of the burning zone-***x*** and the area under the curve temperature distribution in the firing zone-***S*** [1].

From a practical point of view it is important to forecast the indicator density ceramic bricks on the results of measurements of maximum temperature in the firing zone of tunnel kiln. This requires the synthesis of a mathematical model. When constructing the model we used the method of fuzzy sets [2].

Development of a mathematical model consists of several stages. In the first stage on the basis of passive or active experiment, there are ranges of the maximum temperature of the firing tunnel kiln $\boldsymbol{x_u}$ measure the density of a ceramic brick. After concrete temperature measurements $x \in X$ and index density ceramic bricks $y \in Y$, compared with elements u_1 and u_2, the corresponding universal sets U_1 and U_2, it is provided by linear transformed

$$u_2 = a_x x; u_1 \in U; \tag{1}$$

$$u_2 = a_y y; u_2 \in U; \tag{2}$$

where a_x and a_y are constant coefficients.

For measurements of ***x*** and ***y*** degrees of membership functions are constructed $\mu_x(u_1), \mu_y(u_2)$ that characterize the imprecision of measurement. We have accepted that the functions of the degrees of membership $\mu_x(u_1), \mu_y(u_2)$ is the exponential dependence of the form

$$\mu(U) = e^{\frac{-(a-u)^2}{b}} \tag{3}$$

where a is ***a*** coefficient equal to the measured value of the corresponding process parameter, ***b***- is the coefficient determining the degree of fuzzy measurements.

In the second phase construction of the model is determined by the fuzzy definition of ***R***, it creates a connection between the parameters $x \in X$ and $y \in Y$. Formative fuzzy logical relationship is methods based on the evaluation of pairs of measurements of the input ***x*** and output ***y***, i.e. the statement is formulated

"If A_1, B_1 is different if the A_2, then B_2,..., or, if A_n, then B_n" (4)

where A_i, B_i (i=1,*n*) - fuzzy subset describing the measurement of the input ***x*** and output ***y*** values, respectively. The formalization of sentence (4) is based on the equation, $R = A_1XB_1 + A_2XB_2 + \ldots + A_n XB_n$ with computing operations Cartesian product and union of fuzzy sets. The third stage of the synthesis of mathematical models is the use of compositional rules of inference, which is used as a maxmin product: $B = A \circ R$, where *A* and *B* are fuzzy subsets of the universal sets U_1, and U_2, the parameters characterizing the ***x*** and ***y***, respectively. With the aid of degrees appliances this composition is in the form

$$\mu_б(u_2) = \max_{u_2}\{\min[\mu_x(U_1, U_2)]\} \tag{5}$$

Given a fuzzy relation ***R***; which formalized relationship between these process parameters, and the known value of the maximum temperature in the firing zone of tunnel kiln, defined by the function $\mu_x(u_1)$, (and) with the composition (5) can predict a density ceramic bricks in the tunnel kiln. The decision to be the universal set of U2.

The input to the development of a mathematical model is the experimental measurement of the maximum temperature of the firing tunnel kiln and the exponent of the density ceramic bricks. Table 1 shows the measurement results, calculated at different points in time, the $K\Delta t$, where Δt the time step, together with the experimental data shows the elements of universal sets of U_1 and U_2, which correspond to the results of measurements and calculated according to equations (1), (2).

Table 1

Scattered	Moments of time to K					
	1	2	3	4	5	6
$x, {}^0C$	1010,7	1009,4	1007,8	1005,4	1003,7	1001,2
u_1	1011	1009	1008	1005	1003	1001
y, $м^3/(10^5)$kg	0,168	0,166	0,164	0,163	0,162	0,160
u_2	1680	1660	1640	1630	1620	1600

In the calculation, the following values of the coefficients

$$a_x = 10(1/{}^oC); a_y = 10^5\left((1\frac{м^3}{kg})\right)$$

The functions of degrees appliances $\mu_x(u_1)$ and $\mu_y(u_2)$ were constructed by the formula (3). The results of the construction of the functions of degrees appliances measurements are shown in Table 2 and 3.

Table 2

Temperature ^{0}C	Fuzzy subset	Universal of the subset U_1							
		1011	1010	1009	1008	1005	1003	1001	1000
1010,7	A_1	1,00	0,88	0,72	0,64	0,47	0,36	0,01	0,00
1009,4	A_2	0,73	0,82	1,00	0,84	0,68	0,28	0,02	0,01
1007,8	A_3	0,52	0,61	0,73	1,00	0,67	0,44	0,03	0,02
1005,4	A_4	0,31	0,36	0,38	0,42	1,00	0,64	0,23	0,14
1003,7	A_5	0,23	0,25	0,27	0,33	0,75	0,98	0,81	0,42
1001,2	A_6	0,13	0,15	0,17	0,21	0,32	0,56	1,00	0,83

Table 3

Rate densiy ceramic brick	Fuzzy subset	Universal subset U_2									
		159	160	161	162	163	164	165	166	168	169
0,168	B_1	0,00	0,00	0,00	0,01	0,02	0,33	0,46	0,81	1,00	0,82
0,166	B_2	0,00	0,00	0,05	0,01	0,21	0,43	0,81	1,00	0,78	0,53
0,164	B_3	0,01	0,12	0,23	0,56	0,82	1,00	0,83	0,74	0,48	0,13
0,163	B_4	0,10	0,21	0,38	0,78	1,00	0,81	0,72	0,49	0,31	0,21
0,162	B_5	0,31	0,48	0,86	1,00	0,84	0,72	0,61	0,41	0,3	0,10
0,160	B_6	0,83	1,00	0,87	0,76	0,63	0,52	0,47	0,31	0,10	0,00

Using these functions appliances degrees of input ***x*** and output ***y*** signals, we find the fuzzy relation R, which formalizes relationship between these parameters. For this we use the method of logical evaluation, according to which formed the statement "If A_1 and the B_1, otherwise, it A_2, if B_2, ..., or, if A_6 , then B_6"

The formalization of this proposal is executed according to the equation $R = A_1 X\ B_1 + A_2 X B_2 + A_3\ X\ B_3 + A_4 X\ B_4 + A_5 X\ B_5 + A_6 X\ B_6$. Substituting this expression data in Table 2 and

3, we find the fuzzy relation ***R***. The numerical result of the calculation of fuzzy relations shown in Table 4.

Table 4

Universal subset U_1	Universal subset U_2									
	159	160	161	162	163	164	165	166	168	169
1000	0,92	1,00	0,82	0,78	0,61	0,48	0,36	0,22	0,11	0.05
1001	0,84	0,91	1,00	0,88	0,81	0,72	0,46	0,32	0,10	0,03
1003	0,76	0,78	0.83	1,00	0,83	0,68	0,54	0,42	0,31	0,04
1005	0,52	0,58	0,64	0,68	0,78	1,00	0,81	0,61	0,48	0,24
1008	0,48	0,49	0,56	0,63	0,73	0,81	1,00	0,82	0,76	0,48
1009	0,36	0,42	0,48	0,54	0,62	0,71	0,74	1,00	0,81	0,58
1010	0,21	0,32	0,36	0,41	0,45	0,51	0,61	0,77	1,00	0,83
1011	0,01	0,04	0,05	0,10	0,18	0,28	0,42	0,52	0,82	0,90

Thus the quality of the prediction algorithm of the density ceramic bricks during firing in a tunnel kiln can be summarized as follows:

1. Enter the original data.
2. Calculate the average value of the index density ceramic bricks in the zone of maximum temperatures.
3. Calculate the $\boldsymbol{u_1}$ and $\boldsymbol{u_2}$.
4. Calculate the original functions of degrees accessories $\mu_x(u_i)$ and $\mu_y(u_i)$ for all $u_1 \in U_1; u_2 \in U_2$:
5. Calculate the fuzzy relation ***R***.
6. Calculate maxmin produced $\mu_B(u_2)$.
7. Enter the current measurement of x_{k-m}, y_k.
8. Calculate the average value of the exponent of the density in the zone of maximum temperatures.
9. Calculate them, $u_{1,e-m}$ and $u_{2,k-1-m}$.
10. Find *l*- on the proposal, subject to adjustment.
11. Calculate the amount of displacement along the coordinate functions $\boldsymbol{u_2}$ of $\mu_{y(1)}(u_2)$, which characterizes the average value of the exponent of the density in the zone of maximum temperatures.
12. Shift function $\mu_{y(1)}(u_2)$ and coordinate (u_2).
13. Calculate the penalty function $f_k(u_2) = c_1 \exp\{\mu_{B,k-m}(u_2) - \mu_{y(1),k-m}(u_2)], c_1 = \exp(-c)$.
14. Calculate the $\mu_{Bl,k-m}(u_2)$.
15. Calculate the $\mu_{Bl,k-m}(u_2)$.
16. Calculate the fuzzy relation ***R***.
17. Calculate the amount of displacement along the coordinate U_1 function $\mu_x(u_1)$.
18. Shift the function of $\mu_{x,k-i-1-m}(u_1)$ with respect to U_1.
19. Compute function $\mu_{B,k-m}(u_2)$ which characterizes the rate-density ceramic bricks in the zone of maximum temperatures.
20. Calculate the $u_{2,k-m} = \arg\{\max[\mu_{B,k-m}(u_2)]\}$.
21. Calculate the projected value of the index density ceramic bricks in the zone of maximum temperatures.
22. Calculate the projected value of the index density ceramic bricks in place of the measurement at time $(k+1)\Delta t$.
23. The output y_{k+1}.
24. The End.

This algorithm allows to calculate the predicted value of the index density ceramic bricks at a time $(k+1)\Delta t$ the results of measurements of maximum temperature in the firing zone of tunnel kiln at time $k\Delta t$. The algorithm provides for adaptation of the fuzzy relation $\boldsymbol{R}$.

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THE FORMAL REPRESENTATION OF STRUCTURE OF MANAGEMENT SYSTEM BY AN INFORMATION HIGHWAY AT COTTON-RAW PROCESSING

D.A. Xolmatov, G.R. Alimova, T.A. Karimov, O.K. Ahmedov

100100, Tashkent, Uzbekistan, Tashkent institute of textile and light industry,
5, Shohjahon str. Phone: 2533200

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The modern organizational and technological level of the cotton-cleaner industries first of all is defined by the possibility of an operational administration producing processes.

Further development cotton-cleaner enterprises causes the active of implementation communicational technologies, development and implementation of program-mathematical methods and means of assembly automatization, handlings and outputs of information which is necessary for acceptance of operative administrative decisions.[1]

In order to solve the task of formation of an organizational structure effectively, considering a great number of possible structure variants, this task should be "separated" somehow artificially from other tasks of control and search for rational structure with some "typical" compositions and "standard" mechanisms of control. And even at these simplifications of creating structure tasks remain so difficult.

Presence of strong correlations and interdependency between separate technological processes of a unique production cycle unambiguously specified in necessity of creating hierarchical system of optimization of industrial process control as a whole. Thus, according to the system approach, separate fabrication systems can work in economically unoptimal modes as their loading and maintenance modes should be coordinated with the optimization decisions at level of all manufacture taking into account the specified correlations and various factors of influence. Differently, optimization of operation by each technological aggregate should lead to the suboptimal decisions considering setting restrictions, received with the higher level of optimization enveloping all production cycle of the enterprise.

Thus an important point is formalizing an organizational structure of interacting information highways on the basis of some mathematical apparatus at performance of technological operations on each technological node (of a functional block: drying, cleaning, fiber allocation from seeds, etc.). In the structural plan most adequately reflects an information structure of manufactures hyper graphs [2,3].

In this case the information hyper graph has hierarchical structure without loops $I = \langle N, E_I \rangle$ where N - the peak of the graph showing where is transferred the information, communication - $(U,V) \in E_I$ in the informational graph means that from an element U to an element V there is an information stream.

At such approach of functioning of manufacture at informational level possible to present in a type: <technological process → technological a mode → technological operation>.

Thus it is necessary to pay attention that technological process is interconnected sequentially and has the continuous character, controlling by them has discrete appearance.

Manufacture of cotton-raw processing in the structural plan as represents object of control of multi-level hierarchical structure, the purposes of elements of various levels of hierarchy will be coordinated with the purpose of all system. The compact model of structure system in the informational plan is set in the form of a hierarchical state graph $G=(X,\Gamma)$, where X — set of the peaks, representing the private tasks solved by system; Γ — display X in X, defining sequence of the decision of the task. As the graph hierarchical, that ($X = \bigcup_{q\in Q} X^q$, $Q = \{0, p\}$ where p — number of levels of hierarchy), and $X^q \cap X^t = \varnothing (q,t \in Q)$, $\Gamma(X^{q+1}) = X^q$, $\Gamma(X^0) = \varnothing$.

For representation of an informational structure of management system we will use a composition of hyper graphs of separate levels of hierarchy.

Let's explain applications of the hyper graph for the description an informational structure of process control of processing of a cotton-raw. Let — $Y=\{y_1,y_2,...,y_n\}$ be the finite set, characterizing parameters of the technological description of process and — $\varepsilon = \{E_i \mid i\in I\}$ family of subsets of set Y corresponding to technological processes. The pair $H=(Y,\varepsilon)$ is called as the hyper graph, and elements $y_j \in Y$ $(j \in J = \{1,2,3,...,n\})$ are its peaks, and elements — $E_i \in \varepsilon$ are edges if conditions satisfied $E_i = \varnothing$ $(i \in I)$, $\bigcup_{i\in I} E_i = X$.

To each hyper graph $H=(Y,\varepsilon)$ is a unique correspondence $B(H) = \langle F, Y, \varepsilon\rangle$, where Y — is departure area *B(H)*, coinciding with will be substituted $B(H) = \langle F, Y, \varepsilon\rangle$ by the set of peaks of hyper graph *H*; — the ε arrival area *B(H)*, coinciding with set of edges of hyper graph *H*, and set of pairs a type $\langle y_j, E_i\rangle$ $(i\in I, j\in J)$ is formed by schedule F of correspondence *In ()*, and $\langle y_j, E_i\rangle \in F$, if in $y_j \in E_i$ hyper graph H.

If to consider sub graph G^1 of hierarchical state graph *G = (X,)*, formed by peaks $X^{q+1} \bigcup X^q$ it is easy to note that it is correspondence $B(G^1) = \left\langle T, X^{q+1}, X^q \right\rangle$ where — X^{q+1} departure area; — the X^q arrival area, and set of pairs a type $\left\langle X_j^{q+1}, X_i^q \right\rangle \in T$ form schedule *T*, and $X_i^q \in \Gamma(X_j^{q+1})$, $X_i^q \in X^q, X_j^{q+1} \in X^{q+1}$. From this it follows that it is possible to present selected sub graph G^1 *the* hyper graph, proceeding from correspondence $B(G^1) \in \left\langle T, X^{q+1}, X^q \right\rangle$ if to accept as set of peaks of the hyper graph departure area X^{q+1}, as set of edges area of arrival and X^q to consider that the peak X_j^{q+1} belongs to an edge X_i^q, if $\left\langle X_j^{q+1}, X_i^q \right\rangle \in T$. Thus, we receive the hyper graph $H^q(X^{q+1}, X^q)$ where each edge from X_i^q set of edges X^q is a subset of set of peaks X^{q+1}.

So, hierarchical directional graph *G = (X,)*, having *0, 1, 2..., p* levels, it is possible to present *p* hyper graphs H^0, H^1..., H^{p-1}

In this way the task represented by an element X_i^q, can be a hyper graph edge (H^q i.e. a subset of set of peaks X^{q+1}) and at the same time one of hyper graph peaks (H^{q-1} i.e. belonging to any edges from X^{q-1}). The hyper graph H^k is convenient for setting its matrix incidents $I^k = \left\| r_{ij} \right\|$, and lines of a matrix I^k correspond to the peaks from X^{k+1}, and columns — to edges from the X^k hyper graph H^k; $r_{ij}=1$ if $X_j^{k+1} \in X_i^k$, and 0 otherwise situation.

It is natural to assume that depending on value of technological parameters of a current state each element $X_j^q \in X$ it is possible present some own set of varieties of the states $P(X_j^q)=\left\{x_{i1}^q, x_{i2}^q, x_{i3}^q, ..., x_{ij}^q\right\}$, being subset of set of varieties $P(X^q)$ of the given level of hierarchy $X^q : P(X_i^q) \subseteq P(X^q)$. In each variety $P(X_i^q)$ there is at least one element $x_{ij}^q \in P(X_i^q)$, agreeing with an element X_j^{q-1} of higher level.

Within the limits of operations over hyper graphs the following tasks arising at the analysis information structures of management system by productions of processing of a cotton-raw can be solved:

- Determination of entrance of elements of lower layers of hierarchy in the given element (or group of elements) top level and vise-versa (at construction of structure of management personnel by technical system when it is necessary is information to compare links of technological process);
- Determination of sequence of peaks of hyper graphs of different levels hierarchy with the maximum probabilities of passages (at determination of routing of the material flow of a cotton-raw between aggregates).

These tasks can be solved by means of operation of a composition of the operators set by hyper graphs of levels of hierarchy. A composition of hyper graphs also H^{k+1} H^k we will designate

$$H^{k+1,k} = H^{k+1,k} \circ H^k$$

Operation of a composition of the hyper graphs set by matrixes incidents, corresponds to operation of multiplication of matrixes. So, a $I^{k+1,k}$ hyper graph matrix $I^{k+1,k}$ $H^{k+1,k}$ we present in a type $I^{k+1,k} = H^{k+1} I^k$.

For a composition of hyper graphs validly ratio [9]

$$(H^{k+2} \circ H^{k+1}) \circ H^k = H^{k+2} \circ (H^{k+1} \circ H^k).$$

On the basis of the offered approach we consider the decision of tasks of the analysis of structure of management system process of processing of a cotton-raw.

1. For determination entrance of elements in an $P(X^{k+2})$ element $P(X_i^k) \in P(X^k)$ we select the column vector and $\left[P(X^k\right]$ we fulfill operation $I^{k+2}(\, I^{k+1} \left[P(X_i^k)\right])$.

2. For determination dependence on an $P(X^k)$ element $P(X_j^{k+3}) \in P(X^{k+3})$) a vector-line also $\left[P(X_j^{k+3}\right]$ we fulfill operation $(\left[P(X_j^{k+3})\right] \, I_\alpha^{k+1}) I_\alpha^k$.

Usage of hyper graphs for representation of an information structure of management system allows describing rather compactly functioning of hierarchical management systems and, by using the formal operations over hyper graphs, carrying out structural analysis of correlation of information highways as on levels of control and compatibility with the information on horizons of these systems.

On the basis of system structural approach formalized organization structure of informational interrelation of technological operations in the type hyper graphs differing from with simplified relation in ECM and provides with the analysis of appearing different situations in the process of recycling cotton-raw.

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ALGORITHMS OF THE DECENTRALIZED MANAGEMENT OF THE INTERCONNECTED DYNAMIC OBJECTS IN THE CONDITIONS OF INFORMATION UNCERTAINTY

I.X. Siddikov, M. Sapaev, R.N. Izmaylova

100095, Tashkent, Uzbekistan
Tashkent State Technical University, Department of Electronic and Automatic
2, Universitetskaya st. Phone: 246 03 45

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1. Introduction

Management efficiency increase by production is an actual problem in the conditions of increasing complexity of processing equipment, processes and systems. For design of control systems difficult, structural the distributed dynamic objects, the important role is played by the solution of problems of creation of adequate mathematical models and synthesis of algorithms of the management providing the solution of objectives in the conditions of information uncertainty.

Feature of structure of modern control systems in particular the oil refining, chemical companies is that they consist of number of cooperating subsystems and have the distributed character. This circumstance causes for effective management of application of the concept of the decentralized management [1, 2].

The concept of decentralization of management demands their automation to use of the modern information technologies which are based on multimicroprocessor systems.

In this case for each microcontroller the laws of management are defined, using aprioristic information on uncertainty of all interconnected system.

Let there is the partial and uncertain dynamic system consisting of set of the M cooperating subsystems, the model of each of which is described by the equations in conditions:

$$x_i(t) = A_i x_i(t) + \Delta A_i x_i(t) + (B_i + \Delta B_i) u_i(t) + \sum_{j=1,\, j\neq i}^{M} \Delta A_{ij} x_j(t)$$

$$x_i(t_0) = x_{0i}, \;\; \forall\; i = 1,\ldots,M \;.$$

Here $x_i \in R^{n_i}$ and $u_i \in R^{m_i}$ – vectors of conditions and managements of *i*-subsystem, $x \in R^n$ and $u \in R^m$ – compound vectors of conditions and managements of all system, $\sum_{i=1}^{m} n_i = n$, $\sum_{i=1}^{m} m_i = m$, $A_i \in R^{n_i \times n_i}$, $B_i \in R^{n_i \times m_i}$ – the matrixes of factors characterizing dynamics of linear subsystems, and matrixes $A \in R^{n \times n}$ and $B \in R^{n \times m}$ – to dynamics of all system, are characterized by interrelation between subsystems, *Ai* and *Bj* – operated uncertain matrix elements $\Delta A \in R^{n\times n}$ – a full block matrix with blocks $\Delta A_{ij} \in R^{n_i \times n_j}$.

Uncertain elements ΔA, ΔB belong to sets:

$$\Delta A \in A, \quad A = \{\Delta A : A^- \le \Delta A \le A^+\},$$

$$\Delta B \in B, \quad B = \{\Delta B : B^- \le \Delta B \le B^+\},$$

where are A^+, A^-, B^+, B^- - the known matrixes defining intervals of uncertainty.

Such task of uncertain matrix elements reflects discrepancies of models the control systems arising because of linearization, approximation or errors of identification of parameters, and also errors of a rounding off, measurements etc.

Thus system of managements the following types of restrictions are imposed:

1) structure of management object completely decentralized, i.e. process operate the *M* independent actuation devices with laws:

$$u_i(t) = f_i(x_i(t));$$

2) the top borders of uncertain matrix elements ΔA_i, ΔA_{ij}, ΔB_i are known:

$$\|\Delta A_i\| \le a_i^*, \ \|\Delta A_{ij}\| \le a_{ij}^*, \ \|\Delta B_i\| \le b_i^*, \tag{1}$$

where are – the set constants;

3) the system can be presented in the form of a cooperating set of the *M* subsystems:

$$\dot{x}_i(t) = A_i x_i(t) + (B_i + \Delta B_i)u_i(t) + \sum_{j=1}^{M} B_i (L_{ij} + \Delta L_{ij}) \cdot x_j(t)$$

$$x_i(t_0) = x_{0i}, \ \forall i = 1,\ldots,M \ .$$

The matrix of uncertainty Δ*L* belongs to a set:

the top borders of uncertain matrix elements ΔL_{ii}, ΔL_{ij} are thus known:

$$\|\Delta L_{ii}\| \le l_{ii}^*, \ \|\Delta L_{ij}\| \le l_{ij}^*,$$

where are l_{ii}^*, l_{ij}^* – estimates which can be counted from (1).

In this case the problem of synthesis will be formulated in the following look:

It is required to find the decentralized algorithms of management for system:

$$\dot{x}_i(t) = A_i x_i(t) + B_i u_i(t), \ \forall i = 1,\ldots,M, \tag{2}$$

providing a minimum to criterion

$$I = \frac{1}{2}\int_0^{\infty} \left\{\|x(t)\|^2_{Q_{1\times d}} + \|u(t)\|^2_{R_d}\ dt\right\}, \tag{3}$$

where $Q_{1\times d}$, R_d – block and diagonal weight matrixes.

Thus algorithms of management should provide stability to system with uncertainty and interrelations:

$$\dot{x}_i(t) = A_i x_i(t) + B_i u_i(t) + \sum_{j=1}^{M} B_i (L_{ij} + \Delta L_{ij}) \cdot x_j(t), \tag{4}$$

$$x_i(t_0) = x_{0i}, \ \forall i = 1,\ldots,M.$$

The solution of an objective we will look for in a class of robustness management, using a method of synthesis of optimum control of the decentralized systems of big dimension, being based on properties of a block and diagonal of dominant of matrixes [2]. Then the solution of an optimizing task defines the following type of local managements:

$$u_i(t) = -K_i(P_i) \cdot x_i(t), \tag{5}$$

$$K_i(P_i) = R_i^{-1} B_i^{+} P_i,$$

where $P_i = f(Q_{2xi})$ – solutions of the corresponding equations of Rikkati:

$$A_i'P_i + P_iA_i - P_iB_iR_i^{-1}B_i'P_iQ_{1x_i} = 0. \quad (6)$$

Matrix parameters also are defined from ratios:

$$q_i > 2\left(\sum_{j=1, i\neq j}^{M} l_{ij}^2 r_j + q_i^2 (b_i')^2 r_i^{-1} (\lambda_{\max}^2 \{A\})^{-1} + \sum_{j=1,\, j\neq i}^{M} \sum_{l=1, i\neq j}^{M} l_{ji} r_i l_{ji} \right), \quad (7)$$

where $l_{ji} = \lambda_{\max}\{L_{ji}\},\ r_i = \lambda_{\max} R_j,\ \Delta L_{ij} = l_{ij}^*$.

The behavior of dynamic system will be described in this case by a nominal and optimum trajectory of x_0(t). Let's make the function constructed on this trajectory of movement:

$$V = x'(t) \cdot P \cdot x(t),$$

where P – a block and dynamic matrix with Pi blocks from (6) also we will write down a derivative of function $V(t)$ in system of the equation (4):

$V(t) = x'(t) \cdot (A_d'P + PA_d - 2 \cdot P \cdot B_d \cdot R_d^{-1} \cdot B_d' \cdot P + P \cdot B_d \cdot L + P \cdot B_d \cdot \Delta L + L' \cdot B'_d \cdot P + \Delta L' B_d \cdot P)x(t)$ Under condition of $V'(t)$<0 will be conditions of asymptotic stability all coherent systems (4) will be satisfied.

Taking into account (6) this expression it is possible to write down:

$$v(t) = x'(t) \cdot (Q_{1xd} + 1/2(2L - R_d^{-1}B_d'P)'R_d(2L - R_d^{-1}B_d'P) + 1/2(2\Delta L - R_d^{-1}B_d'P)'R_d \times$$

$$\times (2\Delta L - R_d^{-1}B_d'P) - 2L'R_dL - 2\Delta L'R_d\Delta L)x(t) \le -x'(t) \cdot (Q_{1xd} - 2L'R_dL - 2\Delta L'R_dL)x(t).$$

For providing a condition of asymptotic stability systems all coherently it is necessary performance of a condition of negativity derived at performance

$$W = Q_d - 2(L'R_dL - \Delta L'R_d\Delta L) > 0.$$

This condition is provided with a choice of matrixes of Q_{1xd}. For providing W>0 and properties of a robustness, it is necessary to choose parameters of a control system which are calculated only on the basis of local data.

Important thus is properties block of dominant matrixes, i.e. condition performance

$$\left(\left\|W_{ii}^{-1}\right\|\right)^{-1} \ge \sum_{j=1}^{m} \left\|W_{ij}\right\| \forall\ i = \overline{1,m}$$

at $W_{ii} = W_{ii}' > 0$.

Thus a matrix of W should satisfy to conditions that W – a block matrix of W=W'.

The solution of a task consists of the following stages:

1. Matrixes of Q_{1xd} and R_d of criterion of an optimality (3) are defined.
2. Factors of feedback of K_i the law of management (5) pay off.
3. The behavior of system with uncertainty is modelled, using (4).
4. Stages 1÷3 repeat for various ratios of q_i and r_i, yet won't be satisfied conditions (7).

Offered procedure of synthesis of algorithms of management allows providing properties in other controllers of a robustness of system to interval uncertainty irrespective of situations. Thus synthesis of algorithms of management is carried out with use of aprioristic information on uncertainty only in local subsystems, thanking use of properties of a block and diagonal of dominant of matrixes. In this case to finding of operating influences $U_j(l)$, $j = \overline{1,M}$, for each local subsystem determination of predicted values of a vector of a mistake $E_i = Z_i - y_i(L + N_U)$ according to an actual state of object of management should precede. Here Z_i – demanded i-values of a target variable, y_i – i-values of a target variable on the termination ($L + N_U$)-step, L – a present situation of time, N_u – quantity of steps of management. It is caused by that the actual state of object of management owing to discrepancy of mathematical model, mistakes in realization of the calculated operating influences, existence of the various revolting factors operating on real object, practically never coincides with a condition calculated only on models.

For determination of predicted values of mistakes, or that too most, predicted values of target variables the approach based on use of discrete transfer functions of object of management [4] is offered. Let's designate through:

$$W_{ij}(Z) = \frac{B_{ij}(Z)}{A_{ij}(Z)} \tag{8}$$

discrete transfer function of the i-channel of an j-exit, where $A_{ij}(Z)$ and $B_{ij}(Z)$ – polynoms on degrees respectively degrees n_{ij}^{+} and n_{ij}^{-}. Then it is possible to present *Z*-transformation of a target variable in a look:

$$Y_i(Z) = \sum_{j=1}^{M} \frac{B_{ij}(Z)}{A_{ij}(Z)} \cdot U_j(Z), \qquad j = \overline{1, N} \tag{9}$$

Having reduced the right part of expression (9) to a common denominator, we will receive:

$$Y_i(Z) \cdot \prod_{j=1}^{M} A_{ij}(Z) = \sum_{j=1}^{M} \left(B_{ij}(Z) \cdot \prod_{k=1;k\neq j} A_{ik}(Z) \cdot U_j(Z) \right). \tag{10}$$

Or in other look:

$$y_i(Z) \cdot C_i(Z) = \sum_{j=1}^{M} D_{ij}(Z) \cdot U_j(Z) \tag{11}$$

where

$$C_i(Z) = \prod_{j=1}^{M} A_{ij}(Z), \; D_{ij}(Z) = B_{ij}(Z) \cdot \prod_{k=1;k\neq j}^{M} A_{ik}(Z) \tag{12}$$

Having divided the left and right parts (11) on we will receive:

$$y_i(Z) \cdot R_i(Z^{-1}) = \sum_{j=1}^{M} P_{ij}(Z^{-1}) \cdot U_j(Z), \tag{13}$$

where $R_i(Z^{-1})$ and $P_{ij}(Z^{-1})$ – polynoms on return degrees of the operator of Z of a look:

$$R_i(Z^{-1}) = 1 + \sum_{k=1}^{n_s} r_i(k) \cdot Z^{-k}$$

$$P_{ij}(Z^{-1}) = \sum_{k=0}^{n_s} p_{ij}(k) \cdot Z^{-k} \tag{14}$$

$$r_i(k) = \frac{c_i(k)}{c_i(0)}; \qquad p_{ij}(k) = \frac{d_{ij}(k)}{c_i(0)}$$

On the basis of expression (13) taking into account (14) the recurrent formula for forecasting of target values of object of management easily turns out:

$$Y_i(L+1) = -\sum_{k=1}^{n_s} r_i(k) \cdot y_i(L+1-k) + \sum_{j=1}^{M} \sum_{k=1}^{n_s} p_{ij}(k) \cdot U_i(L-k+1). \tag{15}$$

Here n_s – a total order of the transfer functions connected with i-oh target variable.

For determination of value of target variables we will use expression:

$$Y_i(N_U + k) = \sum_{j=1}^{M} \sum_{l=0}^{N_U} \Delta U_j(l) \cdot h_{ij}(N_U + k - l),$$

where $\Delta U_j(l)$ – an increment of *j*-entrance managing director of influence in *l*-step concerning its full value in (*l-1*)-step, i.e. $\Delta U_j(l) = U_j(l) - U_j(l-1)$.

Thus full value of operating influence

$$U_j(N_U + m_j) = U_j(N_U - 1) + \sum_{k=0}^{m_j} \Delta U_j(N_U + k),$$

$$m_j = \sum_{i=1}^{m} n_{ij}$$

automatically it turns out equal to the size providing demanded established conditions for each local subsystems of decentralized object of management.

Conclusion.

The algorithm of optimum control based on properties of a block and diagonal of dominant of matrixes and providing properties of a robustness of a control system to information uncertainty irrespective of a fuzzy of situations is developed for the decentralized objects.

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ALGORITHM OF THE CHOISE OF OPTIMUM REGIMES THE WORK OF THE AGGREGATES COTTON RAW PROCESSING IN THE CASE OF INDEFINITE

D.A. Xolmatov, N.U. Setmetov, U.O. Hujanazarov, O.K. Ahmedov

[1,3]100100, Tashkent, Uzbekistan, Tashkent institute of textile and light industry,
5, Shohjahon str. Phone: 2533200, holdav@mail.ru
[2]220100, Khorezm, Uzbekistan, Tashkent university information of Urgench branch, nematjon@rambler.ru

Abstract: *It is offered the effective algorithm of searching of rational regime of work technological aggregates on the basis of situational model of process of processing a cotton raw.*

Keywords: *Process of processing of cotton, technological monitoring, situational model, information stream, an operating mode, multi-variant approach of regime of work of aggregates, the generalised parameters.*

Introduction

It is known that process of functioning of technological aggregates cotton cleaning factory is connected with uncertainty of various industrial situations.

The vagueness in cotton cleaning manufacture is connected by that n cotton batch should be processed by m units and then go on packings of bales of a fibre and lint. It is necessary to construct optimum routes for processing of all sets batch of the cotton, satisfying to some general criteria. In this case preferable functions let solve given task. Besides, each batch of cotton, consisting of a fibre, is characterised by certain quality characteristics (sort, humidity, a contamination, and etc.) and technological sequence of operations of manufacture. Choice procedure of technological regimes of the equipment (units) for processing of each batch of a cotton is also uncertain. In this case the batch of a cotton from a i totality to n will have various functions of preference in relation to each of types cleaning machines and aggregates that leads to vagueness of restrictions.

The combination of discrete process of control managerial process and discrete-continual production on set of diverse parameters of cotton processing, uncertainty of evaluation of its condition and ambiguity in choice of ways of the making decision, which characterised of the control of process of cotton processing, construction of the situational models allowed to quant information streams of operating influences on time and size cause. The situational model of process of cotton processing as an object of control is represented by terms of the accepted signature [1]:

$$M_{OC} = \langle O, \Omega, \Omega_\delta, P_S(\Omega), P_t(\Omega_\delta) \rangle, \quad (1),$$

where — $O = O_{OC} \cap O_{EO}$ set of the information parameters of processes of cotton processing (drying, cleaning, ginning etc.); — O_{OC} set of parameters, characterizing objects of control (OC); — O_{EO} set elementary operations; - $\Omega = \langle O_1 \times O_2 \times O_3 \times ... \times O_n \rangle$ space of conditions of a control system, - n quantity of the information on cotton processings; — Ω_δ set of technological reglaments of cotton processing $\Omega_\delta \supset \Omega$; — $P_S(\Omega)$ restrictions on technological reglaments $P_S(\Omega) \to \Omega_\delta$; — $P_t(\Omega_\delta)$ rules the regime of work of aggregates in space of conditions (choice of a trajectory of movement): $\Omega_\delta^1 = P_t(\Omega_\delta^2)$ where - Ω_δ^1, Ω_δ^2 conditions OC in the process of transition.

Industrial – i situation S_i is possible to present a situation S_i on set of conditions OC in accord and with the accepted designations of concepts in the view of

$$S_i = \left\langle \Omega^{S_i}, P_{ij}(\Omega_\delta), U_K(t), \Omega_\delta^K, \varphi(\Omega_\delta^T, U_K(t)) \right\rangle, \tag{2}$$

where - Ω^{S_i} set of conditions OC making a situation S_i ; - Ω_δ^T current condition OC; - $P_{ij}(\Omega_\delta)$ rules of formation of conditions Ω^{S_i}, $P_{ij}(\Omega_\delta) \to \Omega^{S_i}$ for OC at transition from – j oh to – i oh situations; - the $U_K(t)$ operating influences directed on final condition OC according to the purpose of control; - Ω_δ^K set of desirable final conditions OC; - $\varphi(\Omega_\delta^T, U_K(t))$ rules of transformation of sizes of operating influences for transition OC from flowing in a new condition Ω_δ^H $\Omega_\delta^H = \varphi(\Omega_\delta^T, U_K(t))$.

Breaking of space conditions into elementary OC on set of situations allows to construct the space of situations in which making decision is for realized the account of choice of the sequence of changing the situations or trajectory of movement OC in accordance with the purpose control.

The model of searching the rational regimes of aggregates, characterising by certain conditions on several time interval $[t_n, t_k]$ the well known parameters of processing corresponding to a certain structural condition, is represented by the form of [2]:

$$d_1, d_2, d_3, \ldots, d_w \in \{D\}, f_1, f_2, f_3, \ldots, f_v \in \{F\}, w << \left|\{D\}\right|, v << \left|\{F\}\right|, \tag{3}$$

also allows to order them on degree of importance of the given information:

$$R(d_z) > R(d_x) > R(d_c) >, \ \ldots, > R(d_t), \ z, x, c, t \le w;$$

$$R(f_{z1}) > R(f_{x1}) > R(f_{c1}) >, \ \ldots, > R(f_{t1}), \ z1, x1, c1, t1 \le v, \tag{4}$$

where $d_1, d_2, d_3, \ldots, d_w$ and $f_1, f_2, f_3, \ldots, f_v$ - the information necessary for making decision in the considered industrial situation; - the $R(d_z)$ rank of the information d_z characterising degree of importance of the information; - w, v quantity of information, characterising the industrial situation; - $z, x, c, t, z1, x1, c1, t1$ well known constants; | | - the symbol of power of set.

Thus, during any moment of time the condition of aggregates of the enterprise S is characterised by set $P_S = \langle X(t), Z(t) \rangle$ where - $X(t)$ set of generally interconnected parameters, and the meanings of these parameters, and their structure depend on the time, - $Z(t)$ set of meanings of these parameters. Changing also $Z(t)$ $X(t)$ occurs situationally, i.e.

$$(X(t_{i+1}), Z(t_{i+1})) = F(X(t_i), Z(t_i), A(t_{i+1})), \tag{5}$$

where $X(t_{i+1}), Z(t_{i+1})$ - values $X(t_i)$, $Z(t_i)$ after a fulfillment $(i+1)$ - i situations; t_i - t_{i+1} the times of a fulfillment of two consecutive (i th and $(i+1)$ th) situations; - $A(t_{i+1})$ attributes $(i+1)$ of the event; - F functional dependence the characteristics of aggregates of the enterprise from occurring events.

As the enterprise units represent the system of the control, one part of parameters ($X(t)$ accordingly - and meanings $Z(t)$) is management parameters $X_C(t)$, and another - condition parameters $X_S(t)$.

On the basis of these models is developed the algorithm of performance operation of the information processing, allowing to define a rational variant of technological regimes of aggregates from set of the variants, corresponding to production reglaments in a considered time. On the input of algorithm comes vector of the parameters, containing defined information and forming j - group

$$\widetilde{Y}_j^{(k)} = \left|\widetilde{y}_{j1}^{(k)}, \widetilde{y}_{j2}^{(k)}, \ldots, \widetilde{y}_{jn}^{(k)}\right|^T, \tag{6}$$

Set of possible meanings of parameters $y_{j1}^{(k)}, y_{j2}^{(k)}, \ldots, y_{jn}^{(k)}$ with the help display factorisation

$$V_j^{(k)} : \widetilde{Y}_j^{(k)} \rightarrow^F Y_j^{(k)} \quad , \tag{7}$$

breaks into uncrossed classes forming quotient sets:

$$^F Y_j^{(k)} = \{^F y_{j1}^{(k)},\ ^F y_{j2}^{(k)}, \ldots, ^F y_{jn}^{(k)}\}. \tag{8}$$

To each type of technical condition is controlled by parameters defining as a result of processing of the information, corresponded a certain subset of current meanings of parameters of the group united by some general properties, so as for which the same decision can be accepted. We will present set of controllable parameters of technological aggregates in this view:

$$^O Y_j^{(k)} = \{^O y_{j1}^{(k)},\ ^O y_{j2}^{(k)}, \ldots, ^O y_{jn}^{(k)}\}, \tag{9}$$

where $^O y_{ji}^{(k)}$, - $i = \overline{1,n}$ number of the condition of the parameter $y_{ji}^{(k)}$, defined on factorial space of its possible conditions $^F y_{ji}^{(k)}$, with the help of implicating displays is put in accordance with quotient set: group parameters

$$H_{j1}^{(k)} : {}^O Y_j^{(k)} \rightarrow^F Y_j^{(k)}, \tag{10}$$

and also the vector of probabilities of occurring aggregate conditions

$$H_{j2}^{(k)} : {}^O Y_j^{(k)} \rightarrow P_j^{(k)}. \tag{11}$$

For taking evaluation of the generalised parameter on k th level due to information containing in time section j group, it is necessary to make the display

$$\theta_j^{(k)} = \eta_{j1}^{(k)} \cap \eta_{j2}^{(k)} \cap \psi_j^{(k)}, \tag{12}$$

where - $\eta_{j1}^{(k)}$ display classifying a current vector of parameters estimations (6) in a current vector of numbers of conditions of the parameters defined by quotient set (8); - $\eta_{j2}^{(k)}$ display classifying a current condition of aggregates on set of possible kinds (9); - $\psi_j^{(k)}$ display of evaluating of the current condition of aggregates of controlled subsystem.

Display $\eta_{j1}^{(k)}$ is set in a kind:

$$\eta_{j1}^{(k)} : \widetilde{Y}^{(k)} \times {}^F Y_j^{(k)} \rightarrow^T Y_j^{(k)}; \tag{13}$$

$$^T Y_j^{(k)} = \{\ ^T y_{j1}^{(k)},\ ^T y_{j2}^{(k)}, \ldots, ^T y_{jn}^{(k)}\}, \tag{14}$$

where $^T y_{ji}^{(k)}$, - $i = \overline{1,n}$ current number of parameter condition of $y_{ji}^{(k)}$.

Display $\eta_{j2}^{(k)}$ is defined as

$$\eta_{j2}^{(k)} : {}^T Y_j^{(k)} \times {}^O Y_j^{(k)} \rightarrow Y_j^{(k+1)}, \tag{15}$$

where - $Y_j^{(k+1)}$ set of current meanings of the generalised parameter $Y_j^{(k+1)}$ received as a result of classifying on k-m level. Display $\psi_j^{(k)}$ is set in a kind

$$\Psi_j^{(k)} : Y_j^{(k+1)} \times P_j^{(k)} \rightarrow \widetilde{Y}_j^{(k+1)}, \tag{16}$$

where - $\widetilde{Y}_j^{(k+1)}$ set of evaluating of the generalised parameter $y^{(k+1)}$ received on the exit of algorithm, realised the problem of information processing.

In the course of performance of operation of information processing is formed the matrix showing any possible regimes of work aggregates (table 1.)

The choice of rational regimes of aggregates due to this matrix is carried out on the following algorithm

1. On the base of the analysis of indicators processing cotton is formulated the set of the decisions providing performance of the plan and $Y = \{y_l\},\ l = \overline{1,k}$ registered in the left column of the table.

2. On the base of the analysis of technological reglaments the condition of the equipment is formulated set of the conditions influenced the decision.

3. On the base of the analysis of the equipment condition of for each case is defined the set of meaning of this condition (the regime of work of the equipment corresponded to performance the technological reglaments) $X = \{X_{ji_j}\}\ i_j = \overline{1,n_j}$.

4. The set of possible decisions and $Y = \{y_l\},\ l = \overline{1,k}$ set of possible meanings of conditions $X = \{X_{ji_j}\},\ i_j = \overline{1,n_j}$ define the matrix of conformity dimension: $K \times \sum_{j=1}^{m} \sum_{i_j}^{n_j} i_j$.

5. For each decision in y_l l th line of the table in cages corresponding to those meanings of conditions for which the given decision is existed, are filled by units.

Table 1

The matrix of multi-variant regimes of work aggregates

Variant of technological process (index $i = \overline{1,I}$)	Sort a made cotton (index $m = \overline{1,M}$)																	
	1				2				…	m				…	M			
	Stages of technological processes (index $l = \overline{1,r_1}$)				Stages of technological process (index $l = \overline{1,r_2}$)				…	Stages of technological process (index $l = \overline{1,r_m}$)				…	Stages of technological process (index $l = \overline{1,r_M}$)			
	1	2	…	r_1	1	2	…	r_2	…	1	2	…	r_m	…	1	2	…	r_M
1	q_{11}^1	q_{11}^2	…	$q_{11}^{r_1}$	q_{12}^1	q_{12}^2	…	$q_{12}^{r_2}$	…	q_{1m}^1	q_{1m}^2	…	$q_{1m}^{r_m}$	…	q_{1M}^1	q_{1M}^2	…	$q_{1M}^{r_M}$
2	q_{21}^1	q_{21}^2	…	$q_{21}^{r_1}$	q_{22}^1	q_{22}^2	…	$q_{22}^{r_2}$	…	q_{2m}^1	q_{2m}^2	…	$q_{2m}^{r_m}$	…	q_{2M}^1	q_{2M}^2	…	$q_{2M}^{r_M}$
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
I	q_{I1}^1	q_{I1}^2	…	$q_{I1}^{r_1}$	q_{I2}^1	q_{I2}^2	…	$q_{I2}^{r_2}$	…	q_{Im}^1	q_{Im}^2	…	$q_{\mathrm{Im}}^{r_m}$	…	q_{IM}^1	q_{IM}^2	…	$q_{IM}^{r_M}$

Conclusions

1. Are developed situational models of the process of functioning of the technological aggregates, considering multi-variant regimes functioning aggregates, corresponding several producing situation.

2. The algorithm of a choice of rational regimes of work the technological aggregates on the base of the analysis of the generalised parameters corresponding to technological reglements the regime of work of aggregates is developed.

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MODELING OF A FUZZY INFERENCE BASED ON THE USE OF GENETIC ALGORITHM WITH ARTIFICIAL SELECTION

M.R. Agzamxodjaeva

Tashkent University of Information Technologies,
Tashkent Amir Temur st. 108
Phone: 238-65-07, asinumxon@mail.ru

Abstract: *In the work are presented a model based on fuzzy inference rules and a genetic algorithm with artificial selection.*

Keywords: *fuzzy experimental data, fuzzy inference rules, a genetic algorithm with artificial selection, choice, reflection, stretch and contraction.*

Given a sample of fuzzy experimental data (X_r, y_r), $r = \overline{1, M}$; here $X_r = (x_{r1}, x_{r2}, \ldots, x_{rn})$ - the input n- dimensional vector and $y_r = (y_1, y_2, \ldots, y_M)$- corresponding output vector.

In general, it is required to construct a model based on fuzzy inference rules [2]:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} - \text{с весом } w_{jp}\right) \to y_j = b_{m0} + b_{m1}x_1^j + \ldots + b_{mn}x_n^j.$$

In the process of constructing a model needs to find values of the coefficients of the rules

$$B = (b_{ij}), i = \overline{1, m},\ j = \overline{0, n}$$

at which the minimum of the following expression:

$$\sum_{r=1}^{M} \left(y_r - y_r^f\right) \to \min , \tag{1}$$

where y_r^f - the result of fuzzy inference rules with parameter in B r-th row of the sample (X_r).

Input matrix X_r matches the following result of fuzzy inference:

$$y_r^f = \frac{\sum_{i=1}^{m} \mu_{d_i}(X_r) \cdot d_i}{\sum_{i=1}^{m} \mu_{d_i}(X_r)}; \tag{2}$$

here $d_i = b_{i0} + b_{i1}x_{r1} + b_{i2}x_{r2} + \ldots + b_{in}x_{rn}$ - i-out rules; $\mu_{d_i}(X_r)$ - membership function corresponding to each of the experimental information:

$$\begin{aligned}\mu_{d_j}(X_r) = {} & \mu_{i1}(x_{r1}) \cdot \mu_{i1}(x_{r2}) \cdot \mu_{i1}(x_{r3}) \cdot \ldots \cdot \mu_{i1}(x_{rn}) \vee \\ & \vee\, \mu_{i2}(x_{r1}) \cdot \mu_{i2}(x_{r2}) \cdot \mu_{i2}(x_{r3}) \cdot \ldots \cdot \mu_{i2}(x_{rn}) \vee \\ & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ & \vee\, \mu_{im}(x_{r1}) \cdot \mu_{im}(x_{r2}) \cdot \mu_{im}(x_{r3}) \cdot \ldots \cdot \mu_{im}(x_{rn}),\end{aligned}$$

$$\beta_{ir} = \frac{\mu_{d_i}(X_r) \cdot d_i}{\sum_{i=}^{m} \mu_{d_i}(X_r)}.$$

Then (2) can be written in the form:

$$y_r^f = \sum_{i=1}^{m} \beta_{ir} d_i = \sum_{i=1}^{m} \left(\beta_{ir} \cdot b_{i0} + \beta_{ir} \cdot b_{i1} \cdot x_{r1} + \beta_{ir} \cdot b_{i2} \cdot x_{r2} + \ldots + \beta_{ir} \cdot b_{in} \cdot x_{rn}\right)$$

The following notation:

$$Y^f = \left(y_1^f, y_2^f, \ldots, y_M^f\right)^T,$$
$$Y = \left(y_1, y_2, \ldots, y_M\right)^T.$$

Then the problem (1) can be written in the following matrix form: to find a solution to satisfy the condition

$$E = (Y - Y^f)^T \cdot (Y - Y^f) \to \min . \qquad (3)$$

To solve problem (3), we use a genetic algorithm with artificial selection [1].

Based on the proposed algorithm is based on the synthesis of conventional evolutionary genetic approach to the ideas of adaptive optimization and, above all, consistent integrated method for finding extrema of functions of several variables. In this case, each time the current population is identified with the population - complex points in the search space and in addition to traditional genetic operators of mutation, crossover and selection operators are introduced additional complex search-such as choice, reflection, stretch and contraction. Moreover, in difference to the traditional method of the complex is proposed to reflect more than one vertex of the worst, and a whole lot of the worst individuals of the population.

In general, the optimization procedure based on a consistent set of common method is as follows: it is required to find the minimum of a function

$$E(x) = \sum_{r=1}^{M} \left(y_r - y_r^f\right)^2 \to \min$$

rather general form, with the nature of this function is done almost no a priori sentences. The algorithm starts with the formation of the initial complex

$$x_i(t) = \begin{pmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_N(t) \end{pmatrix} = \begin{pmatrix} x_{11}(t) & x_{12}(t) & \dots & x_{1n}(t) \\ x_{21}(t) & x_{22}(t) & \dots & x_{2n}(t) \\ \vdots & & & \\ x_{N1}(t) & x_{N2}(t) & \dots & x_{Nn}(t) \end{pmatrix} \qquad i = \overline{1, N} \ge n+1$$

representing a population of chromosomes, rather arbitrarily placed in n-dimensional search space. From the beginning of the operation performed selection, then crossover and mutation. From this we obtain a new population of chromosomes $x_i(t)$.

After that, the operation of choice. At this stage the value of all the chromosomes and is the average fitness of the population

$$E_{сред} = \frac{1}{N} \sum_{i=1}^{N} E(x_i(t))$$

Then chromosome fitness less than the average over the whole population is replaced by the "best" chromosome.

If $E_{сред} < E(x_i(t))$ then $x_i(t+1) = x_i(t)$, which gives $\min\limits_{i=\overline{1,N}} (E(x_i(t)))$.

Among this set of chromosomes is "the worst" $x_i(t)$, in which the maximum value of the function $E(x_H(t))$, then this point is reflected through the center of gravity of all the other vertices-points, producing a new set of $x_i(t), j = \overline{1, N}$. Such reflection, along with stretching and compression provide movement to the extreme complex functions $E(t)$, in this case, thanks to fairly random distribution of chromosomes in the population, the search is global.

From a formal point of view, we consider the optimization process for k-th iteration of the search, when the complex is formed $x_i(t), j = \overline{1, N}$. Among the many $x_i(t)$ is the "worst" such that

$$E(x_H(t)) = \min_i \left(E(x_1(t)), \dots, E(x_H(t))\right),$$

after which the center of gravity of the population without the worst point:

$$x_{cj}(t) = \left(x_{1j}(t) + x_{2j}(t) + \dots + x_{Nj}(t) - x_{Hj}(t)\right) / (N-1) \qquad j = \overline{1, n}$$

$x_H(t)$ further reflected through the centroid $x_C(t)$, forming a new vertex of $x_R(t)$, which in theory is closer to the extreme than $x_H(t)$ and $x_C(t)$, i.e.

$$E(x_R(t)) < E(x_C(t)) < E(x_H(t)).$$

Reflection operations formally is the following:

$$x_R(k) = x_C(k) + \eta_R\left(x_C(k) - x_H(k)\right) =$$
$$= \frac{1}{N-1}x_1(k) + \ldots + \frac{1}{N-1}x_{N=1}(k) + \frac{\eta_R}{N-1}x_1(k) + \ldots$$
$$+ \frac{\eta_R}{N-1}x_{N=1}(k) - \eta_R x_H(k) = X(k)R,$$

where η_R - setting step of reflection, often set to be equal to unity, $X(k) = \left(x_H(k), x_1(k), \ldots, x_{N=1}(k)\right) - (n \times N)$-coordinates of the vertices of the complex matrix, $R = \left(-\eta_R, \frac{1+\eta_R}{N-1}, \ldots, \frac{1+\eta_R}{N-1}\right)^T - (N \times 1)$-vector.

If the reflection peak $x_R(k)$ would "best" among all other populations of chromosomes, i.e.

$$E(x_R(k)) < E(x_i(k)) < E(x_H(k)), i = \overline{1, N-1},$$

the operation is complex stretching from the center of gravity $x_C(k)$ to $x_R(k)$ according to expression

$$x_E(k) = x_C(k) + \eta_E\left(x_R(k) - x_C(k)\right) = X(k)E,$$

where η_E – parameter step stretch, often set to be equal to two,

$$E = \left(-\eta_E, \eta_R, \frac{1-\eta_E(1-\eta_R)}{N-1}, \ldots, \frac{1-\eta_E(1-\eta_R)}{N-1}\right).$$

If $x_R(k)$ be the worst of all $x_i(k)$, complex contracts according to the relation

$$x_S(k) = x_C(k) + \eta_S\left(x_R(k) - x_C(k)\right) = X(k)S,$$

where η_S –setting step of compression, usually rely to 0.5,

$$S = \left(-\eta_S, \eta_R, \frac{1-\eta_S(1-\eta_R)}{N-1}, \ldots, \frac{1-\eta(1-\eta)}{N-1}\right)^T.$$

Thus, in the course of its movement to the extreme range of the optimized function at each iteration loses one the worst top and gets a new location so that $(k+1)$- iteration of the new complex is also N points-vertices.

In difference to the complex-method in genetic algorithms as a result of the selection from the population at the same time excluded some individuals with the worst (maximum) values of the fitness function. Thus, the complex method of acquiring the features of a genetic algorithm, which as a result of selection at each iteration of the population removed some of the worst individuals.

Combining introduced a modification of the complex method with genetic Holland’s procedure, we arrive at an algorithm that realizing the idea of artificial selection, consisting in this case is that of the population, not only removes the worst individuals, but at the same time they are "opposites", having improved properties.

The work of such an algorithm is formed by a sequence of the following steps:

- Creating an initial population formed by $P(t)$ individuals chromosomes - vertices of the complex;
- operation crossover with increasing population $P_{CR}(t) > P(t)$;
- operation mutation $P_M(t) > P_{CR}(t)$;
- first selection (the definition of the worst individuals) without reducing the population $P_{SEL1}(t) = P_M(t)$;
- operation replaces the value of the best choice in the general population;
- operation reflection to remove P of the worst individuals $P_M(t) < P_{SEL1}(t)$;
- operation stretching without increasing the population $P_E(t) = P_R(t)$;
- operation contraction without increasing the population $P_I(t) = P_E(t)$;

- second selection to remove $P_W(t)$ of the worst individuals $P_{SEL2}(t) = P_I(t) - P_W(t) = P(t+1)$ and the formation of a population $P(t+1)$ the next iteration of the algorithm.

The proposed algorithm can be represented by the scheme shown in fig.1.

This paper deals with the problems associated with the processing of incomplete, inaccurate and misleading information in artificial intelligence systems. New approaches based on evolutionary methods for optimization of fuzzy rule bases can significantly reduce the formation of solutions and improve the accuracy of its decision in intelligent systems.

Decided to create a model of a fuzzy inference based on the use of genetic algorithm with artificial selection and create software solutions for this task, using a genetic algorithm with artificial selection.

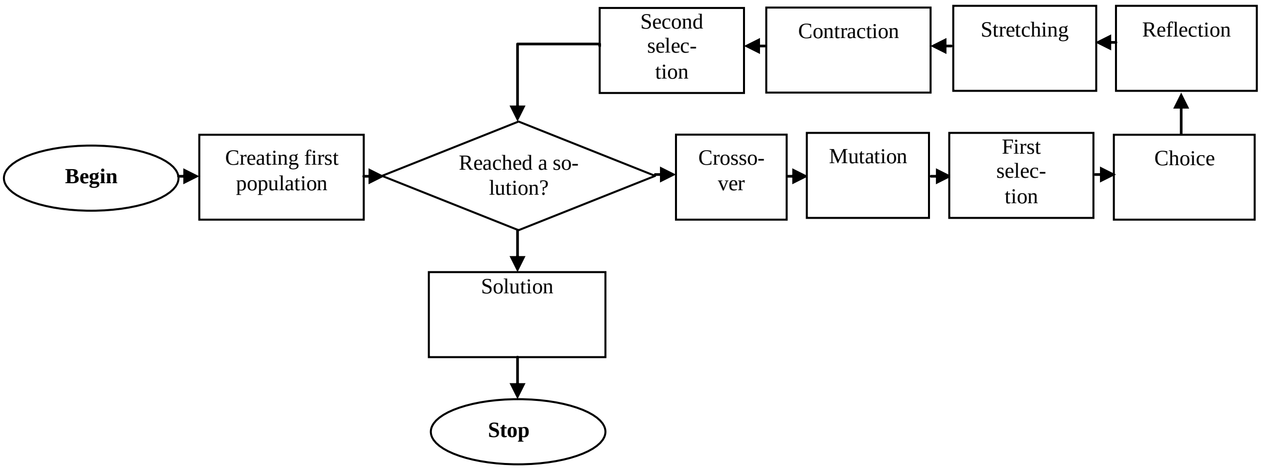

Fig. 1. ***A genetic algorithm with artificial selection in a coherent complex method.***

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ANALYSIS OF DYNAMIC STRESS INTO INFORMATION TRANSMISSION SYSTEMS

Z.T. Azamatov, I.A. Kulagin, V.I. Redkorechev

Institute of Applied Physics, National University of Uzbekistan,
Talabalar shaharchasi, 3A, Tashkent, 100074, Uzbekistan
Phone: (+99890) 9020361; E-mail: zakir.azamatov@mail.ru

Keywords: *information transmission, optical fibers, digital holographic interferometry*.

Introduction

There are a lot of elbows, adapters between the cables of different sections, and connectors with available equipment in the modern fiber-optic data transfer lines and in the local network lines particularly. All this equipment endures by various continuous mechanical traffics and weather exposures, which can bring in distortions and additional noise to a flow of the transmitted information. For qualitative work securing the exact monitoring of fiber-optic data transfer lines is extremely necessary. To the present time the advanced methods of fiber-optic line diagnostics are reduced basically to measurement of losses and are not sensitive to small external perturbation.

Methodological base

In our work the diagnostics of optical communication lines developed on the basis of modern information technology achievement of registration and processing of digital information is described. The offered technique is based on a supersensitive method of digital double-exposed holographic intreferometry [1]. In contrast to traditional holography [2,3] where the electromagnetic field wavefront record and reconstruction are occurred in an analog form (using a photoplate, thermoplastic, photorefractive materials), the digital holography is a way of wavefront record in a digital form with the subsequent its retention, measurement, transformation, and reconstruction by mathematical methods in computers [4,5]. In digital holographic interferometry, two wave fronts reconstructed from two digital holograms Γ1 and Γ2 are compared (numerically interfere). In this case Γ1 is the hologram of the unperturbed object and Γ2 is the hologram of object with induced optical heterogeneousness. As a result of two wave front summing the interferogram is obtained. It is possible to determine the phase changes arisen at the temporal interval between records of Γ1 and Γ2 holograms in the investigated objects on basis of analysis of curvatures and locations of fringes at the obtained interferogram. Each digital hologram is recorded in the field of pulse or cw laser radiation using a CCD matrix of the digital chamber. At this case the shot time is specified by digital chamber control gate or laser pulse durations.

The idea of application of computer processing for wave-front reconstruction using the images written down holographically was offered for the first time by J.W.Goodman and R.W.Lawrence [6], and also by R.W.Kronrod with co-workers [7]. The development of information technologies and solid-state radiation detectors has allowed writing down the holograms with the help of photosensitive matrixes on basis of charge-transfer devices (CCD chambers) in a digital form. In these cases the processes of retention and processing of the holograms are completely digital ones and were called as digital holography. The application of digital holography opens great potentialities for qualitative and moreover exact quantitative analysis of object properties such as precision displacement of surface points at the deformation and fault analysis, definition of the object shape, measurement of refraction index in transparent media, study of microparticle trajectories, and so on.

The numerical reconstruction of the hologram written down by a digital image is carried out according to the scalar diffraction theory in the Fresnel approach for the Rayleigh-Sommerfeld diffraction integral [8,9]. This technique serves as a starting point for numerical reconstruction of the images in the digital holography in paraxial approximation. The resulting field is determined by twofold Fourier transform of intensity distribution product in the obtained hologram. At accounts the quantization is entered taking into account the pixel sizes of a CCD matrix.

Algorithm Description

In our measurements of induced phase heterogeneities in optical fibers the algorithm of digital intreferogram reconstruction under the recorded holograms was similar to algorithm submitted in [4]. The intensity distribution in a plane of hologram record $I(x, y)$ is determined by summing of a module squares of complex amplitudes of object O(x, y) and background R(x, y) waves:

$$I(x,y) = |R(x,y)|^2 + |O(x,y)|^2 + R(x,y)\,O^*(x,y) + R^*(x,y)\,O(x,y) \qquad (1)$$

The last two terms of the Eq. (1) contain the information appropriate to amplitude and a phase of the object wave. This information can be discriminated by the Fourier transform method. If the hologram is recorded by a light source with the restricted output aperture (in our case, the restricted light beam), after transformation we receive a Fourier spectrum of the hologram with four located areas of spatial frequencies, which correspond to the various terms of the Eq. (1). First two terms of Eq. (1) form the zero order of the spectrum, which is located at the centre of two-dimensional Fourier plane. The third and fourth terms of Eq. (1) form two connected spectral areas located symmetrically concerning the centre and correspond to the complex amplitude of object wave. If one of these located spectrum areas is separated and then the inverse Fourier transform is applied, the phase front of object wave (real or imaginary ones depending on the chosen separation area) can be reconstructed in the object image plane.

Thus the following algorithm the recording and reconstruction was used. In the beginning the hologram Γ1 (non-loaded optical fiber) is recorded, then in the next light pulse the hologram Γ2 (loaded optical fiber) is recorded. Then the two-dimensional Fourier spectrum is constructed under the obtained holograms. In this spectrum the area for reconstruction is selected. Under this selected area the digital phase fronts Γ1 and Γ2 are reconstructed by inverse Fourier transform and their interferogram is calculated. Then the algorithm of a phase unwrapping similar to [4] is used. The real surface of the indignant phase of radiation transmitted through deformable optical fiber is reconstructed.

Experimental

For record and analysis of induced optical heterogeneities in optical fibers the traditional schemes of Young and Michelson interferometers were used. The interferometer was assembled using two pieces of single-mode fiber for optical telephony. The diameter of fiber core was 125 мm. The lengths of each optical fiber pieces were 2 m. The cable sheath was removed from the fiber input and these cable inputs incorporated together in parallel for input of laser radiation in the interferometer. At the interferometer input the He-Ne laser beam with wavelength of 0.63 мm and radiation power of 3 mW are transmitted without focusing optics.

The cable sheath was also removed from the fiber end and these cable ends incorporated together in parallel at the spatial interval. The interferometer optical fibers were rolled by rings with diameter of about 30 cm and were situated in the free (unfixed) conditions on an optical table.

In such scheme, two optical fibers formed object and background light beams. In Fig.1 and Fig.2 the meter schemes assembled by the Young and Michelson interferometers are shown.

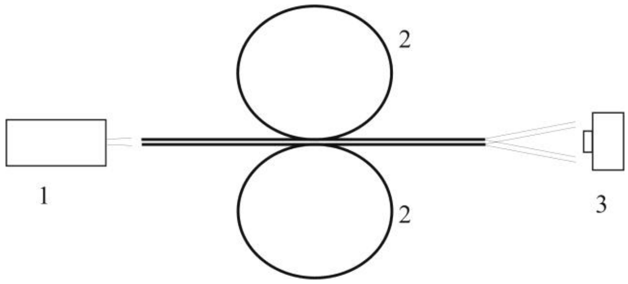


Fig. 1. ***Meter scheme based on the Young interferometer. 1 : laser, 2 : optical fiber, 3 : photographic camera.***

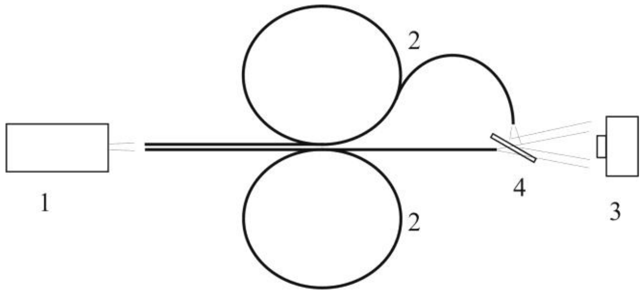


Fig. 2. ***Meter scheme based on the Michelson interferometer. 1 : laser, 2 : optical fiber, 3 : photographic camera, 4 : splitter.***

The analysis of interferometer response on external influences was carried out by loaded of the first background fiber by paper belt weighing 3 mg or by location at the distance of 10 cm интерферометра of a heat source with the temperature of 35 C (at the temperature of ambient space of 25 C).

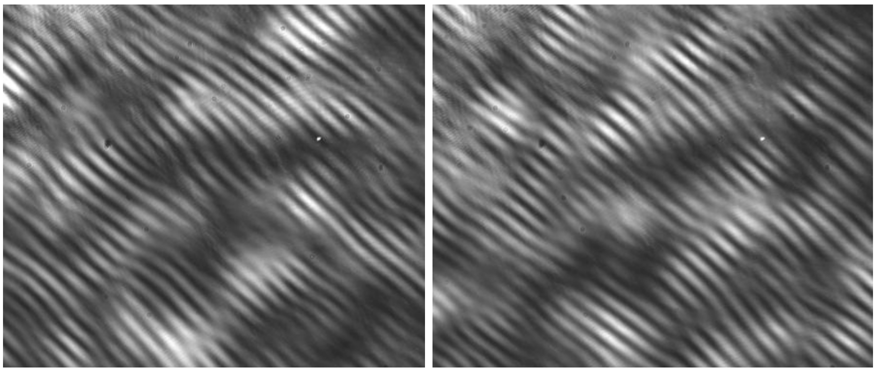
At the interferometer output for digital registration of the holograms formed by interference of background and object beams the monochrome digital photographic camera with the pixel size of 9 x 9 мm was used. The record was carried out on the matrix area of 1000 x 1000 pixels. Time of exposure was 1/10000 sec.

Results and Discussion

The holograms were recorded using the experimental arrangements described above. In Fig. 3 the digital holograms recorded in a condition of interferometer loaded by the paper bent (a) and without loading (b) are presented. The camera objective is removed. The large heterogeneity of intensity is connected with poor-quality chip of the input and output ends of the optical fibers.

In Fig. 4 the digital hologram recorded by camera equipped by objective is shown. The record was carried out under the scheme presented in Fig.2. The objective forms the image of interference pattern at the distance of 5 mm from the beam splitter.

At the next stage the differented interferogram was reconstructed under the recorded holograms with the help of algorithm described above. This interferogram contains the quantitative information on phase changes in laser radiation transmitted through loaded optical fiber. Then the area shown in Fig.4 by rectangle was selected on this interferogram. In the borders of selected area the surface of phase distortions shown on Fig. 5 was reconstructed.



a b

Fig. 3. ***Images of digital holograms recorded in a condition of loaded (a) and unloaded (b) interferometer.***

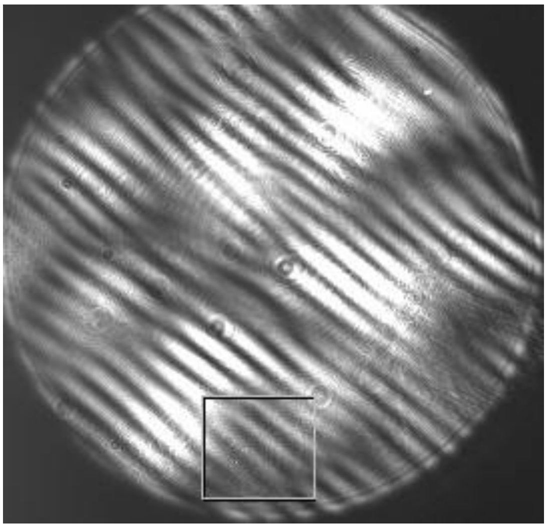


Fig. 4. ***The digital hologram recorded by objective equipped camera.***

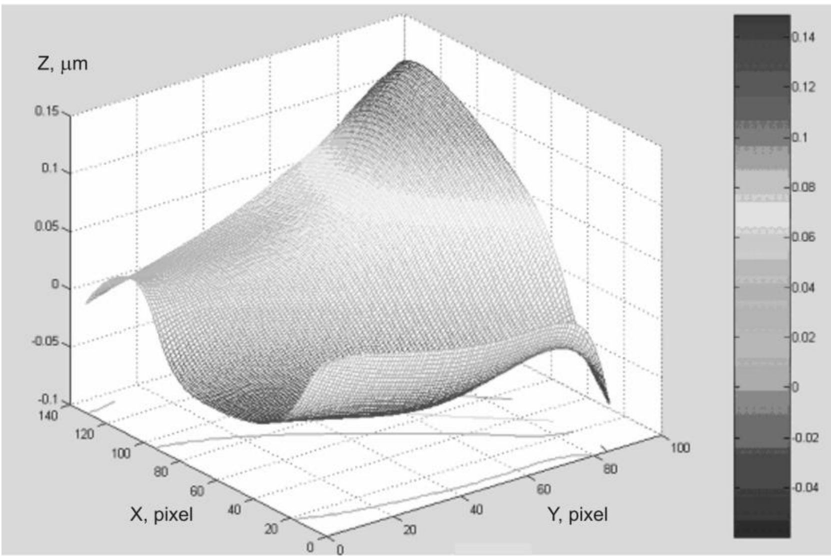


Fig. 5. ***Interactive presentation of phase changes in the selected fragment of tested optical fiber section.***

From this figure one can see that the phase incursion in laser radiation transmitted through the selected area in the fiber section in recalculation on optical path length is 0.22 мm at external dot loading on a cable of 3 mg. The accuracy of measurements along z axis was 5 nm.

Conclusion

Thus the capacities of a digital double-exposed holographic intreferometry method and developed computational procedure for quantitative analysis of phase changes arising in radiation propagated in optical fiber at over small mechanical influences are shown. In our experiments the accuracy of measurements along z axis in recalculation of a phase on an optical path was 5 nm. The above described method can be applied to diagnostics of optical splitters, connectors, focusing optics, welded assemblies of optical fibers. On the basis of the developed schemes the sensitive gauges of external influences can be created.

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ON INTEGRATED ELECTRONIZATION INTELLECTUAL BOARD COMPUTER COTTON MACHINE-TRACTOR UNITS

E. Uljaev, A. D. Abdazimov, I. I. Usmanov, F. A. Tulbaev

100095, Tashkent, Uzbekistan
Tashkent State Technical University, Department of Electronic and Automatic
2, Universitetskayast. Phone: 246-03-45

Keywords: *electrification, cotton-picker, automatic control, management, intelligent information - measuring device.*

One of the key components of the technical level of modern agricultural units is their level of equipment with systems of the automatic control and management (SACM).

Cotton machine and tractor units (CMTU), consisting of domestic and TTZ tractor series of mounted to it machinery or implements for cotton cultivation and harvesting his crops are not sufficiently equipped with modern SACM that reduce their feasibility and performance and competitiveness.

In this regard, a research, design and experimental works for the development of such systems and devices based on the study of foreign best practices specific to CMTU and technical resources to the domestic industry, including electronic, is relevant. [1]

Currently used in Uzbekistan with tillage and seeding CMTU gradually updated by agricultural foreign-made machine, imported or produced in the joint venture «UzCaseMash», «UzCLAASAgro» and others, such as tractors and firms CaseNewHolland CLAAS, plows and harrows company Lemken, cotton planter CASE-1200. These machines are equipped with sufficient SACM, providing high performance and reliability of the unit.

The most difficult CMTU certainly is currently produced at JSC "Texnolog" and "TTZ" semi-mounted on a tractor TTZ cotton-picker (CP), MX-1,8, is a complex multi-dimensional object composed of many working parts and systems for collection of raw cotton bushes and transporting it into the hopper.

For performance and agronomic performance (AP) CP, the technical specifications and standards, the need to monitor and manage technological and operational parameters and, if necessary, take decisions to change them in the course of the CP.

However, the development SACM machines for cotton, whose production was mainly concentrated in Uzbekistan, far neglected, not given.

At the same time, tractors and agricultural machine Western firms that have appeared in recent years in Uzbekistan, which are fitted with electronic and microprocessor-based control and management, including on-board computers that are going to shoot with multiple sensors information, process it and display the results to the driver through the instrument panel. They also warn of the dangerous condition of components and assemblies with the audio and video channels and control the various systems of the tractor and of mounted guns with him.

One way of accelerated digitalization complex domestic CMTU in the initial stage is the use of electronic systems of cars of foreign firms, but this way is limited to the known objective and subjective factors:

Currently the specialists of JSC "SKB Tractor" at JSC "TTZ" and scientists, engineers departments "Automation and Control" and "Land transport system" shall be neither TashSTU to develop their own electronics and components, as well as on the application of international instruments and other resources for domestic SACM CMTU [1,2,3]. In particular, The synthesis of mathematical models of the assembly agricultural machine, with CMTU, as the object of automation and control, is represented as a complex system [4,5,6,7]. Designed electrical wiring diagrams set type KD8083 in the cab TTZ. Fundamentally and wiring diagrams onboard microprocessor device control and signaling standard and custom parameters TTZ tractor and CP. Selected component parts: sensors, cables, connecting terminal blocks, microcontroller, display, etc. However, due to lack of funding difficulties arise in the implementation of these projects.

As part of the innovation project of "Technologist" developed and tested a number of local automated devices and control systems for units CP MX-1, 8. For example, device control and regulation of the working gap cleaning apparatus CP [2,6].

One of variants of a function chart of the microprocessor monitoring system and regulation working crack cleaning machine consists of a reference selection and management of the actuator, the display unit indicators and audible alarms, the control unit work actuator, the actuator, the object of control and regulation of the working gap monitoring sensors, analog multiplexer, a frequency converter.

The microcontroller receives the incoming frequency (signals), and according to pre-embedded software in its memory processes, compares the processed data to a specified value. If the measured value is equal to the specified value, the device cancels outputs a control signal, as a result of shutting down the power to the winding selected electromagnet. EGD valve solenoid moving shuts off the oil from the hydraulic pump in GS. Moreover, if the width of the working gap is less than the set value of the piston GS continues - reduced labor gap. Sensor control of the working gap (1-SCWG) monitors and sends a signal to change the width of the working gap. Thus, for automating the control and regulation of the working gap harvesting machine hum.

Designed microprocessor control and regulation of the working gap cleaning machine tested on a pilot CP MX 1.8.

In [6] proposed an intelligent information-measuring device control (IMDC) to automate the assessment of white cotton field. It is very effective technical tool is intelligent IMDC built from a vision system (VS) [14,15]. VS, can be divided into three main sub-classes of the low, medium and high levels. VS low level designed to process data from sensors sensitization.

The assessment whiteness of cotton row is based on segmentation. Segmentation of cotton fields at harvest is one of the main elements of the nascent intellectual IMDC whiteness, as it is at this stage of processing the whiteness of cotton row stand out from the scene for further recognition and analysis. In this case, the studied cotton rows are divided into components or objects. Segmentation algorithms are based on two fundamental principles: the discontinuity and the like. In the first case, the basic approach is based on defining the contours of whiteness harvested cotton field, and the second - on the definition of the threshold and the expansion area. These concepts apply to both static and dynamic (time-dependent) scenes of cotton row.

By digital image means-square matrix of dimension NxN elements with integer values from 0 to 9 V. In theory, digital processing of the information (DPI) is called a pixel picture element. According to [10] by a neighborhood of the current pixel is understood eight neighbors surrounding elements.

One of the simplest approaches is the connection points of the contour analysis of the pixels in a small neighborhood (for example, in a neighborhood of size 1,0 X 1,0 or 2,0 X 2,0 m) of each point (x, y) of the cotton row, which has already underwent the procedure detection circuit. All points are similar, join to form the border of pixels that have some common properties. In such an analysis to determine the similarity of the contour pixels of cleaned cotton white order to determine:

- the gradient required for the construction of a contour pixel is characterized by frequent cotton row;

- the direction of the gradient.

The gradient (first feature) the magnitude of

$$G\{f(x,y)].\tag{1}$$

Here, the pixel circuit with coordinates (x ', y') is similar in size to some earlier neighborhood of (x, y) of the pixel at (x, y) if the inequality

$$|G[f(x,y)] - G[f(x',y')]| \leq T\ ,\tag{2}$$

where G - threshold.

The direction of the gradient is set to the angle of the gradient vector defined in equation

$$G[f(x,y)] = \begin{bmatrix} G \\ G_y \end{bmatrix} \begin{matrix} G[f(x,y)] = [G_x^2+G_y^2]^{1/2} = \left[\left(\frac{\partial f}{\partial x}\right)^2\right]^{1/2} \\ G[f(x,y)] \cong |G_x|+|G_y| \end{matrix}$$

$$\theta = arctg \begin{bmatrix} G_x \\ G_y \end{bmatrix}\tag{3}$$

where θ - angle (relative to the x-axis) along which the rate of change is greatest. We can then say that the angle of the pixel coordinates of the contour of cotton row (x', y') in a neighborhood of (x, y) is similar to the pixel at the corner of the cotton row (x, y) if the following inequality:

$$|\theta - \theta'| < A\tag{4}$$

where A is the threshold angle. It should be noted that the direction of the contour of the cotton row at the point (x, y) is actually perpendicular to the direction of the gradient vector at that point. However, to compare trends inequality gives equivalent results.

Based on these assumptions, connects the dots in a neighborhood of c (x, y) pixel with coordinates (x, y), provided the criteria for the magnitude and direction. Moving from pixel to pixel and representing each connectable point as the center of the neighborhood, the process is repeated for each of the cotton field. To establish a correlation between the level of light intensity that is The brightness of parts of cotton fields and successive pixel circuit according to [1,6] proposed to use the standard library routine.

Intelligent IMDC degrees disclosure boxes (white) cotton field can be constructed in two variants - active and passive. In Figure 1.shows the block diagram of passive IMDC. [6] The device consists of the following functionally blocks: the object of control (OC) means of distribution of the reflected radiation (RR), Lens (L) electron optical converter (EOC), analog-to-digital converter (ADC), a microcontroller (MCU), the RS- 232, lines of communication, the controller (C), the display (DIS), block keyboard (BK). In this case, OC EOC is - a digital camera, scanner, video camera.

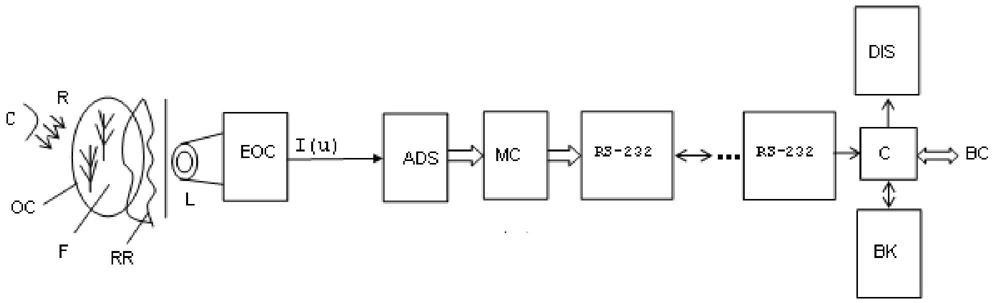

Fig. 1. ***Block diagram of a passive intellectual information - measuring device controls***

the extent of disclosure cotton field.

The information processed by the MC via RS-232 is transmitted to the central controller for further processing and management decisions (exposure) of the assembly machine.

In other studies [8,9], the authors propose a mathematical model and algorithm of intelligent system monitoring and control operational parameters agricultural machines. The principle of construction of such intellectual process control systems based in the comparison and analysis of logic states (positions) working parts, operation units of machines and the decision to form the control signals. Meeting these challenges will require the creation and management of intellectual IMDC.

Since modern CP controlled mechanic, an intelligent system must be set to a counselor, which gives the best advice on what to do to improve performance mechanic hum and improve the collection of raw cotton. In [8] made an attempt to construct an algorithm that allows to control the process parameters and work units CP, and the parameters that affect the performance and quality of the cotton-wool.

Because of machine operators to a final decision on the need to implement one or the other team, to analyze the influence of parameters and modes of operation of the units CP, and for the algorithm synthesis is used the theory of switching functions [9].

In constructing the logic of mathematical models that assess work CP, introduced the following notation: x_{1s} - spindle speed (x_{1s} - norm, $\overline{x_{1s}}$ - below normal);x_p - the pressure in the pneumatic system (x_p - norm, $\overline{x_p}$ – below normal); x_r - roller speed (x_r - the norm, $\overline{x_r}$ - below normal); x_{2s} - spindle speed after changing the drum at a high speed (x_{2s} - norm, $\overline{x_{2s}}$ – below normal);x_{wc} -whiteness of cotton row (x_{wc} -above normal, $\overline{x_{wc}}$ - below normal); x_q - the loss of cotton in a row (x_q – normal$\overline{x_q}$ –above normal); x_h - the height of the vehicle with respect to the surface of the beds (x_h - above normal, $\overline{x_h}$ - below normal); x_m - speed of the machine (x_m - above normal, $\overline{x_m}$ - below normal).

In this case, the logical mathematical model that provides the condition of "NORMAL" operation HUM described as follows:

$$Y_{nor} = f\left(x_{1s}\boxtimes^{x}_{p^{x}_{q}}\right) = f\left(1^{1^{1}}\right) = 1 \tag{5}$$

Present a mathematical model shows that the CP should work ("NORMAL") if: $x_{1s} \geq$ norm; $x_p \geq$ norm; $x_q \geq$ norm. Similarly, to make the approach to the construction of mathematical models of other operational parameters CP, for example, stopping the machine must be carried out under the following conditions (stop mode) if $x_{1s} \geq$ norm; $\overline{x_p} \leq$ below normal; $x_r \geq$ above normal; $\overline{x_{2s}} \leq$ below normal.

Using these logical operations logical states constructed mathematical models "STOP THE MACHINE" in two versions, the first version:

$$Y_{STOP1} = f\left(x_{1s}^{\overline{x_p}}\right) = f\left(1^{0}\right) = 0 \; . \tag{6}$$

A second version of the logic of the mathematical model of "STOP THE MACHINE" is the following:

$$Y_{STOP2} = f\left(x_{1s}^{x_r^{x_{2s}}}\right) = f\left(1^{0^{0}}\right) = 0 \tag{7}$$

The authors of this paper are designed structure and concepts of intellectual onboard microprocessor SAKM process parameters and operating modes of CMTU with tractor TTZ (Fig.2).

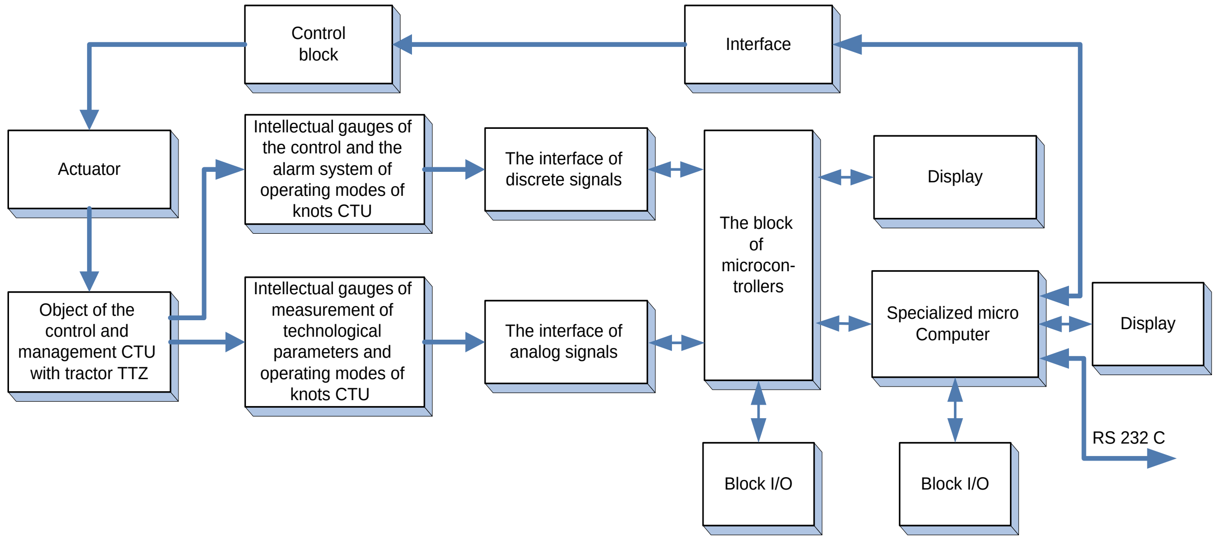

Fig.2. ***Block diagram of intellectual onboard microprocessor control of technical condition, operation and control of technological parameters of the tractor CMTU TTZ.***

It includes two channels of transmission - digital and analog signals from transducers (sensors) parameters control the technical condition and operation modes of the tractor and process parameters MTU.

The most important and challenging task to clarify the component parts and the structural parameters of this scheme are the selection and specification of controlled functions and parameters of the tractor and CMTU as a whole.

Here, as the primary device is desirable to use both analog and digital smart sensors and control modes nodes CMTU. In this case, the microcontroller processes the information received, compared with the set values and outputs to the input of a dedicated microcomputer. Last equipped with a purse program that allows you to think, to analyze the values of the complex of the data coming from the device and make a decision about the management or change the mode of the relevant parameters (nodes) process parameters CMTU. Here, as the display is proposed to use multi-function display with dot matrix liquid-crystal display that allows you to display on a digital form as well as full-custom mode parameters of the unit. The use of such displays, based on the modern control microcontrollers are provides an opportunity to make a compact intelligent onboard SAKM modes CMTU.

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DEVELOPMENT OF ALGORITHMS FOR DIAGNOSTIC DECISIONS USING NEURO-INFORMATION TECHNOLOGY

Z.B.Mingliqulov

TUIT, 100084, Str. Amir Temur 108,Tashkent, Uzbekistan
zafarbek1402@mail.ru

Abstract: *Development of algorithms for diagnostic decisions using neuro-information technology is presented in this work.*

Keywords: *intellectual analysis of data, neural networks, fuzzy expert system, the terms of neuro-information technology.*

Introduction

All problems that are solved by humans can be roughly classified into two groups in terms of neuro-information technologies [1].

1. Tasks that have known and defined a set of conditions under which you want to get a clear, precise and unequivocal answer from a known and specific algorithm.
2. Problems in which it is not possible to consider all actual conditions that affect the answer, and can only provide a rough set of the most important conditions. Since part of the environment is not taken into account, the answer is inaccurate, imprecise, and the algorithm for finding the answer can not be written exactly.

The problems of the first group can be solved by using the traditional computer programs. No matter how complex the algorithm, the limited set of conditions (input parameters) makes it possible to find solution algorithm and to write a specific program that solves this problem. There is no point in using neuro-information technology to solve these problems, because in this case the neural network methods are a priori worse to solve such problems. The only exception is the case when the algorithm for computing the answer is too big and cumbersome and time to solve a particular problem with this algorithm does not meet the practical requirements and, in addition, the solution does not require absolute precision.

In solving problems of the second group the application of neuro-technology pays off by all parameters, but following two conditions should be observed: first, the presence of a generic type of architecture and a single universal learning algorithm (no need for them to develop for each type of task), in-second, the availability of samples (background, fixed experience) for training neural networks. Under these conditions the rate of creation of expert systems increases tenfold, and thus their cost is reduced.

Virtually all medical and biological science consists precisely of the problems relating to the second group, and in most of these tasks is easy to recruit the necessary number of examples for the second condition. This is the problem of diagnosis, differential diagnosis, prognosis, the choice of strategy and tactics of treatment and others. Medical problems almost always have several ways to solve and "fuzzy" nature of the response, which coincides with the kind of output neural networks [3].

In medical diagnostic tasks work of the system often begins with an input of the patient's data (symptoms, medical history, test results, etc.) to computer and ends with the issuance of a possible diagnosis and prognosis. Often, one problem consists of multiple sub-tasks. In this case, each subtask can fit a separate act of the system, but to the user it can be quite noticeable. For example, it is required to establish the diagnosis and appropriate treatment according to the patient. Diagnosis based on the input parameters - the first sub-task, assignment of therapy - the second, and not only the original data, but the result of solving the previous problem – diagnosis is also required for assigning of therapy.

Formulation of the problem

It is useful to determine the type of each subtask: classification, prediction, vector prediction. Typically, each sub-problem is solved by one neural network or more neural networks, combined into one functional unit (small experts [2]). In this case, the input data are fed sequentially to each unit and each neural network gives the answer. Answers may vary, so in this situation developing a way to obtain a single answer is required.

This can be done in two ways:

1. By logical rules. For example, if five of neural networks give the answer " healthy", and 2 - "sick", the general solution - "healthy" because for this voted more neural network experts. If you can not formalize a rule, you can make a decision based on the degree of certainty of each of the networks.

2. By changing parameters on the unit of low-experts of the neural network - "supervisor" who is trained to take action on the results of these small experts.

After the definition of the work of the system and breakdown (if required) into sub-tasks developing of schemes of training examples for each of the subtasks is required. The scheme includes a sample list of input and output parameters for the sub-tasks.

Determining the list of input data – work of the subject’s specialist, which requires knowledge of the study area and estimated the importance of various parameters required for a response. Setting of some redundancy in the list input at the start of the project is preferable. In the future, the "extra" parameters can be easily deleted from the system, but adding new parameters is somewhat difficult, primarily because of the need to re-apply these parameters to the data sources.

It is recommended to make a visual diagram of motion information in the expert system beginning with the data input from the external world and ending with the withdrawal response (answer) to the user.

Determining of the approximate sizes of the training samples is necessary. For example, in classification problems (sub-problems) it is desirable that each class of response is presented enough examples. Not necessarily, but it is desirable that the number of examples of each class do not differ too much (more than an order of magnitude). Preliminary training and testing of neural networks can be performed on a small sample size to determine the strategy and tactics training, and to clarify the overall size of the training set.

The process of constructing a fuzzy expert system is carried out according to the following algorithm:

A°. Determining the characteristics of the system.

B°. Formation of the tree of logical conclusion.

C°. Determination of membership functions of linguistic terms.

D°. The definition of expert rules IF-THEN, describing the behavior of the object. Expert IF-THEN rules are made to the relevant knowledge matrix.

E°. Setting of fuzzy expert system by solving optimization problems using the training set.

Successful treatment of the disease is determined by the possibility of its differential diagnosis, i.e. referring to one of the accepted levels in clinical severity. Quality of diagnosis depends heavily on practitioner. This shows the urgency of the problem of creation of computer system of intellectual support for diagnostic decisions.

In accordance with established practice, clinical severity of the disease will be determined at levels from lowest to highest. Levels assume types of diagnoses, which are subject to recognition. Disease at diagnosis for a particular patient will take into account the following parameters, which are measured in the laboratory.

To estimate the values the linguistic variables we will use a single scale qualitative terms: L - low, BA - below average, A - average, AA - above average, H - high. Each of these terms is a fuzzy set defined by the corresponding membership function.

Using these terms of quality and experience of the expert we will present the ratio in the table.

Using the table, and operations • (AND - min) and $\vee$ (OR - max), it is easy to write the system of fuzzy logic equations relating diagnoses and membership functions of input variables [4].

RESULTS OF EXPERIMENT

In general, each input variable $x_i,\ i=\overline{1,n}$ have their own membership functions of fuzzy terms (L, BA, A, AA, H), which are used in the equations. To simplify the model we will use for all variables $x_i,\ i=\overline{1,n}$ only one form of membership functions. To do this, we present ranges of each variable to a single universal interval [0,4] using the following equations:

$$\mu^j(x_i)=\tilde{\mu}^j(u),$$

$$u = l\,\frac{x_i-\underline{x_i}}{\overline{x_i}-\underline{x_i}}, \quad j = L, BA, A, AA, H,$$

where $[\underline{x_i}, \overline{x_i}]$ - interval of variation of $x_i,\ i=\overline{1,n}$, l – number of terms.

The analytical model of membership functions is as follows:

$$\tilde{\mu}^j(u)=\frac{1}{1+\left(\frac{u-b}{c}\right)^2} \tag{1}$$

The choice of these functions is due to the fact that they are good approximations of the membership functions that are derived from the expert method of paired comparisons.

Fuzzy logic equations with the functions of fuzzy terms to take decisions about the level of disease in the following manner:

1°. We fix the values of the patient

$$X^* = (x_1^*, x_2^*, \ldots, x_n^*)$$

2°. Using the model (1) and the parameters b and c, we determine the values of the membership functions $\mu^j(x_i^*)$ with fixed parameters $x_i^*,\ i=\overline{1,n}.$

3°. Using logic equations, we calculate the value of membership functions of the state vector at $\mu^{d_j}(x_1^*, x_2^*, \ldots, x_n^*)$ with the state vector $X^* = (x_1^*, x_2^*, \ldots, x_n^*)$ for all diagnoses $d_1, d_2, \ldots, d_m$. In this case, the logical operations AND ($\wedge$) and OR ($\vee$) on the membership functions are replaced by the operations min and max:

$$\mu(a)\wedge\mu(b)=\min[\mu(a),\mu(b)],$$

$$\mu(a)\vee\mu(b)=\max[\mu(a),\mu(b)].$$

4°. Define a solution d_j^*, for which:

$$\mu^{d_j^*}(x_1^*, x_2^*, \ldots, x_n^*) = \max_{j=\overline{1,n}}[\mu^{d_j}(x_1^*, x_2^*, \ldots, x_n^*)].$$

After determining the algorithm of the system and the breakdown (if required) into sub-tasks developing schemes of training examples for each of the subtasks is required. The scheme includes a sample list of input and output parameters for the sub-tasks.

We summarize the existing advantages of neural network expert systems over conventional, which, as already mentioned, appear only in solving of problems with difficult algorithms. In figures 1 and 2 initial data and the solutions of program based on the algorithm are given.

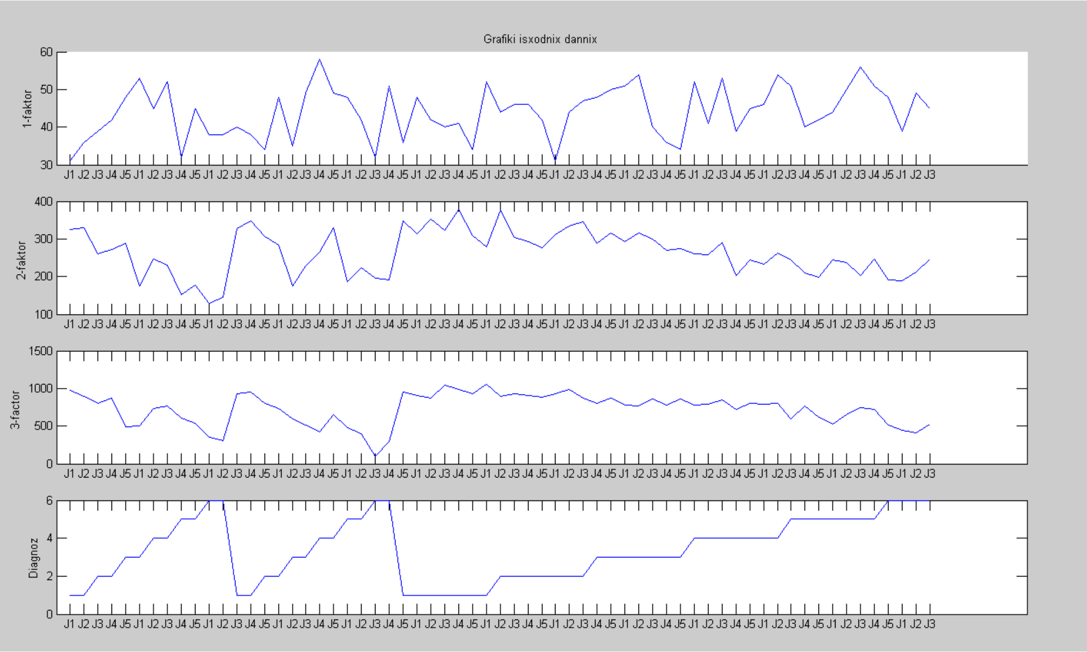

Fig.1. ***Initial data.***

Capabilities of neural networks (correction of the classification model, minimizing the learning parameters, etc.) make it possible to simplify the process of creating expert systems, to determine the direction of scientific research.

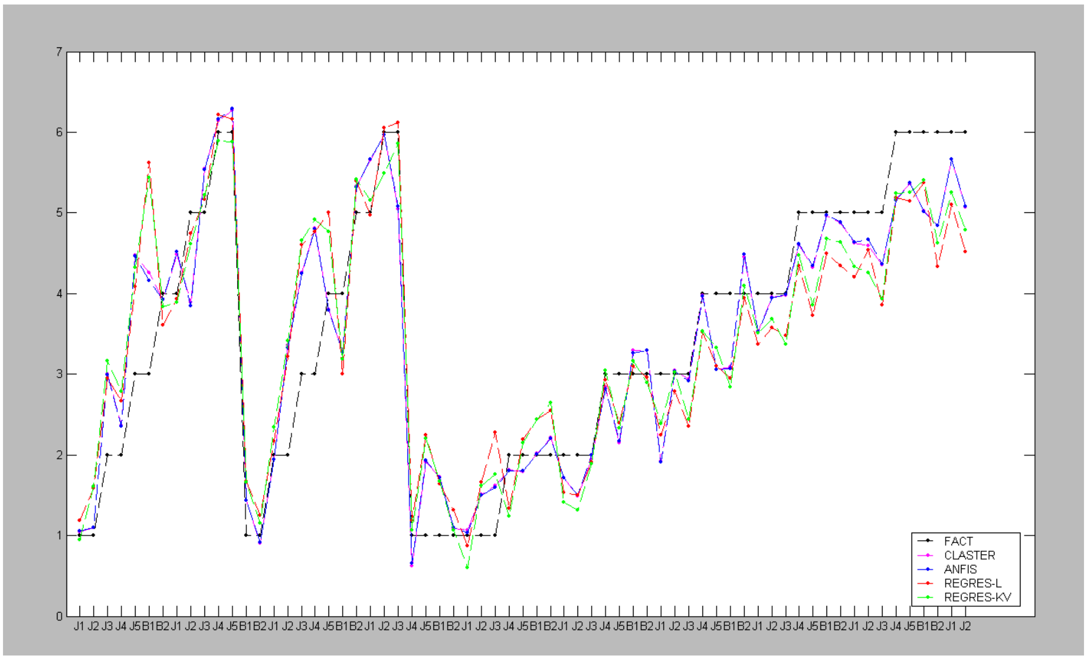

Fig.2. ***Solution of the program***

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DEVELOPMENT LOGICAL INFERENCE PROCEDURES IN DIAGNOSTIC EXPERT SYSTEM

A.A. Djaylavov, A.E. Kuvnakov

Tashkent University of Information Technologies. Department of Information Technologies,
108, A.Temur str., 100084, Tashkent, Uzbekistan
Phone (+99871) 238 64 37, djaylavov@mail.ru, avaz_a@yahoo.com

Abstract: *In this paper the experience of creating expert systems and the problems of developing logical inference procedures in diagnostic expert system of computer systems are considered.*

Keywords: *expert systems, computer diagnostics, logical inference.*

1. Introduction

Study of the experience of creating expert systems (ES) showed that the use of their development methodology adopted in traditional programming lead to excessive delays the process of creating the ES, or even lead to a negative result. Herewith, the use of EC is most effective in solving the problems of diagnosis, interpretation of data, forecasting, monitoring of technical conditions and ensure efficient operation of computer systems (CS).

Theoretical and practical aspects of the application of technology to solve problems of ES for diagnostics of computer systems are considered in [1-5].

It should be noted that in most cases modern ES do not meet in effective application of ES technology to solve problems of diagnostics for the following reasons:

1. Database management tools, such as, SQL-server, capable of delivering only the specific information to specific requests in the appropriate language and they can not make a conclusions and train themselves.

2. Searching tools on the Internet can not guarantee success, because they do not use the semantics of the subject area.

3. The system should be Internet oriented. On each of the servers involved in the organization of distributed knowledge bases and data must be installed on kernel. Knowledge Base (KB) of each server stores information about a particular area of human activity or natural science. The users have an access on the local computer that connects to the server. Suppose the user asks a question, and server in own turn could not find the answer in own database. In this case, the machine sends a network request to other servers. Demand is generated by a special algorithm and transmitted through a special transport protocol. There is another option - the server asked for clarification of the question, by doing this, server fulfill tasks to fill his knowledge base during in dialogue process.

2. Methodology

It is known that, to determine the causes and troubleshooting symptoms of CS, instability of personal computers (PCs) connected to the server of local area network is widely described in [6]. According this to determine the causes and troubleshooting symptoms of CS followings should be performed:

1. Fulfillment a complex diagnostics of system unit. After fault isolation of PC, recommendations should be given to eliminate them. Since the system unit consists of a large number of blocks, the functioning of which is closely dependent on each other, so testing PC requires some experience in this field. For example, the failure of the system that boot from the hard drive can be called as a failure of the hard drive and the fault in the controller unit on the motherboard, or improper configuration of the system. Therefore, in any fault of PCs, successive tests should detect that a component of which is the primary cause.

2. Verifying power supply unit (PSU) to clarify its fundamental performance on the phase "switching-on". PSU is also being tested in operation mode for compliance actual output parameters displayed on the stability characteristics at different levels of the ultimate load. It should be noted that a normal and stable operation of the PC in general, and for individual functional units

(FU) directly depends on the quality of output power, obtained from PSU. Faulty PSU often leads to failure of the other expensive parts of your PC.

3. Conducting a complex inspection of the motherboard for the stable operation of all peripheral devices with special diagnostics software. The process of testing the motherboard may take a long time because of the complexity of the motherboard device itself, and the compatibility with other components of the PC units. The motherboard testing may involve other components to determine the causes and not correctness of operation in this configuration.

4. Memory is being tested in the normal mode (on standard frequencies) by using specialized software to check random access memory. Herewith, the process of memory test can take a long time, so must be checked each logic cell memory for serviceability. Performed testing of each memory module separately, and only then collaborative operation with other memory modules. Having compatibility issues fully functional memory module may not work in conjunction with other modules or specific motherboards and CPUs.

5. Checking the performance of the processor in the normal mode (standard frequencies) by using specialized software testing processors are performed. The check processors can be effected together with the motherboard and on the test platform with a known working components: motherboard, memory, etc.

6. Identifying possible causes of incorrect booting of operating system (OS): The system is not fully loaded, with errors, the boot process is terminated at any stage. In this case, attempts to diagnose hardware or software reasons that cause a problem with loading the OS are performed. In the case of hardware suspicions, further testing of separate FB are required. In case of software problems, an additional integrity check of OS, their component parts and installed drivers and programs should be checked.

7. Identifying possible causes of improper operation of the OS, booting the OS, which took place without problems and errors: during operation PC freezes, appear warnings about the errors in the OS, errors during running any programs, occurrences of spontaneous shutdown or reboot of PC, etc. In this case, attempts to diagnose hardware or software reasons that cause malfunctioning of the OS are performed. In the case of hardware suspicion in the future, required testing of individual FB, In case of software problems, an additional integrity check of OS, their component parts and installed drivers and programs should be checked.

In our case, the knowledge base (KB) is formed as a collection of the following relational database in the format of database management system (DBMS) of SQL-servers, which is running on computer networks: a database with descriptions of malfunctions; database with descriptions of symptoms, table of correspondences symptoms and faults, weights table of symptoms for troubleshooting.

To make a decision and to show a final result, usually the systems used familiar concepts such as **weight symptoms** - the probability of a fault in percentage; **underdetermined specification** - a set of data on which it is impossible to make a final decision; **the factor of confidence** - confidence in the reliability of the system which made logical conclusions and the threshold of confidence - a number predetermined by the user - maximum weight of a fault and below it the hypothesis simply rejected.

The work of the prototype of diagnostic ES begins with an initialization function that is responsible for assigning initial value to data. Then takes control procedure named "Main Menu." Furthermore, depending on the user choice, it calls one of the following procedures: work with knowledge bases, work with database of faults; directly initiate a prototype of diagnostic ES, customized context-sensitive help system.

In our case we consider the processing of the following items:

Work with the current knowledge base: read data from files on disk, and use the information available in accordance with the following description, processing of incoming information, decision-making and delivery of the final result.

At each step of the algorithm, the system has the possibility for the user if he forgot something, go back to the previous state by pressing the button "Back". If he wants to start all over again, he should click "Cancel" button, after that the system returns to its original state. The input to the system (data, entered by the user from the keyboard) initially received incomplete information, so the system can not uniquely diagnose.

To solve this problem, the following algorithm should be used:

1) Collection of initial information.

When log in, the user sees a list of all symptoms that are available in the database. In front of listed items symptoms, user puts a "tick" (these symptoms that he was discovered during work). By clicking "Next" the system moves to the next item.

2) Preparation of the initial list of faults, which fits to discovered set of symptoms.

After entering the initial symptoms, the system analyzes faults belonging to the specific symptoms and based on following algorithm determines the initial list of faults:

1) Open a table of correspondences.

2) For all $k=1$ up to the maximum number of symptoms:

3) Take *k-th* symptom from the original list;

4) Refer to the table of correspondences: simple cyclic do a full search of all faults, standing in the column of the symptom;

5) Cheking:

5.1) If the fault is already in the list, go to step 6;

5.2) If the tables = 0, then the fault is not in the list;

6) Increasing k by 1;

7) If all the symptoms of (k) iterated, the original list of faults formed;

8) Close the mapping table.

Each symptom can belong to several faults, so the original list of faults is not the same as the symptoms. It should also be noted that the symptoms can be significant and insignificant, also, weight in relation to the symptom of a fault can be large or small. This process is regulated by the system, so does not depend on the user.

With an initial list of faults, the system performs their differentiation. Next, the system begins to conduct "reasoning" to clarify information. The most common methods of inference -it is a direct chain of reasoning (direct conclusion) and reverse the chain of reasoning (the opposite conclusion). In the developed system implemented the mechanism of mixed conclusion, which allows both direct conclusion from facts to conclusions, and vice versa - to confirm or reject the hypothesis.

In the process of clarifying information system by asking the user, conducts "screening" unnecessary hypotheses with low weight. For calculation of weight of hypotheses system opens the data from the file, namely the table of weights. Weight table size [Number of faults] to [No. of symptoms] is at the intersection of cell number, equal to the weight of the symptom for this problem; confidence threshold should be given during initial setup an advance.

If the user is not able to answer some questions during the initial interview, the system makes recommendations, how to collect this data (check the power, continuity test signals or testing ....) and on the basis of these collect additional data. Recommendation system gives only for hypothesis, having a higher weight (to confirm their weight, and the expert should not have to carry out unnecessary diagnostic procedures again).

In the process of the previous steps, should be identified several versions of the final result, where systems distributes the order of increasing probability of faults. Probability of failure is also considered in the table of weights, ie, the algorithm that calculates weight, implementing the following procedures:

-select fault from the list generated in the previous stages.

-system looks at what symptoms from a list of symptoms are related to this problem.

-performed the sum of weights of all symptoms related to the fault (again, according to the table of weights).

-memorizing the final weight of the problem.

After calculation the weights of all the faults, should be selected that fault, which has the maximum weight, and the weights are normalized.

Next, the system selects the failure, that probabilities are in some part, predefined by system programmer (so-called "confidence threshold"). The threshold of confidence can be set in the program settings.

Conclusion

In this paper we investigate and analyze the experience of creating expert systems and the problems of developing logical inference in diagnostic expert system of computer systems. The analysis shows that, this methodology can be applied not only for the diagnosis of computer systems and computer networks, also for diagnostics including systems working on the Internet.

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THE FORMATION OF A DECISION RULE OF CLASSIFIER SIGNALS

S.S.Kasymov, M.B.Zaynutdinova, Yu.A.Yakovleva, O.Q.Mahmanov

Tashkent University of Information Technologies,
Tashkent Amir Temur st. 108, 100084, Tashkent, Uzbekistan,
Phone: 2386437, email Dilfuza65@gmail.com

Abstract: *Synthesized block diagram of a recognizable device based on the likelihood functional.*

Keywords: *recognition, method, signal, approximation, polynomials.*

Introduction

In addressing problems of recognition signals in a non-parametric a priori uncertainty is most common situation where the communication channel is not specified and the problem of distinguishability of classes is unsolvable by traditional methods. In this case we can proceed as follows.

We assume that the output signals of the transmission channel of information - is the implementation presented in the space of informative features, and classified training sample set: {r, r = 1,2, ..., ni; i = 1,2, ..., M}. We construct a decision rule in the most difficult conditions, when the feature space is given classified sample, and absolutely no information on the likelihood function. In this case, it is expedient to approximate the likelihood function is a partial sum of the series, and then for them to determine the decision rule [3].

Denote $p^i(\bar{y}) = p(\bar{y}/f^i)$ as the unknown input signals the likelihood function f^i, defined on a probability space and the space of signals belonging to F. We represent the $p^i(\bar{y})$ Fourier series expansion in the orthonormal system $\{e_k(\bar{y})\}$ and restrict the partial sum

$$\bar{p}^i(\bar{y}) = \sum_{k=1}^{Q} d_k^l \cdot e_k(\bar{y}),$$

where $e_k(\bar{y})$ is chosen a priori and assumed to be known as the expansion coefficients to be determined.

In this case the likelihood function and be written as a known function that depends on the unknown vector parameter $\bar{d}^i$, etc.

$$\bar{p}^i(\bar{y}) = \bar{p}(\bar{y}/f^i, \bar{d}^i).$$

As shown in [4], estimates of the expansion coefficients, provided that space is a set of training sample can be determined from the expression

$$d_k^i = \frac{1}{n_i}\sum_{r=1}^{n_i} e_k(\bar{y}_r),\ \text{k=1,2,3,…,Q.} \tag{7}$$

Algorithm (7) allows to find an estimate of the vector d_k^i by the classification sample { $\bar{y}_r$,r =1,2,…,n_i} for all i = 1,2, ..., M. In accordance with an adaptive Bayesian approach, it gives an estimate of the likelihood function in the form

$$\bar{p}^{i^*}(\bar{y}) = \hat{p}(\bar{y}/f^i, \bar{d}^{i^*}),\ \text{i = 1,2,…,M.} \tag{8}$$

In the special case of a simple loss function, which leads to the requirement of minimizing the average error detection, the decision rule can be written as follows:

$$p_i \cdot p(\bar{x}/f^i, \bar{a}^{*l}) \geq p_i \cdot p(\bar{x}/f^l, \bar{a}^{*l}),\ \text{l = 1,2,…,M},\ l \neq i, \tag{9}$$

where $\bar{a}^{*l}$ - the maximum likelihood estimator of the vector of random parameters $\bar{\gamma}$.

Substituting the estimate of the likelihood function (8) in the decision rule (9), we obtain

$$p_i \cdot \hat{p}(\bar{y}/f^i, \bar{d}^{i*}) \geq p_l \cdot \hat{p}(\bar{y}/f^l, \bar{d}^{l*}).$$

It should be noted that the quality of approximation of functions $p^l(\bar{y})$ with a help of the chosen system of basis functions depends on the number of members of the expansions of Q. As we know in advance the form $p^l(\bar{y})$, then the accuracy of the approximation turns out to "test" in the experimental verification of the classifier. The choice of basis functions depends on the nature of changes in the density distributions of the parameters of technological processes, subject to classification. In the absence of a priori information about the nature of the density distribution are based on the terms of ease of implementation of basic system functions.

In recognition of the signal phase is introduced to reduce the dimension descriptions to ensure the feasibility of such algorithms. But in this situation, you can go in two directions:

- to find effective methods of reducing the dimension of the original description of the signals and thereby simplify the implementation of the decision rule;
- use simple algorithms to reduce the dimension of the original description of the signals and on the stage of the decision to choose a system of basis function $e_k(\bar{y})$,s , which would allow for the specific task a simple technical realization.

Staying in the second direction, the likelihood function can be approximated by a system of moment functions just implemented a stochastic manner. It is known that in the case of approximation of the density $p(y/f^l)$ of the orthonormal Hermite polynomials with weight function $k(y/f^l) = (2\pi)^{-1/2}\sigma^{-1}{}_i \exp(-0.5 \cdot y^2/\sigma_i^2)$, and its approximate expression can be written as

$$\begin{gathered} p(y/f^l) = 1/((2\pi)^{1/2}\sigma_i)\exp(-y^2/(2\sigma_i^2))[1 + m_3/(3!\sigma_i^3)\{(y/\sigma_i) - 1.5\cdot(y/\sigma_i)\} + \\ + (1/4!)\cdot(m_4/\sigma_i^4 - 3)\{(y/\sigma_i)^4 + 2(y/_i)^2 + 1\cdot 3(4/4)\}], \end{gathered} \tag{10}$$

where m_i – i - th moment of the probability density $p(y/f^l)$, the technical realization of which can be carried out using the following algorithm [5].

Suppose that a clustered training set { $\bar{y}$ } is taken from the implementation process $\xi(t)$, having a density distribution $p_\xi(y)$. We will create a process sgn z = 1 – when $\xi \succ h$ and sqn z = 0 – when $\xi \prec h$, where $\eta(t)$ - - a support process with a one-dimensional density. In this case, the probability:

$$p(\xi \geq \eta) = p(\eta \leq \xi) = M\{p(\eta \leq \xi)\} = \int_{-\infty}^{\infty} \int_{-\infty}^{y} p_\eta(y_l) p_\xi(y) dy_l dy. \tag{11}$$

This shows that the reference signal must be not less than the interval distribution of the test definition process $\xi(t)$. If p(y)=1, $y \in [0,1]$, p(y)=0, $y \notin [0,1]$ and the values of the process $\xi(t)$ lie in the interval [0,1], then

$$p[\operatorname{sgn} Z = 1] = M[SgnZ] = \int_{-\infty}^{\infty} y p_\xi(y) dy \approx m_l^* = \frac{1}{N}\sum_{i=0}^{N} \operatorname{sgn} Z_i\,, \tag{12}$$

i.e. an estimate of the first entry point.

For the initial moment of the k-th order probability density of the reference signal should have a look of a $p_h(y) = dF_n(y)/dy = dy^k/dy = ky^{y-1}$ when $y \in [0,1]$, otherwise $p_h(y) = 0$. At the same time

$$p(\xi \geq \eta) = M[\operatorname{sgn} Z] = \int_{-\infty}^{\infty} y^k p_\xi(y) dy \approx m_l^* = \frac{1}{N}\sum_{i=0}^{N} \operatorname{sgn} Z_i\,. \tag{13}$$

Thus, depending on the type of distribution function of the reference signal without changing the structure of the meter can be used to estimate the moments of different orders. Using these estimates in the approximation of the likelihood function, we can construct a decision rule in accordance with an adaptive Bayesian approach.

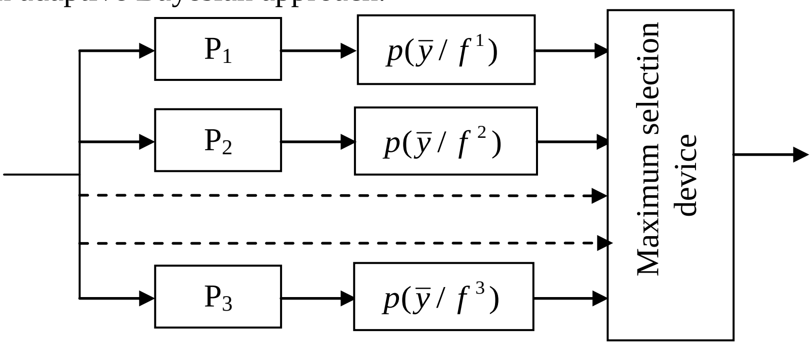

Fig. 3. ***Block diagram of a recognition unit.***

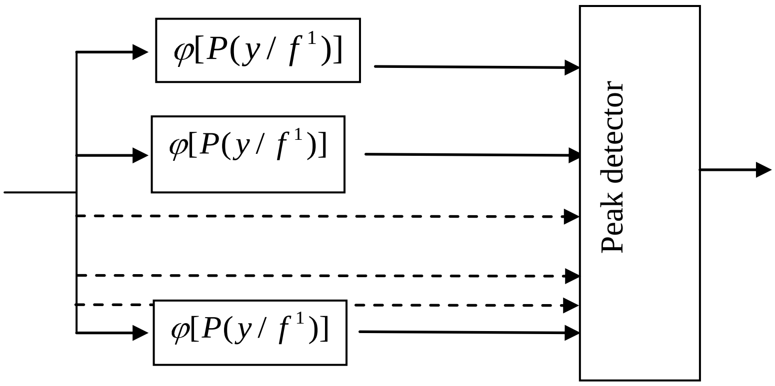

Fig. 4. ***Block diagram of the classifier using the likelihood functional.***

Block diagram of signal recognition device M for a simple loss function, based on the criterion of minimum average error probability of detection is shown in Fig.3. The output signal transmission channel information into M parallel channels are measured by the function $\overline{p}^{i*}(\bar{y})$. They are multiplied by the number of equal probabilities of presenting the signals are fed to the device and select the maximum, which decides in favor of the maximum value found.

In practice, it is more convenient to calculate not just the conditional probabilities, and a monotonic function of these probabilities. She may be a logarithmic function. In the case where $\sigma_i = 1$, the expression (10) can be transformed to the form (14):

$$\varphi[p(y/f^i)] = -\ln y + \ln[y + (m_3/3!)(y^4 - 3y^2) + (1/4!)(m_4 - 3)(y^5 - 6y^3 + 3y)] - \ln\sqrt{2\pi} - 0.5\cdot y^2 \quad (14)$$

Practical implementation of (14) is rather complicated and can be justified only when the assumption of normality of the distributions of attributes of classes does not provide the required reliability of recognition.

Thus, in the case of the classification of signals, characterized by a single sign-Gaussian one-dimensional distribution of the unknowns and the probabilities of recognizable classes, the minimum average error detection is provided by using the criterion of the ideal observer, involving equal a priori probabilities of classes p_i. The signal presented by the implementation can be classified in accordance with the decision rule $\varphi[p(y/f^i)] \geq \varphi[p(y/f^i)]$, a block diagram of the classifier will have the form shown in Fig. 4.

The classifier was built in accordance with the structural scheme in Fig. 4, calculates the logarithmic function of the conditional probabilities of the form (14) and requires storage in the memory of the initial moments of the classifier of the third and fourth orders. Estimates of these moments can be obtained at the training stage the method discussed above.

Conclusion

It can be concluded that the method of synthesis of linear non-Gaussian random signals classification, based on the approximation of the likelihood function will lead to solutions close to optimal, only if reasonably accurate estimates of the likelihood function. Because the source of the likelihood function is unknown, the accuracy of their assessment test does not directly possible. Therefore, it is necessary to verify the quality of recognition to "test". At this stage, we can finally specify whether the adopted sufficient accuracy of the approximation of the likelihood function.

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MANAGING COMPLEX OBJECTS IN CONDITIONS OF UNCERTAINTY AND AMBIGUITY, WHICH ARE GIVEN IN INTERVAL FORM

E.M. Khachaturova, Sh.Sh. Sadikova

Tashkent University of Information Technologies
Tashkent Amir Temur st. 108, 700087, Tashkent city, Republic of Uzbekistan
Phone: 238-64-37, email Dilfuza65@gmail.com

Abstract*. The paper deals with the management of structurally complex systems, in which the parameters of the object specified in the interval form.*

Keywords*: interval data, static control systems, complex engineering systems.*

Introduction

These technical systems are measurable characteristics of products, processes, production and operations, materials and equipment involved in the production. This information is not just the numbers a, b, c ..., and the interval [a, b], [a, c]. But to this date, a complete measure (interval) little information is used both for modeling and for the management of complex technical systems. In most cases, there is a substitution of interval data by nature some of the numerical values of the intervals. Proper use of the theory of probability and statistics in this situation are often not justified, that in turn leads to serious difficulties, and sometimes just to error in data analysis. In this case, the most appropriate for the study of complex technical systems with the measured parameters is by using interval analysis.

Interval approach considers a set of data that can be represented as follows.

There interval matrix $\boldsymbol{A} = / \boldsymbol{a}\ ij\ /$, dimension $m \times n$, containing the entire set of characteristics associated with instances of products, where the i columns correspond to each individual characteristics (factor) based on the copy of the product, (i = 1, n), and j lines contain specific values to the characteristics (factors) copies of the product obtained in the j-th dimension, (j = 1, m). A matrix is a global system of interaction parameters small pieces. On the complex structural relationships in the data and form relationships in these structures do not know anything. In the study of such systems need to be identified due to the complicated structural parameters, as well as simulate the kinds of dependencies in structures [1].

Most of the complexity associated with two important features:

mathematical structure components (subsystems) and the way these components are related.

The first feature of the system allows for the possibility of reducing the visible complexity of the system by combining the individual variables in the subsystem. With such decomposition aim is to allow the researcher to simplify the analysis of the system, considering it as a loosely coupled set of interacting subsystems.

The second property of the system reflects the following characteristics of system, the dimension, hierarchy, circuit connectivity, diversity components, the interaction force.

Scheme connectivity system determines the flow of information transmission in structure and limits the impact that can have one part system (Fig. 1)

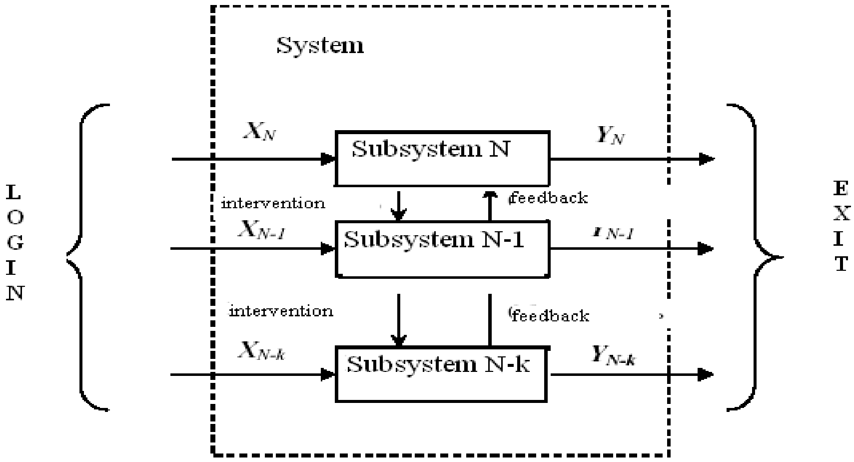

Fig.1. ***System Structure.***

Currently, there are several approaches to describe and perception systems of Σ.

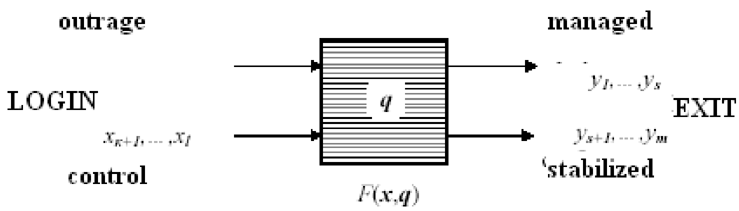

Fig. 2. ***Block diagram of a static control system.***

Consider that the static interval control system (Fig. 2.). It includes a set of input signals:

- Disturbance ***x1****, ..., xr,* which operate independently of our will within the intervals ***x1****, ...,* ***x*** *r*, and

- Management of *x +1, ..., xl,* the values of which we are able to set the intervals for ***x*** *+1, ...,* ***xl****.*

Perturbations have a destabilizing effect on the system, tend to bring it out of a given regime, while we seek to appropriate departments to offset the impact of these disturbances and contribute to the achievement of required performance. The introduction of interval to describe the destination system makes its own nuances. So we have to divide the set of all outputs of the system to:

- Components y*1, ..., ys,* we can put in any number of pre-defined intervals ***y1, ..., ys*** (control output);

- Components y s +1, ..., ym, for which we need to be sure that getting into intervals ***ys +1, ..., ym.*** (Stabilized outputs). One of them is statistics interval data (LED). In this direction uncertainty is only statistical. Its use is considered in the context of the small width of intervals, or small measurement errors. This in turn imposes significant restrictions on the use of these methods, and philosophy analysis in this case is a stochastic trend.

The second direction is based on the analysis of data as whole objects (intervals). Therefore, the method of analysis includes the following tasks: -Analysis of data from a known structure of the system, known inputs and outputs. But in the case of simulation of the measured process information first problem arises due to the receipt and the structure of the system Σ develop appropriate interval clustering algorithms input process information from the matrix A. (See Figure 1.).

The inverse problem of system analysis or identification of static systems, given the dependence of input-state-output (See Fig. 2) using clustering algorithms. The task of identifying a static object management formulated as a problem of determining its operator (in this case F) at observation of random input and output signals. [3] Note that the main thing for us is that the randomness in the data, but there is only interval uncertainty. Obtaining such an operator is using the approximation of the set of prisms or receiving external estimates of the solution of the problem.

And the last problem - is the development of methods and algorithms, implemented in a software application that allows a short time to process the measurement of technological information.

Conclusion

Thus the analysis of the data accumulated during the life cycle of a complex structural system that provides a variety of hidden patterns in production parameters.

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MODELING OF STRUCTURES OF THE SPECIALIZED PROCESSOR FOR SIGNAL PROCESSING IN PIECEWISE–POLYNOMIAL BASES

H.N. Zaynidinov, M.B. Zaynutdinova, E.Sh. Nazirova, U.A. Azimova

Tashkent University of information Technologies,
108, Amir Temur st., 700087 Tashkent city, Republic of Uzbekistan
Phone: 2386437, e-mail: tet2001@rambler.ru

Abstract: *In this work the results of research of algorithms of fast spectral transformations in various bases are shown. The algorithm of fast transformation in the piecewise-quadratic bases, using good differential properties of parabolic basic splines is proposed. The structure of the specialized processor of signals processing in piecewise-polynomial bases is developed. By modeling in MATLAB environment with application standard Simulink - components possibilities of the offered algorithms and structure of the specialized processor are shown.*

Keywords: *specialized processor, polynomial Bases, discontinuity, Adamar.*

In the various systems intended for automation of scientific researches, the increase in productivity of the decision of problems in many respects occurs due to search of new algorithms of parallel calculations, including by revealing so-called "internal parallelism" problems and creation of architecture of the computing systems providing distribution of resources on the big number of processors. The most simple and effectively sold hardware are piecewise–polynomial and piecewise-rational methods. Piecewise-constant bases have received the progress from the spectral theory of discrete orthogonal functions with the limited number of values. For such algorithms as fast spectral transformations the greatest possible speed can be reached, and in the systems containing quite a limited number of processors.

This work analyses deficiencies of known systems orthogonal piecewise–polynomial basic functions applied in processors of fast spectral transformations: weak convergence approximation, discontinuity, etc. principles of creation of systems of piecewise–polynomial basic functions of higher degrees by a method of integration with a variable top limit is being developed:

$$\psi(\mathrm{x}) = \int_0^x \varphi(x)\,dx \tag{1}$$

Features of integrated systems of (Haar, Shauder and Harmut) functions, convergence speed of interpolated numbers on their basis and an opportunity of applying of fast spectral processing (FSP) algorithms to these systems are examined. It has been proven through mathematical transformations and modeling, that it is necessary to apply algorithms of (FSP), developed for orthogonal piecewise of bases to fast calculation of factors, to the derivatives of interpolated splines constructed according to readout of signals.

System haar's functions

For construction models of the signals received from real objects, traditional harmonious functions are widely applied. It tells that many signals received from real objects can be easily presented by set sine and cosine waves fluctuations, which is using for the device of Fourier analysis. Result of it is transition from time to frequency functions. However, representation of time function sine and cosine wave functions is only one from many representations.

Any full system of orthogonal functions can be applied for expansion in a series, which correspond with Fourier series.

Wide distributions to technical appendices have received orthogonal systems continual the explosive basic function, given on the valid axis, which also have algorithms of fast transformations. They can be split in two classes:

- global basal functions - which value are not equal to zero neither one subinterval. Walsh's functions has a concern to this class, numerical, saw tooth;
- localizable basic functions, which nonzero values are set on the enclosed pieces. Examples are Haar and Harmut's functions.

Bases of Haar involve attention of experts for two reasons:

1. Reduction of number of the factors necessary for approximation (with the set accuracy) in relation to the general number of binary pieces.
2. Absence of "long" operations. Operations of addition, subtraction and displacement are used only.

The limitations of rectangular orthogonal Haar's bases is weak convergence of numbers on sectionally - to constant functions, i.e. necessity of storing of several hundreds factors for many functions with the purpose of maintenance of errors of the order of 0,1 %.

Searches on the methods of reduction of volume of tables of factors, improvements of parameters of "smoothness" obviously lead to systems piecewise–polynomial basic functions of higher degree. Most simply results to piecewise- linear basic functions (function of Shauder) as a result of integration with a variable upper limit orthogonal piecewise-constant functions of Haar:

$$Shd_k(x) = 2^p \int_0^x har_k(r)\,dr$$

It is necessary to consider also, that $Shd_0^0(x) \equiv 1$ and $Shd_0(x) = x$

Often in practical appendices of numbers piecewise-linear functions with the objective of getting the amplitudes of all basic functions equal to unit, it is convenient to operate with the "normalized" systems:

$$\widetilde{Sh}d_k(x) = 2^p \int_0^x har_k(\tau)\,d\tau \qquad (2)$$

$$P = 0,1,\ldots; \qquad k = 0,1,2,\ldots$$

Functions har_k (x) can be arranged a put in an orderly manner (by analogy ordering of functions (Walsh) in three ways:

1. To arrange binary fractions k in the natural order of increament – Adamar’s ordering;
2. To arrange k in ascending order of inverted code - dyadic ordering;
3. To group k in group with number of categories after a comma 1,2,3, etc., and inside of each group to arrange fractions in ascending order - classical ordering;

Adamar’s ordering of Haar functions leads to reception of the optimal algorithms FTH, but practical use of spectra in adamar is inconvenient ordering, as in such spectrum is not provided uniform convergence of the partial sums for continuous functions which are usually considered as signals.

Algorithm Of Fast Spectral Transformations In Piecewise-Polynomial Bases

One of the basic features of orthogonal bases is presence of fast algorithms for definition of spectral factors. Fast algorithms allow to reduce quantity of arithmetic operations and volume of necessary memory. As a result we obtained an increasing speed when using orthogonal bases for digital processing signals.

Having designated through any valid orthogonal piecewise-constant basis, we shall write down the formula of forward and backward fast spectral transformations for sequence of readout of a signal {xi}.

$$C_k = \frac{1}{2^p}\sum_{i=0}^{n-1} x(i)\cdot\varphi(k,i) \qquad (3)$$

$$X_i = \sum_{k=0}^{n-1} C_k \cdot \varphi(k,i) \qquad (4)$$

where k = Number of spectral coefficient, i=number of an element of sequence of the valid readout.

Algorithmically both of a kind of transformations differ from each other only by the presence of a constant multiplier.

Requirements for algorithms of fast spectral transformation consist first of all in a minimality of quantity of operations, simplicity of each operation and a minimality of the demanded volume of operative memory.

Fig.1. shows the graph of forward FTH on Cooley-Tukey at N=16. Here and in the later graphs, continuous lines conform to operations of addition, and shaped lines - to operations of subtraction. Entrance readout are designated X_0, X_1..., X_N, and results are designated C_0, C_1, C_2..., C_N. Let's consider approximating number on piecewise-quadratic Harmut’s functions:

$$f(x) \cong \sum_{k=0}^{n-1} C_k\, hid_k(x) \qquad (5)$$

The limitations of a given set is the absence of fast algorithm of calculation of factors. This limitation can be eliminated by the application of a parabolic spline. If we take the second derivative of a parabolic spline, interpolating on [0,1] function f (x), it will represent piecewise-constant function with changes of values of steps in units of a spline, and of some on piecewise-constant orthogonal basic functions. We shall write down, for example, decomposition of the derivative of a spline in a Harmut set:

$$S_2''(x) \cong \sum_{k=0}^{n-1} C_k\, hrm_k(x) \qquad (6)$$

Where hrm = Harmut’s function.

According to theorems of the limited convergence and of integration of the closed systems as a result of integration of both parts we will get:

$$S_2'(x) = 2^p \int_0^x S_2''(u)\,du = \sum_{k=0}^{n-1} C_k\, hin_k(x) + S_2'(0) \tag{7}$$

$$S_2(x) = \int_0^x S_2'(u)\,du + S_2(0) = \sum_{k=0}^{n-1} C_k\, hid_k(x) + S_2'(0) + S_2(0) \tag{8}$$

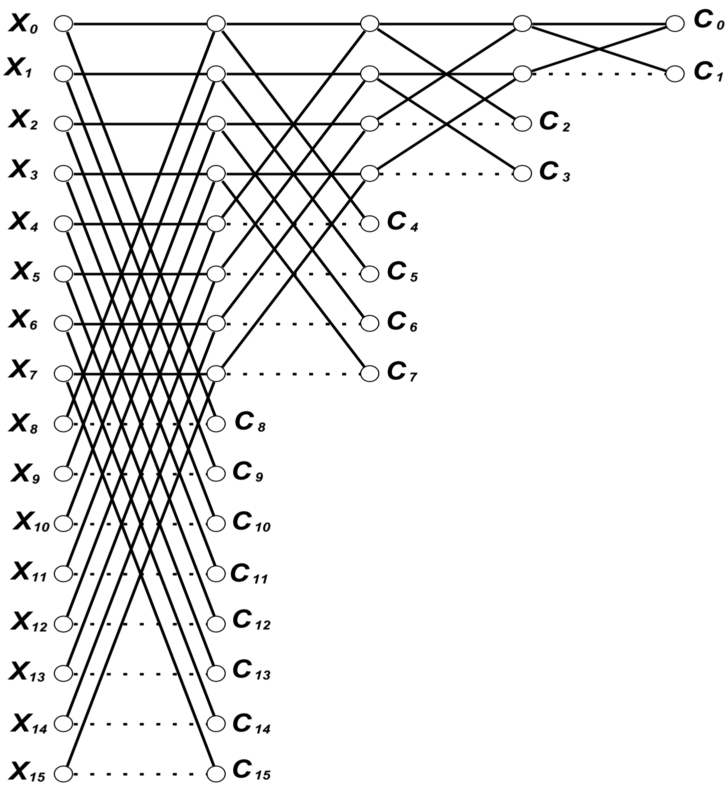

Fig. 1. ***Graph of Haar fast transformation by Cooley-Tukey*.**

Whence follows, that factors of decomposition in a set by orthogonal functions of Harmut of the second derivative of the parabolic spline, interpolating the function in binary-rational units, are factors of decomposition of the first derivative of a spline on hin - to functions, and the spline on hid - to functions. The factor at a linear part of decomposition will be defined as value of the first derivative of spline $S_2(x)$ in a point x=0, and constant component - as value of a spline in this point.

Result of algorithm modeling and structure of the specialized processor

In Fig. 2. The Simulink-model of the specialized processor is shown. For modeling of the proposed structure in the environment of MATLAB with application of resources Simulink following blocks are used:

- Two blocks of Sine Wave and Add block for feigning of an entry signal;
- Zero-Order Hold block for simulation of digitization and quantization of input analogue signal;
- Four blocks Integer Delay and summators, summators-subtracters for performing the operations of addition-subtraction under column (X.)
- Several blocks of XY Graph, Scope, To Workspace for the control of signals at various stages of processing and for link with MATLAB environment.

The input signal also can be entered in form of a data array from working environment MATLAB. With the application developed Simulink models, modeling operation of structure has been done. In table 1. Results of modeling of function $y=e^x$ in an interval [0, 1] for N=64 readout in piecewise-quadratic basis of Haar are shown. Results were achieved with the application developed Simulink models.

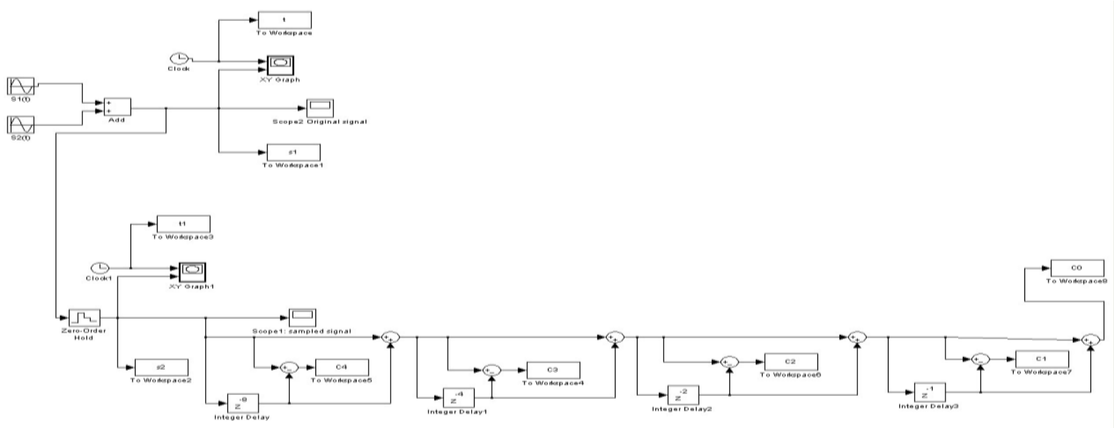

Fig. 2. ***The Simulink-model of the specialized processor.***

Table 1

Executed: FT Haar Function: y=exp (x) N=64 Array of factors in Haar's piecewise-quadratic basis

i	C_i	i	C_i	i	C_i	i	C_i
1	0.029808	17	0.045295	33	0.013813	49	-0.000006
2	0.080928	18	-0.000017	34	-0.000004	50	-0.000007
3	0.044062	19	-0.000017	35	-0.000004	51	-0.000007
4	0.40078	20	-0.000020	36	-0.000005	52	-0.000007
5	0.45037	21	-0.000019	37	-0.000004	53	-0.000007
6	-0.000353	22	-0.000021	38	-0.000005	54	-0.000007
7	-0.000453	23	-0.000023	39	-0.000005	55	-0.000008
8	0.041561	24	-0.000024	40	-0.000005	56	-0.000008
9	0.045246	25	-0.000025	41	-0.000006	57	-0.000008
10	-0.000073	26	-0.000028	42	-0.000005	58	-0.000008
11	-0.000084	27	-0.000030	43	-0.000005	59	-0.000009
12	-0.000093	28	-0.000032	44	-0.000006	60	-0.000010
13	-0.000105	29	-0.000034	45	-0.000006	61	-0.000009
14	-0.000120	30	-0.000035	46	-0.000005	62	-0.000010
15	0.000135	31	-0.000037	47	-0.000006	63	-0.000009
16	0.041988	32	0.042103	48	-0.000006	64	0.042132

Thus, as a result of research of systems of piecewise -constant, piecewise-linear and piecewise-quadratic bases their limitations are shown. For elimination piecewise of the limitation of these bases, and also on the improvement purpose approximation properties of investigated bases, the algorithm of fast transformation in the piecewise-quadratic bases, based on applications of a parabolic basic spline is proposed. The structure of the specialized processor for processing of signals of the bases under study were also proposed. The modeling of algorithms and structure of the specialized processor makes it possible to draw a conclusion that the proposed algorithm of fast transformation in piecewise-quadratic bases makes it possible to achieve the compression factor of signals from 1,05 to 3,70 at value of accuracy $10^{-4} \div 10^{-6}$.

This makes it possible to save a memory size necessary for the storage of spectral factors during the processing of real experimental files from 5 % to 24 % and during the processing of elementary functions (and functions consisting of their combinations) from 11 % to 70 %. The proposal structure of the specialized processor realizes an investigated class of signals with demanded accuracy, possesses the big factors of compression at the expense of application of piecewise-quadratic basis.

Application of results of researches in various systems of modeling, the control and management has shown that developed piecewise-polynomial methods of approximation of signals can be successfully realized algorithmically in the form of a system of program components, and also in hardware in the form of subsystems of digital signals processors.

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THE SYSTEM ANALYSIS, THE AUTOMATED CALCULATION AND ADOPTION OF OPTIMUM DECISIONS

Ascar Artikov

700011, Uzbekistan, Tashkent, 32 Navoi street,
Tashkent Chemical-engineering institut, chair «Informatics, automation and management»
Artigof@rambler.ru, Tel.: 3782570, 4348951

Summary: *In the future almost all researches will be carried out on the basis of the system analysis. There is a set of fine works and various approaches to the system analysis. The technique, allowing analyzing system without special difficulties is offered. Applying a recommended way, the researcher, can carry out the system analysis, step by step, to go deep into studied system, consistently to pass from simple to a complex analysis. To develop algorithms of the automated calculation, on the basis of computer models. To carry out search of optimum decisions from the chosen deep level.*

Keywords*: computer model, system analysis, algorithmic formula, multistage, quasidevice, search of the optimum decision.*

Problem condition

View at this world from positions of a system approach, gives the chance to put and solve the following problems:

• to deepen own ideas of structure and structure of studied object – systems.

• to expand and deepen own ideas of "mechanism" of interactions of elements in object - system; to study and, probably, to open its new properties;

• and the most important to increase efficiency of functioning of system which interests us most of all.

That is available

Originally studied object was considered as unary system (one hierarchical level), in the subsequent there was a definition of macro kinetics of process and process micro kinetics in the chosen system (the analysis in two hierarchical levels). In decision-making the jump from the analysis of processes of deep level to big system is observed, sometimes studying systems of intermediate hierarchical steps insufficiently.

Though the moment of origin of the theory of systems and the system analysis carry to the middle of last century, however, it is possible to understand that its age makes exactly so much, how many there is Homo Sapiens. The term [1,2], it is shorter — the system approach, still didn't find the standard, standard interpretation. Even in definition of the concept system [1,2,3] it is possible to find many options.

A number of tendencies of development of the system analysis was outlined:

1. The analysis of definition of structure and structure of studied object without process (region structure, enterprise structure, group structure, a physical or chemical composition of a material, etc.).

2. **The system is considered as set of making elements** [1-4]. The system (element), secondary process is primary. Search of decisions is carried out by the analysis as though intersystem (interelement) processes [3]. In fine works [4,6] **to the system analysis** adoption of the correct decision if there is a sample is assigned. Originality the approach of the system analysis on adoption of optimum decisions differs at a choice of technological lines [5]. **Difficulties are that the analysis is turned into system synthesis.** Most of all system analysis is turned into search of the optimum decision. **Because of what the system analysis will seem difficult procedure.**

3. **System analysis of processes.** For example, the original approach [7] system analyses of processes of chemical technology was offered, accepting five stage physical and chemical system. Good development of this idea received in [8] where as big primary system chemical production is accepted. **What difficulties:** Desire at the same time to capture all processes occurring in systems complicated applications of this approach. **Because of it the system analysis will seem difficult procedure.**

That is offered.

Technique [9-11] offered by us, developing existing methods, allows to analyze system without special difficulties. By the offered technique, indicators - input, target and other parameters of system and events process in system originally are defined. Then the considered system (element) is dismembered on making elements, parameters for each chosen element and its process are specified. And so on, the partition of an element (system) on the subsequent systems isn't limited. It is carried out on degree of need and research possibility for decision-making.

Algorithmic formula of the analysis of system

For the analysis of each system we offered an algorithmic formula, it is possible to express it in a look:

$$CA = 2+1,$$

Here, 2 means joint consideration of system and studied process proceeding in it, 1 means all necessary parameters of system and process together taken, parameters in the subsequent are divided on entrance and target.

The multistage analysis of system consists in the following

1. The studied object is accepted to primary big system (the first hierarchical level). Studying system, and studied process occurring in it, input and target parameters, both for system, and for studied process are defined. Definition of interrelation of days off from input parameters allows to carry out more exact analysis and to make more correct decision. However decisions acceptance at restrictedly chosen level of researches without advance deep into sometimes are insufficient. Then, step by step it is possible to go deep into the chosen object.

2. The main system is dismembered on elements. In each element - system of the second hierarchical level concrete process is considered, and system parameters are defined.

3. So further division into subsystems proceeds to possible deep level. Since deep level search of the optimum decision is carried out.

Thus, system the analysis and synthesis of system is carried out in the following sequence:

First stage (the system analysis)

• previously the chosen element – system is studied. Requirements to system are formed;

• In each system (element) there is a set of processes. Those processes which are necessary for the correct decision-making of a task get out of a set of processes; previously studied process in system is studied;

• input and target parameters, both systems, and studied process are defined. Definition of interrelation of parameters, in most cases, demands deepening of researches in system, then,

• elements – subsystems are defined. (For group of tasks of structure and structure of studied object it is possible to carry out without processes). The considered system (element) is dismembered on making elements, process and its parameters for each chosen element are specified. And so on, deepening in system - the partition of an element (system) on the subsequent systems isn't limited. It is carried out on degree of need and research possibility for adoption of the optimum decision.

Second stage (Definition of interrelation of parameters)

Here by the form object and the maintenance of an objective each researcher can use a big arsenal of ways of that branch on which research is conducted.

Third stage (Choice of the optimum decision)

Here requirements on the basis of the system analysis are specified and concretized. Criteria of optimization, both for primary system, and for subsystems of each hierarchical step get out. The way of search of the optimum decision gets out. The optimum decision is defined.

The first stage – the beginning - the system analysis is universal for all sciences. The second and third stages can be carried out depending on an objective is specific to each branch. The system analysis opens the road to many ways of search of optimum decisions of systems available in various sciences.

Example. The multistage analysis of the tubular heat exchanger with steam heating.

The first stage – the system analysis.

In the first hierarchical level the heat exchanger in the form of system with heat exchange process in it is considered, input and target parameters of system are defined.

In the second hierarchical step it is considered that installation consists of elements of a supply of heated-up and heating-up agents, a working zone and zones of removal of agents. Indicators – input and target parameters of each subsystem are defined.

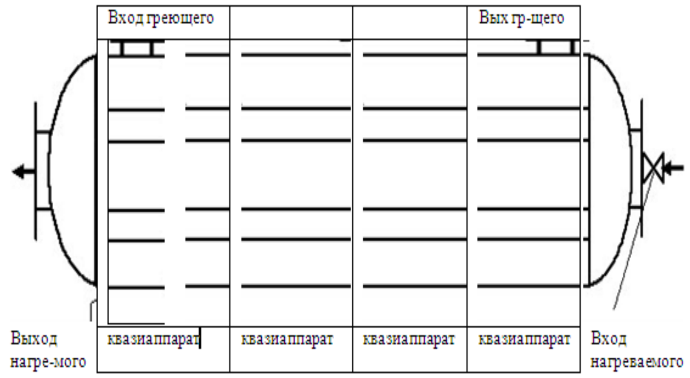

Fig. T.1. ***The simplified view with mental divisions on length of a tubular working zone on quasidevices in the counterflow heat exchanger.***

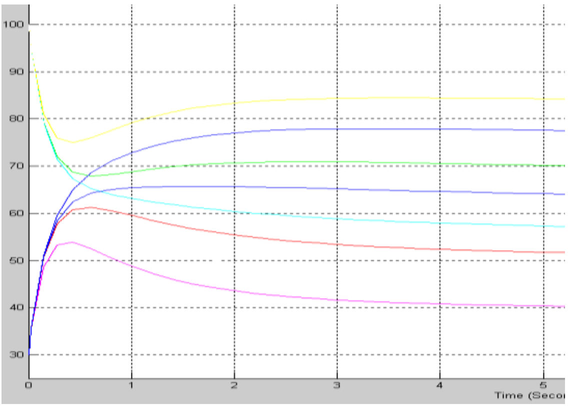

Fig. T.2. ***Dynamics of start-up. Changes on time of temperatures of heated-up and heating-up agents in quasidevices.***

In the third hierarchical step it is possible to present a long working zone of the heat exchanger to multiquasiequipment rooms. Indicators – input and target parameters of everyone of a subsystem - the quasidevice are defined. In the fourth hierarchical step it is possible to present each quasidevice from the heating chamber, a pipe wall, and an interior of a heating pipe. In the fifth hierarchical step heating chamber can be dismembered on three subsystems, a phase of steam and a condensate phase, a case wall. The tubular part consists of heating pipes (quantity, diameter, length).

We show the multistage analysis and calculation of processes in a working zone of the case trumpet heat exchanger. The simplified view with mental divisions is shown on the fig. T.1.

On the basis of hydrodynamic structure of streams of a tubular zone the heat exchanger on length of heatexchange pipes is mentally divided into quasidevices (here 4 quasidevices).

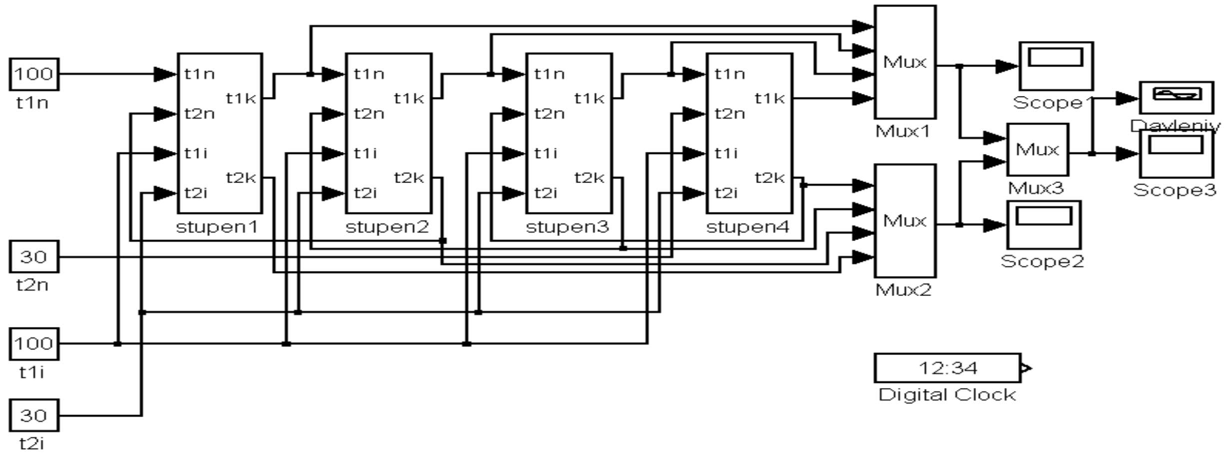

Fig. T.3. ***Computer model of process of a working zone case trumpet 4 quasihardware heat exchangers.***

Second stage. The technique of computer modeling is applied to definition of interrelation of parameters. **The computer model**, algorithm of calculation and research of a working zone of the case trumpet heat exchanger, fig. 3 is formalized.

Third stage.

Search of the optimum decision. From the fifth level factors of heat exchange, diameter of a heating pipe, etc. are defined. At the fourth level length of a pipe of the quasidevice. On fig. 2 the result of the automated calculation of dynamics of the starting period of the tubular heat exchanger is shown. Apparently on quasidevices the temperature of cold liquid increases, and the temperature of hot liquid decreases. At the third level the optimum sizes of a working zone of the heat exchanger are defined. With increase in number of quasidevices accuracy of model increases. At the second level is made heat exchanger configuration. At the first level optimum values of all parameters will be defined.

We carried out the analysis and optimum decisions on a number of systems of chemical technology [11] are made.

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PNEUMOSEPARATION PROCESS COMPUTER MODELING OF THE CRUSHED ORE IN A PSEUDO BOILING LAYER

B.I.Yunusov, D.T.Karabaev, A.A.Artikov

Tashkent chemical-technological institute, department "Informatics, automation and control"
32 Navai Street, 700011, Tashkent city, Republic of Uzbekistan
Phone: 3782570, 4348951. E-mail: Artigof@rambler.ru

Keywords: *Separation, a pneumoseparation in a pseudoboiling layer, mathematical model, computer model, speed of a pseudo boiling speed of vitiation (ablation).*

Summary: By research process of a pneumoseparation of loose materials on its mathematical model schedules of change (nomograms) of speed of a pseudo boiling, and vitiation of particles, for the particles were constructed, having different sizes and density and recommendations are developed at what sizes of particles it is necessary to carry out a separation. The technological scheme of pneumoseparation in a pseudo boiling layer is offered.

The enrichment of non-ferrous, precious and rare metals is an important link in the production of metals. Studies conducted in recent years have shown the possibility of implementing a more cost-effective and easy way to air separation of bulk materials [1].

The emergence of computer programs will allow for accurate modeling of the process pneumoseparation, identify bottlenecks range modes, providing better separation of the material. It is known that the ore consists of splices many minerals, which have different densities. By studying the process of pneumoseparationof loose materials on its mathematical model can be defined according to reflect the variation of particle sizes for various design parameters of the separator, set the pattern change in the output concentration of mineral components in the ore, depending on the geometry and density of the particles as well as the design size of the unit.

If to present that each particle of the crushed material has a sphere form, with the identical sizes, but different masses, the task consists in removal by means of an air stream of easy particles from a mix.

Each particle is influenced by the following two forces:

Force of weight of the spherical particle, operating with top down is equal:

$$F_1 = m_p * g \tag{1}$$

where m_p – mass of a particle, g – acceleration of a free fall.

The force created by an air stream, lifting a particle from below up is equal:

$$F_2 = \lambda * s * \rho_a * \frac{w^2}{2} \tag{2}$$

where, λ – the factor expressing a turbulent or laminar mode, w – speed air a stream, ρ_a – density of air, s – the area of a spherical particle which the stream affects.

If the forces operating on particles, are equal each other, particles are in balance. Mathematical expression of this condition looks as follows:

$$F_1 = F_2$$

$$m_p g = \lambda * s * \rho_a * \frac{w^2}{2} \tag{3}$$

where it is possible to replace mass of a particle m_p with the following equation:

$$m_p = \rho_p * V_p \tag{4}$$

where ρ_d particle density, V_d – particle volume.

It was accepted that the particle has a form of a sphere and, considering that the volume of a particle is equal:

$$V_0 = \frac{4}{3}\pi * r^3 = \frac{1}{6}\pi * d^3 \tag{5}$$

And having substituted value in the equation (4), and the received expression in the equation (3), we find:

$$\rho_p \frac{1}{6}\pi * d^3 * g = \lambda * \pi \frac{d^2}{4} * \rho_a * \frac{w^2}{2} \quad (6)$$

Solving this equation of rather equilibrium speed, it is possible to receive the well-known equation [2]:

$$w = \sqrt{\frac{4}{3} * \frac{\rho_p * d_p * g}{\lambda * \rho_a}} \quad (7)$$

The form of particles of real disperse materials usually differs from the spherical. Such difference at mathematical modeling of technological processes is considered by means of geometrical factor of a form.

The maximum limit of this speed shouldn't reach the speed deducing particles with heavy weight, i.e.

$$w_в < w < w_h$$

Thus, having calculated speed for the established border it is possible to carry out pneumoseparation process [3].

Essential indicator of process of a pneumoseparation of ores of non-ferrous metals at enrichment is the separation of heavy particles from a stream. It is reached by change of speed of stream. Therefore it is necessary to know, at what speeds particles of heavy fraction are precipitated. It depends on diameter of particles and their density.

At smooth increase in speed of stream from 0 to some first critical value there is a usual process of filtering at which firm particles aren't mobile.

To transition from a filtration mode to a mode of a pseudo boilingcorresponds on critical speed of a pseudo boiling of $W_{пс}$ called in the speed of the beginning of a pseudo boiling. At the moment of the pseudo boiling beginning the weight of the granular material falling on unit of area of cross-section section of the device, is counterbalanced by force of hydraulic resistance of a layer [4].

Since speed of the beginning of pseudo boiling and above, pressure difference in a layer Δp_l keeps almost constant value. This results from the fact that with growth of speed of the pseudo boiling agent contact between particles decreases and they receive a great opportunity for chaotic hashing in all directions. Thus the average distance between particles increases, that is the separation of a layer **ε** increases and, consequently, its height **h**.

For determination of the size $W_{пс}$ there is rather large number of semi-empirical and theoretical dependences. At a formula conclusion the separation of a layer of motionless spherical particles can be accepted equal 0,4.

The top border of a pseudo boiling condition corresponds to speed of a free vitiation of single particles. It is obvious that at the speed of a stream surpassing speed of a vitiation, $W_y > W_{vit}$, will be there is an ablation of particles from a layer of a granular *material*.

On the other hand it is possible to consider classical methods of formalization of descriptions for calculation of process of a pneumoseparation of a loose material in a pseudo boiling layer [5].

Processes of interaction of a gas phase with particles of a firm phase have special value. Considering disorder of the sizes of particles, the concept of equivalent diameter of particles is entered. It is supposed that particles have various values of diameters, changing from the minimum value of diameter to the maximum value [3]. Proceeding from a percentage ratio of the sizes of the particles, equivalent diameter decides on the help of the equation:

$$d_э = \frac{100}{\sum \frac{x_i}{d_i}} \quad (8)$$

If equivalent diameter is known, for determination of speed of the beginning of a pseudo boiling it is necessary to determine Archimedes criteria by the equation:

$$Ar = \frac{d_э^3 * \rho^2 * g}{\mu^2} * \frac{\rho_f - \rho}{\rho} \quad (9)$$

Knowing Archimedes criterion, it is possible to define Reynolds's criterion for a pseudo boiling layer.

$$Re_{ps} = \frac{Ar}{1400+5.22\sqrt{Ar}} \tag{10}$$

It is also known that Reynolds's criterion for a particle is defined by the classical equation on which it is possible to determine speed of a pseudo boiling of gas by the equation:

$$Re = \frac{\omega_{ps}*d*\rho}{\mu}\ \omega_{ps} = \frac{Re*\mu}{d*\rho} \tag{11}$$

Also settlement equation of criterion of Reynolds for a case of a vitiation of particles [4] is known:

$$Re_{vit} = \frac{Ar}{18+0.575\sqrt{Ar}} \tag{12}$$

Taking into account the equation (12), according to the classical equation of criterion of Reynolds, it will be possible to define speed a vitiation of particles that is speed of ablation of a particle.

$$\omega_{vit} = \frac{Re_{vit}*\mu}{d*\rho} \tag{13}$$

This equation gives the chance to define speed and a consumption of gas for providing a pseudo boiling or ablation of particles. Varying diameters of particles it is possible to define a consumption of gas for a material separation with various densities.

Using the known equations of calculation of criteria of Archimedes, Lyashchenko and Reynolds the equations for calculation of speeds the pseudo boiling and vitiation (ablation) beginning for particles of different density and are chosen the sizes and on their basis the computer model of process of a pneumoseparation of firm particles in a pseudo boiling layer, with use of a package of the MATLAB program (the Fig. 1 is constructed.) [6]. On computer model calculations of speeds the pseudo boiling and ablation beginning depending on diameter are made and density of particles for ore test which structure is presented in table 1.

Table 1

№	**Component**	**Massfrac-tionof %**	**Density Kg/m3**	**№**	**Component**	**Massfrac-tionof %**	**Density Kg/m3**
1.	Al_2O_3	13,31	3990	8.	K_2O	3,97	2320
2.	SiO_2	67,52	2650	9.	Na_2O	0,14	2390
3.	TiO_2	0,41	4505	10	CaO	1,55	3370
4.	Fe_2O_3	4,49	5240	11	P_2O_5	0,19	2390
5.	MgO	0,60	3580	12	S_m	3,45	
6.	MnO	0,06	5460	13	H_2O	0,42	
7.	FeO	1,62	5700				

Calculations of speeds depending on diameter and density of particles carried out the pseudo boiling and ablation beginning for minerals of SiO_2, Al_2O_3, K_2O, CaO, MgO, TiO_2, FeO and Fe_2O_3 being in ore. In the crushed ore each particle too consists of joints of minerals. In particles it is more than one mineral and it is less than other minerals. Therefore, the particles containing heavy components will be heavier. With reduction of the sizes of particles, influence of minerals of heavy components on all of a particle will be more.

On computer model (fig. 1) changes of speeds the pseudo boiling and ablation beginning depending on the size of particles of a separated loose material and density are calculated.

The analysis of the received results shows that at the big sizes of particles 0.060÷0.080мм, the limiting sizes of particles providing a good separation increase till seven and nine sizes of particles. It is possible to note that for ore enrichment with the sizes of particles in a range 0.010÷0.030мм, the limiting sizes of particles providing a good separation are in limits of one, two and three sizes of particles. On the other hand, at smaller diameters of particles of influence of the maintenance of an enriched material (heavy components) on particle density it is more than at big diameters of particles.

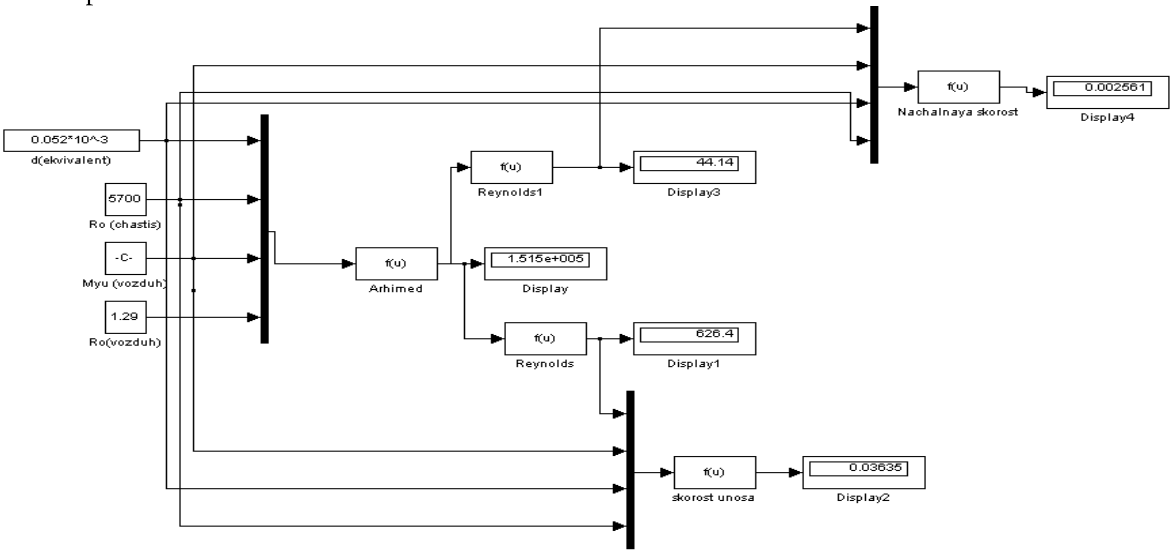

Fig.1. ***Computer model of process of a pneumoseparation of firm particles in a pseudo boiling layer.***

Considering it, we recommend to carry out ore enrichment in a range of the crushed particles from 0.030мм till 0.050мм (fig. 2) where the limiting sizes of particles providing a good separation are in limits from 0.030мм till 0.034мм, from 0.034мм till 0.039мм, from 0.039мм till 0.044мм and from 0.044мм till 0.050мм. Thus, ore enrichment in this range will need four installations with a pseudo boiling layer.

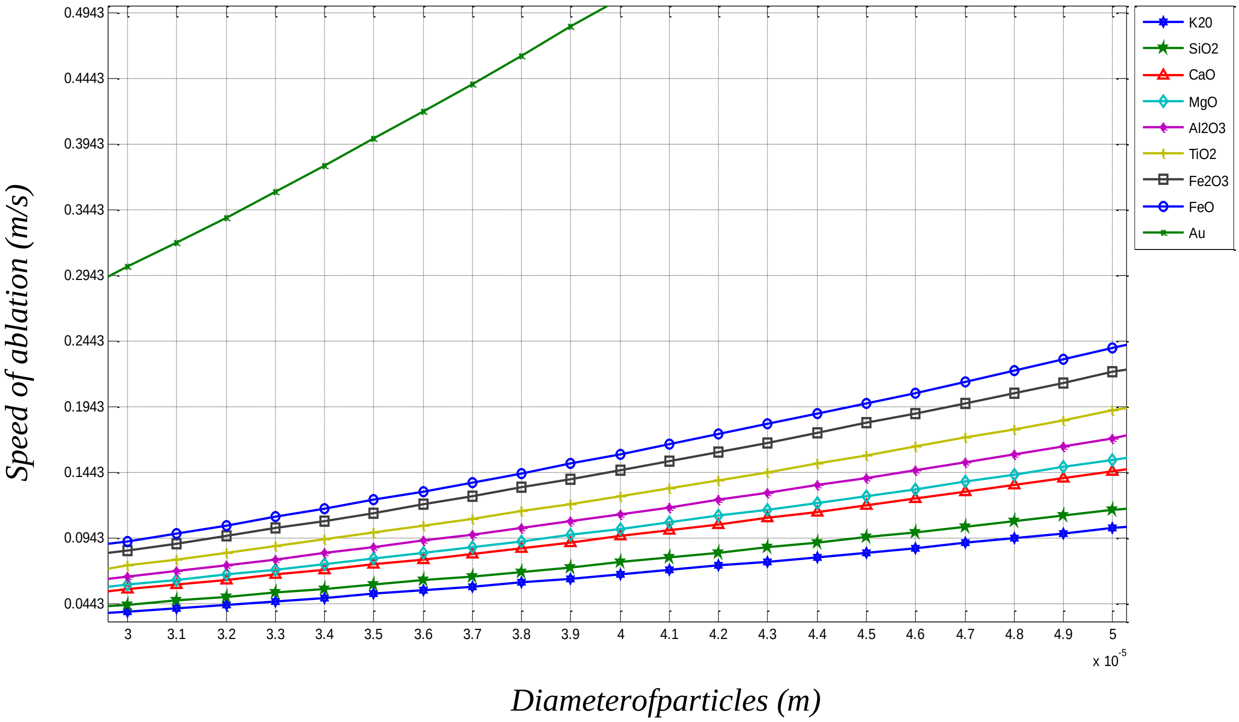

Fig. 2. ***Dependence of speed of ablation from diameter and a type of particles.***

Thus, in the crushed ore each particle consists of joints of minerals and existence of heavy minerals makes strong impact on specific weight of particles. The analysis of results on computer model showed that the best separation can be reached at the sizes of the crushed particles in a range from 0.030мм till 0.050мм.

On the basis of the received results the technological scheme on processing of ores according to the scheme of preliminary enrichment and separation in a pseudo boiling layer is offered.

Crushed till certain sizes and the ore sifted on sets, in limits from 0.030мм till 0.034мм, from 0.034мм till 0.039мм, from 0.039мм till 0.044мм and from 0.044мм till 0.050мм, moves in four separate capacities. Further, sandy pumps, the loose material moves in separate installations of a multistage pneumoseparation in a pseudo boiling layer where there is a separation of a loose material.

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THE AUTOMATED CALCULATION OF PROCESS OF DRYING OF THE MATERIAL AND SEARCH OF THE OPTIMUM HEATSUPPLY

A.A.Artikov, Z.A .Masharipova

700011, Uzbekistan, Tashkent
Tashkent Chemical-technological institute, Department "Informatics, automation and management", 32 . Navoiyst 32.
Artigof@rambler.ru, Phone: +998933782570

Abstract:*The methods for the automated calculation and find the optimal solutions. To do this, formalized mathematical and computer models of heat and mass transfer processes in the gas phase during drying of capillary porous material, based on the equations of material and heat balances of mathematical descriptions of the conditions of equilibrium in a two-phase system. Formalized algorithm. It makes it possible to calculate the temperature of the gas phase, moisture content, partial pressure, and other indicators of the gas phase.*

Keywords: *optimization, heat supply, temperature, drying, balance, concentration, humidity, pressure, mass transfer, the system, the computer model.*

With a multi-stage analysis of drying apparatus is presented as the main system, where the study of the drying process as defined by its input, output parameters. Summary chosen system is divided into individual elements of the system. It is a system for supplying material system - work zone, the system - an element of the material removal. In turn, subdivided into the working area of the system: the area of energy supply, the gas phase and the phase of the dried material. At this level is limited to a depression in the system. Defined input and output parameters

On mathematical modeling of energy supply for drying materials.

Here we consider the formalization of the mathematical description of the energy supply, for example, from the penetration of infrared rays in the product layer (heating of the product, the distribution of thermal energy).

The process of heating the material IR radiation reflects many thermal and thermo radiation characteristics. The action is based on the absorption IR radiation and on the conversion of the absorbed radiant energy into heat. In general mathematical description of the process of absorption of the product of the radiant flux is given by [8]:

$$Q(h) = Q_o \cdot exp^{(-sh)} \qquad (1)$$

where,S - the extinction coefficient of the rays (1 / m) - the energy imparted to the irradiated material, the thickness.

For microwave heating penetration of microwave energy on the order more than infrared energy supply. In this regard, we can write:

$$Q(h) = Q_o \cdot exp^{(-10sh)} \quad (2)$$

For small amounts of dried material can be taken, that is, within limits, the energy absorbed by the entire volume of the dried material.

On mathematical modeling at the level of the solid phase.

In the solid phase is the transfer of heat and moisture. To construct mathematical descriptions of heat transfer in the solid phase we consider the differential equation of heat balance for an elementary volume of the sample drying material.

The heat balance of the drying process the material and infrared radiation can be written as follows [2]:

$$Q_{общ} = dQ_m + dQ_{исп} + dQ_{пов} \quad (3)$$

where is dQ_m –the energy spent on heating the material;dQ_{ucp}- the energy expended on the evaporation of moisture;dQ_{pov}- the energy exchange between the surface of the material and the environment.

Energy spent on heating the material is:

$$dQ_m = G_m \cdot c_m \cdot dt_m \quad (4)$$

where, G_m –the weight of the irradiated material, kg / s;c_m- the specific heat of the material in the wet state, J / kg * K;dt_m- Changing the temperature of the material, and K.

The energy absorbed by the surface of the product for the time is rounded as:

$$dQ_{пов} = \sum_{\lambda_1}^{\lambda_2} A_\lambda \cdot q_\lambda \cdot F \cdot dt \quad (5)$$

Energy spent on evaporation,

$$Q_{исп} = G_{исп} \cdot I \quad (6)$$

where the flow rate of water, steam enthalpy

After mathematical processing of the above equations obtained a digital calculating temperature drying material.

Delving into the phase drying material, built algorithmic calculation unit temperature drying material. It includes the heating of a material change in its temperature, heat capacity, it also shows the change in enthalpy of steam.

On mathematical modeling to gas stage phase.

Similarly, the thermal balance of the gas phase built a computer model of the process of heat transfer from the gas phase to a dried up material. When input data are automatically calculated outlet temperature of the gas phase and the energy transferred to the gas phase at cooling.

Computer mapping interphase relationships - equilibrium, the concentration of water in the liquid phase

For a more accurate calculation of the drying material suggested a digital transition in equilibrium. The element of the two-phase system is solid and gas phases. Presenting them as systems with inputs and outputs is determined by their interaction. In analyzing these interferences involved mainly four factors. Therefore, the driving force of the process [2] can be characterized by a combination of four factors.

$$F(t, x, y, P) = 0 \quad (7)$$

where: t - temperature of the system (mainly the temperature of the liquid phase); x - the concentration of the volatile component in the liquid phase; y - the concentration of the volatile component in the gas phase; P-system pressure.

By aggregating the algorithmic blocks was developed algorithm. Simplified view of a computer model that allows for automated calculation of the drying of the material is shown in Figure 8.

Computer display includes algorithmic blocks. Delving into the system can be seen building blocks of computer model (Fig. 1). One of them, a block heating the material, changing its temperature, heat capacity, it also shows the change in enthalpy of steam. For the calculation of the change process and the equilibrium moisture content by mass transfer unit is built - a computer model.

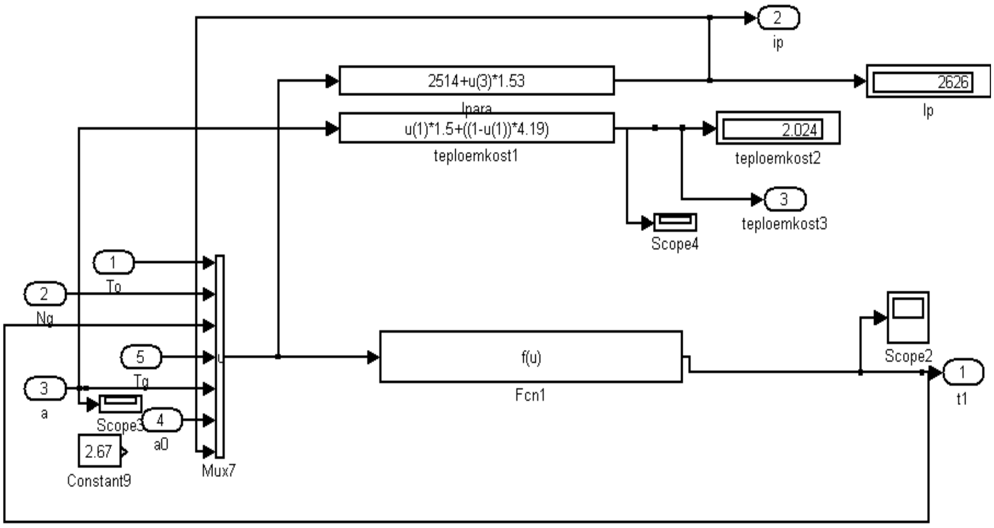

Fig.1. ***a digital model of drying material, which consists of separate blocks of calculation and algorithmic search box optimal heat supply with the use of temperature control.***

The method of searching for an optimal heat supply during periodic drying of the material.

Many products are highly sensitive to high temperatures. In most cases, in order to obtain a high quality product are limited to the maximum value of the temperature of the material being dried. In this case, it is acceptable control heat supply in a discrete mode. The problem arises of determining the duration of τ discrete power supply and an appropriate choice of heater power E. That is, the control function can be written as:

φ (E, τ) = 0 (8)

In order to preserve the quality of dried products, the optimization criterion is selected temperature of the material, which must be less than the specified value.

Based on formal mathematical descriptions developed a computer model that reflects the general functional dependence of temperature on other factors as:

F (w, t, p, G, e, ...,τ) = 0 (9)

Joint consideration of the two relationships (8, 9) revealed an optimal distribution of the discrete effects of heat. The objective function can be written as:

F (w, t, p, G, e, τ, ..., E, τd) = 0 (10)

Examination of the computer model allowed to develop a method of automated calculation of optimum drying process for this to the developed model is enabled discrete process control.

Using a computer model implemented automated analysis of the drying process and the search for the best material of the heat, such as microwave energy - a function of the heat characterizes the power curve of heating time.

The computer input of initial data of the drying process the material (gas flow rate, its relative humidity, flow, temperature and humidity of incoming material, power supply of energy). The computer calculates the patterns of change of process parameters and all intermediate and output parameters of the process and the system. In particular, parameters such as temperature, humidity, drying material, heat capacity, enthalpy, temperature distribution, the partial pressure of water vapor, the flow of water vapor in the gas phase, leaving the cost of drying the material and gas, etc.

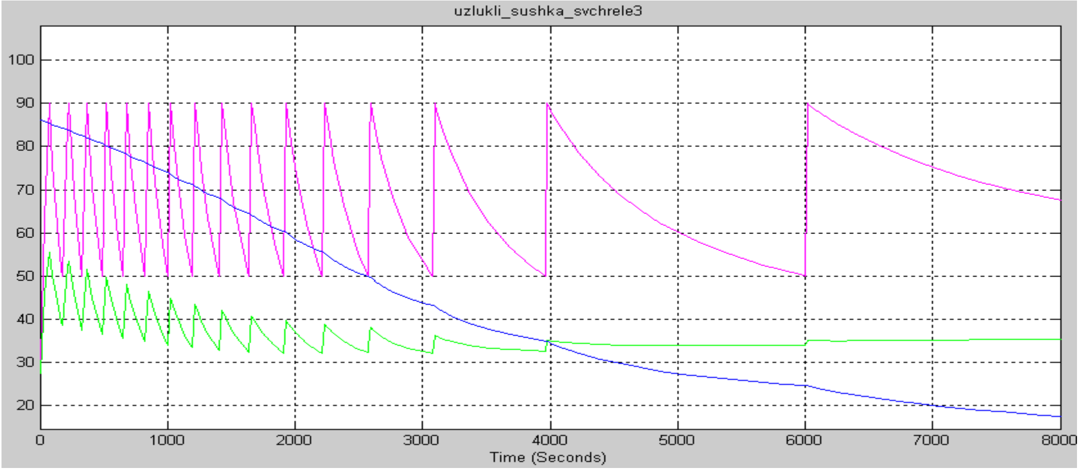

Fig.2. ***The change in temperature of the material time, the optimal discrete heat supply upper curve - the actual temperature, the lower the equilibrium.***

In Figure 2.shows the result of searching for an optimal discrete - oscillating modes of drying material. As can be seen from the upper vibrational line, the temperature of the material is controlled in a certain range (here, 50 - 900 ° C), with the heater on and off. Moisture content consistently decreases over time. In this calculation to determine the driving force of the process proceed on the difference between actual and equilibrium (lower oscillating curve) the temperature of the material.

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NEURO-FUZZY AUTOMATIC-CONTROL SYSTEM PROCESS OF THE STRETCHINGS OF THE TAPE

I.X. Siddikov, Z.E. Iskandarov

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitety st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45. E-mail zohid_1981@mail.ru

Keywords: *intellectual management, neural network, nerve cells, formation of training sample, fuzzy-regulator, dynamic high-speed algorithm, regulators are gained.*

Difficult processes are connected with agency on them of variety of uncertain factors (external and parametric perturbations). For example, in the textile industry drawing down process is influenced by various factors, such as changes of characteristics of a fibre (irregularity of a fibre, a random in character of fields of a frictional force, pressure, smooth finish, humidity of a fibre, quality of clearing of a fibre, fibres in a mix, etc.);

Agencies of parametres of the drawing mechanism (change of a transfer function of the drawing mechanism, palpation of cylinders and beading fillets);

Agency of other processes (palpation of shafts and rollers, roughness of a tape). It follows from this that in the course of a tape drawing down there are the most complicated interacting of factors in which it is impossible to define experimentally.

In such cases the most suitable to the purposes of management of a process of a drawing down of a tape is applications of methods of the theory of intellectual management as regulators built on the basis of illegible assemblage and the illegible logic, in the conditions of heterogeneous uncertainties , are capable to provide higher figures of merit of management. At use of illegible regulating by processes most an important point is sampling of algorithm of instruction of a neural network. For this purpose it is offered to inject dynamics algorithm of instruction of the multilayered neural network that allows to get rid of use of return couplings in a network, and also to merge in uniform process adjustment of weight numbers of a network and formation of function of management by installation.

In this connection there is a necessity to investigate and develop highly effective algorithms and the models of management based on applications of methods of intellectual management.

Proceeding from the aforesaid in the given work the dynamic high-speed algorithm of return extending of the error, working real time is used. For control action $u(k\cdot\Delta t)=q^{(K)}(t)$ it is fair:

$$\left.\frac{\partial y(t)}{\partial w_i^{(l)}}\right|_{t=k\cdot\Delta t}=\frac{\partial}{\partial w_i^{(l)}}\left(\sum_{v=0}^{k-1}A^{k-v-1}Bu(v)\right)=\sum_{v=0}^{k-1}\left(\frac{\partial q^{(K)}(v)}{\partial w_i^{(l)}}\right)A^{k-v-1}B^T\ . \tag{1}$$

Hence, scaling of matrixes $dy(t)/dw_i^{(l)}$ is reduced to scaling of matrixes $dq^{(K)}/dw_i^{(l)}$.

For target K th layer ($i=\overline{1,n_k}$ - number of nerve cells)

$$\left(\frac{dq^{(k)}}{dw_i^{(l)}}\right)^T=[0,0,...,q_i^{(K)},...,0]=Q_i^{(K)}, \tag{2}$$

Here the matrix $Q_i^{(K)}$ dimensions of a quantity [nk-1+1×nk] has nonzero i-й a column $q_i^{(K)}=col\left(q_0^{(K-1)},q_1^{(K-1)},...,q_{nk-1}^{(K-1)}\right)$.

For layer K-1 it is had

$$\frac{dq^{(K)}}{dw_i^{(K-1)}}=\frac{\partial q^{(K)}}{\partial s^{(K)}}\left(\frac{\partial s^{(K)}}{\partial q^{(K-1)}}\right)^T\frac{\partial q^{(K-1)}}{\partial s^{(K-1)}}=f'(s_i^{(K-1)})Q_i^{(K-1)}W_i^{(K)}\ . \tag{3}$$

The matrix $Q_i^{(K-1)}$ has dimensions of a quantity [nk-2+1×nk-1] and structure of an aspect $Q_i^{(K-1)}=[0,0,...,q_i^{(K-1)},...,0]$,

Where $q_i^{(K-1)}=col\left(q_0^{(K-2)},q_1^{(K-2)},...,q_{nk-2}^{(K-2)}\right)$. The matrix of weight numbers of nerve cells of K th layer $W_1^{(K)}$ has dimensions of a quantity [nk-1+1×nk] and structure where the $W_1^{(K)}$ column is removed from a matrix $W_1^{(K)}$ $W_0^{(K)}=col\left(w_{0,1}^{(K-2)},...,w_{0,nk}^{(K-2)}\right)$.

For layers K-2 it is had

$$\left(\frac{dq^{(K)}}{dw_i^{(K-2)}}\right)^T=f'(s_i^{(K-2)})Q_i^{(K-2)}W_i^{(K-1)}\left[diag\left(f'(s^{(K-1)})\right)\right]W_1^{(K)}; \tag{4}$$

In (4) matrixes $Q_i^{(K-2)}$, $W_i^{(K-1)}$ are defined like matrixes and $Q_i^{(K-1)}$ $W_i^{(K)}$ in the ratio (3).

For any layer 1 matrix $dq^{(K)}/dw_i^{(l)}$ is computed by formula

$$\left(\frac{dq^{(K)}}{dw_i^{(l)}}\right)^T=f'(s_i^{(l)})Q_i^{(l)}D^{(l)},$$

Where - the $D^{(l)}$ transition matrix dimensions of a quantity [nl×nk], is defined as product of matrixes:

$$D^{(l)}=W_1^{(l)}diag\left[f'(s^{(l-1)})\right]W_1^{(l-1)}diag\left[f'(s^{(l-2)})\right]W_1^{(K-1)}iag\left[f'(s^{(K-1)})\right]W_1^{(K)}.$$

Important stage in the solution of a problem on the basis of artificial neural networks is formation of training sample (TC). From composition, completeness, qualities TC appreciably depend a time of instruction of a neural network (NN) and reliability of gained models.

For the majority of NN presence of an interval of a legitimate value of arrival signals in which limits signals are discernible is characteristic. Activation function instal admissible boundary lines of values of initial data.

Representation in this range in the core is carried out by means of the elementary transformation – normalisations, however, thus are not considered characteristics of the law of distribution. As consequence – at strong irregularity of the law of distribution the admissible range is used not completely.

At it are present, both poorly filled sections, and sections of density of values of initial magnitude. Poorly filled sections lead to that in the course of NN instruction badly "remembers" these values. And density sections where on rather small pieces a significant amount of values of initial magnitude places, appear poorly discernible. Points, as though, merge on these sections that also leads to decrease in quality of instruction.

In the given work it is offered to use the process of the predata handling consisting in combination of normalisation of initial data with raise of their uniformity of distribution on the normalised interval. Such approach to transformation allows to raise uniformity of distribution that leads to martempering of discernability of training sample and to raise of speed of instruction of NN on 41 %.

In qualities of algorithm of instruction the dynamic high-speed algorithm of return distribution of the error consisting of four functional units (realised in the environment of Control Builder PS 501 on the basis of CoDeSys programming system) which carry out following acts is used:

- The **block definition of input information NN (AssignInputs).** In the capacity of an input information the controlled quantity (T2) acts.
- **«The forward stroke block» (FeedForward).** Here the weighed sums on which through adaptation function target values of nerve cells in the latent and target layers pay off are defined. And also the training stack of target values and values of the weighed sums of nerve cells is formed.
- **«The return block» (SpeedBackPropError).** Values of errors of instruction in nerve cells of the latent and target layers are defined.
- The **block updating or options of weight numbers (AdjustWeights).** Weight numbers are updated in nerve cells of the latent and target layers.

In the capacity of an instance of implementation of an illegible regulator we observe fuzzy-regulator use in a control system of a tape drawing down.

In most cases at designing of control systems by a drawing down [3] the model reflecting only most general characteristics of system and different sufficient accuracy for the analysis at its maximum simplicity is required. In designing of automatic systems of regulating of a drawing down high-speed and metric [3] models of a zone of deformation are traditionally used. In their basis the known differential equation of deformation of a tape is necessary:

$$L\frac{1+\varepsilon_0 d\varepsilon_1}{1+\varepsilon_1 dt} = V_{p2} - V_{p1} + V_{p2}\varepsilon_0 - V_{p1}\varepsilon_1 \pm k_r v_k,$$

Where - L length of a tape a deformation zone; - a ε_0, ε_1 percentage elongation in a zone of deformation and on its entry accordingly; - V_{p1}, V_{p2} linear speeds of a tape on an entry and a zone exit; - v_k linear speed of moving of a measuring roller; - the k_r factor considering geometry of coverage of a measuring roller by branches of a tape.

In high-speed model the percentage elongation is computed directly in the speeds and $V_{p1}\,V_{p2}$, in metric on the basis of lengths of an unextended tape on an entry and an exit of a zone of deformation.

Regulating of a rule of a roller occurs by change of an error signal of linear speeds of traffic of a tape in a zone at the expense of change of speed of twirl of the electric motor of the conducted channel, other magnitude of an error signal depends on a roller rule: to reduce a tape tension, the error signal should be lowered, and on the other hand if the tension is at the set level, the error signal also should match to a preset value.

Thus, it makes sense to target variable of a regulator to appoint a signal of a speed control of the conducted electric drive which defines an error signal of linear speeds of power-driven points, and as one more additional input value we will consider speed of moving of a measuring roller or, accordingly, speed of change of an error of regulating of a rule that is equivalent to use of an is proportional-integrated regulator.

By fuzzy-regulator working out the quantitative task of parametres of a regulator for its entry we convert to correction of a range of change of its input co-ordinates: a range of change of an error of position of a roller x1_pr (matching proportional component of a regulator) and a range of possible values of speed of change of an error of position of a roller x2_int (matching integrated component).

Formation of baseline of rules of a fuzzy-regulator is conducted on the basis of the equation for linear discrete the Pi-regulator in the difference form:

$$\Delta y(k) = y(k) - y(k-1) = k_n \Delta\varepsilon(k) + \frac{\Delta t}{T_u}\varepsilon(k).$$

Thus, for input variables and $\varepsilon(k)$ and the $\Delta\varepsilon(k)$ day off $\Delta y(k)$ can be synthesised a fuzzy-regulator realising the nonlinear law $\Delta y(k) = F\left[\Delta\varepsilon(k), \varepsilon(k)\right]$, equivalent in a sense to an analogue Pi-regulator.

For our case x1_pr $= \Delta h$ matches to an error signal $\varepsilon(k)$, x2_int $= \Delta h / \Delta t$ matches to an error signal increment $\Delta\varepsilon(k)$, and y matches $\Delta h(k)$.

As a result of the spent researches of application of illegible regulators at management of installations with various dynamic properties recommendations about formation of baseline of illegible rules depending on a configuration of systems with Pi-like regulators for maintenance of the characteristics which are not conceding to characteristics of classical regulators are gained.

Application of a fuzzy-regulator of a rule of a measuring roller of the sensing transducer of the tension, which efficiency of use it is shown on an instance of system of the interconnected electric drive with an illegible regulator of a tension for a long tape. Allowed to stabilise adjustable co-ordinate in a wide range of variations of parametres of installation.

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REGULARIZED ALGORITHM OF THE ADAPTIVE SIZING UP OF THE CONDITION OF INSTALLATIONS OF MANAGEMENT

Z.R. Asrayev, U.Z. Narziyev, U.M. Ibragimov, O.O. Yodgorova

Bukhara engineering-technical institute of high technologies,
200117, Uzbekistan, Bukhara, St Murtazayev 15.
Ph.: 2237884, an E-mail: ciulugbek@list.ru

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It is necessary to have arrangement of model system, capability to work in real time in numerous problems of management. Thus the model should not be based on the future measurements. Necessity for formation of such models usually originates that the model is necessary for removal of some judgments about system during its functioning. The methods intended for the solution of similar problems with use of adjusted models of some type, usually are called as adaptive [1-4]. In this sense speaks about adaptive management, adaptive filtering, adaptive machining of signals and adaptive prediction.

Scaling of results of work of model in real time should be made so that machining of measurements on each step always came to the end prior to the beginning of a following step. Otherwise, the built model cannot cope with an information stream.

The identification methods, fulfilling to this demand, name recurrent methods of identification as measured input-output the data is processed recurrently or consistently, as their receipt. Often for such methods use also terms identification in real time or under the current data, an adaptive sizing up of parametres or a consecutive sizing up of parametres.

As it is known [3], the general method of identification is postulated as representation of assemblage Z^t of the parametres given Z^t in space:

$$\hat{\theta}_t = F(t, Z^t), \tag{1}$$

Where function F can be set obviously, for example, as the argument minimizing some function. Such general expression (1) cannot be used in recurrent algorithm as count of value of function F can switch on vast quantity of scaling, which, was possibly, will not be finished prior to the beginning of a following step. Contrary to it the recurrent algorithm should submit to following relationships:

$$\begin{aligned} X(t) &= H(t, X(t-1), y(t), u(t)), \\ \hat{\theta}_t &= h(X(t)), \end{aligned} \tag{2}$$

Here X (t) – the vector of the fixed dimensions of a quantity representing some «the informational condition»; functions H and h are set evidently, and their values can be computed by means of the final number of computing operations known a priori. Thus, it is possible to be assured that $\hat{\theta}_t$ will be computed prior to the beginning of a following step of algorithm.

As the information containing in last pair of measurements y (t), u (t), is usually small in comparison with the information gained as a result of machining of the previous measurements, algorithm (2), as a rule, assumes more concrete air:

$$\begin{aligned} \hat{\theta}_t &= \hat{\theta}_{t-1} + \gamma_t Q_\theta(t), y(t), u(t), \\ X(t) &= X(t-1) + \mu_t Q_X(X(t-1), y(t), u(t)), \end{aligned} \tag{3}$$

where γ and μ – the small numbers reflecting a relative amount of information in last measurements.

In the majority of managerial processes or multistage procedures of decision making in engineering systems occur inherent in them indeterminate form. These indeterminate forms do not allow to size up precisely agency of control actions and, hence, to use the theory of the determined management. The indeterminate form, existing both in the system, and in observations, in many problems can be presented as stochastic processes. To what problems methods of stochastic management [1,4] are applicable.

The sizing up based on a method of least squares, is used in problems of definition of the first and second moments of a condition, noise, a condition and noise of measurements in a discrete linear dynamic stochastic system. Thus the specified statistical characteristics, the more precisely an estimation of a condition of system are more precisely known.

Let's observe modeling structure

$$\mathrm{y}(t) = \varphi^{T}(t)\theta + \xi(t),$$

Where φ^{T} – the matrix operator of dimensions of a quantity (l×d), θ – *d-dimensional* column vector.

The model of the process matching to the observed problem is defined by the equations:

$$\theta(t+1) = \theta(t) + w(t), \tag{4}$$

$$\mathrm{y}(t+1) = \varphi^{T}(t+1)\theta(t+1) + v(t+1), \tag{5}$$

Where $\theta(t+1)$ - a vector of parametres of installation at the moment of a time *t+1*, $y(t+1)$ - a vector of measurements, $\varphi^{T}(t+1)$ - a matrix of measurements; $w(t)$ and $v(t+1)$ - normally distributed disturbing affecting with zero averages and not negatively defined covariation matrixes $Q(t)$ and $R(t+1)$ accordingly.

For a sizing up of state vector $\theta(t)$ of dynamic system (4), (5) the traditional equations of filter Kalman [1,4] are usually used. However accuracy of a sizing up of state vector $\theta(t)$ on a basis Kalman the filter essentially depends on accuracy of the task covariation matrixes $Q(t)$ and $R(t+1)$ noise of a condition and handicap of measurements. In the course of functioning of installation of management covariation matrixes $Q(t)$ also $R(t+1)$ can change in a time. The concept of the identification approach [4,5] which consists in sizing up in the course of functioning of the filter of a priori unknown parametres and their subsequent use in algorithm of a dynamic filtering is rather effective. According to this method for the state vector containing unknown parametres covariation and linearly changing in time, it is possible to write down the equation in an aspect:

$$\theta^{c}(t+1) = \theta^{c}(t) + w^{c}(t),\ \theta^{cT}(t+1) = \left[\tilde{P}^{T}(t+1|t)\tilde{Q}^{T}(t+1)\tilde{R}^{T}(t+1)\right],\ \ w^{cT}(t) = \left[v^{QT}(t)w^{RT}(t)\right]. \tag{6}$$

In (6) $\theta^{c}(t)$ – state vector for an actual matrix of dispersions of a predicted estimation of a condition, a matrix of dispersions of noise of a condition and a matrix of dispersions of noise of measurements; $w^{c}(t)$ – a vector of noise of a condition of parametres covariation.

The model of measurements covariation in the case under consideration can be accepted in an aspect

$$\tilde{c}(t+1) = \varphi^{Tc}(t+1)\theta^{c}(t+1) + \overline{\Delta}\tilde{c}(t+1), \tag{7}$$

where $\varphi^{Tc}(t+1)$ $\overline{\Delta}\tilde{c}(t+1)$ can be defined from discrepancy vectors in the suboptimum detecting filter.

Having now expressions (4) - (6) and aprioristic values of their parametres for a sizing up of state vector of installation and parametres covariation it is possible to apply one filter to a prototype system (4), (5), and another - to system of the equations for covariation (6), (7), using discrepancies of the first filter as the data for an estimation of parametres covariation in a prototype system.

For a state vector sizing up $\theta(t)$ it is possible to use an expansion method also. According to this method the aspect equations are formed:

$$\theta^{a}(t+1) = \theta^{a}(t) + \Gamma^{a}(t)w^{a}(t), \qquad y(t+1) = \varphi^{Tb}(t+1)\theta^{a}(t+1) + \overline{\Delta}v(t+1),$$

$$\theta^{aT} = \left[\theta^{T}\overline{w}^{T}\overline{v}^{T}\right], \qquad w^{aT} = \left[\Delta w^{T} w_{\overline{w}}^{T} w_{\overline{v}}^{T}\right],$$

Estimations of vectors $\theta(t)$, $w(t)$ here again $v(t)$ also it is possible to gain on a method of least squares by means of one filter and an estimation of matrixes $Q(t)$ and $R(t+1)$ by means of other filter as noise of the expanded condition and measurements have now a zero mean.

Results of modeling of the observed approach on various modeling problems showed that required estimations have good convergence and are consistent. Thus the method of expansion of a condition in the installed regime concerning attained accuracy is almost equivalent to a method of a dynamic filtering on the basis of relationships (6), (7) with use of system of filters Kalman type, but thus the method of expansion demands considerable memory and a time of scaling.

Resulted above a relationship allow to adapt algorithms of a sizing up of state vector of dynamic installations to real countermeasure signals to the conditions caused by aprioristic indeterminate form and by that to raise accuracy of definition of a vector of options of a regulator.

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STEADY RECURRENT ESTIMATION OF FACTOR OF STRENGTHENING OF THE KALMAN FILTER IN THE CONDITIONS OF APRIORISTIC UNCERTAINTY

O.O. Yodgorov, E.T. Safarov, S.I. Fayziev, Z.H. Khankeldiyeva

Bukhara engineering-technical institute of high technologies,
15, St. Murtazayev, 200117, Bukhara city, Republic of Uzbekistan,
Ph.: 2237884, e-mail: tsyorik@mail.ru

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The considerable attention to synthesis of high-precision followed systems, in particular adaptive, working in the conditions of aprioristic indeterminate form [1,2] is paid in the literature lately. At the same time it is known that one of approaches to synthesis of adaptive followed systems consists that adaptation is carried out on the basis of the methods assuming direct adjustment of coefficients of amplification of the filter. Therefore introduces interest taking more convenient for calculations and expression of a matrix of soefficients of a reinforcement of a linear filter possessing computing stability in the presence of indeterminate form of a matrix of a condition of the forming filter which use allows to size up limits of change of accuracy and sensitivity of adaptive systems to aprioristic indeterminate form of parametres of the useful message functioning on the basis of a method of direct regulating of coefficients of amplification of the filter.

Let's observe the problem of searching matrix of soefficients of a reinforcement K^* of a linear filter

$$\hat{x}_{i+1} = \hat{x}_{i+1|i} + K^*_{i+1}[z_{i+1} - H\hat{x}_{i+1|i}], \qquad (1)$$

$$\hat{x}_{i+1|i} = A_2\hat{x}_i, \qquad (2)$$

Minimising figure of merit

$$J(e) = M\left\{\sum_{i=0}^{e-1}[z_{i+1} - H\hat{x}_{i+1|i}]^T R^{-1}[z_{i+1} - H\hat{x}_{i+1|i}]\right\}, \qquad (3)$$

For the linear system presented by the stochastic difference equations

$$x_{i+1} = A_1x_i + \Gamma w_i,\ x(0) = x_0, \qquad (4)$$

$$z_i = Hx_i + v_i, \qquad (5)$$

In case $A_2 \neq A_1$.

In relationships (1) - (5) $M\{\cdot\}$ – the operator of mathematical expectation, x_{i+1} – *n-dimensional* state vector of system, A_1 – a matrix of a condition of the forming filter a size $n\times n$, Γ – a matrix at noise of excitation by a size $n\times m$, w_i – normal discrete white noise with zero mathematical expectation and a correlation matrix $M\{w_l w_j^T\} = Q\delta_{lj}$, Q – symmetric неотрицательно a certain matrix, z_i – *r-dimensional* vector of observations, H – a matrix a size $p\times n$, v_i – normal discrete white noise with zero mathematical expectation and a correlation matrix $M\{v_l v_j^T\} = R\delta_{lj}$, R – symmetric not negatively a certain matrix $M\{v_l w_j^T\} = 0$, $\hat{x}_{i+1}$ – an optimum estimation of a condition of system, $\hat{x}_{i+1|i}$ – the extrapolated estimation of a condition, A_2 – a matrix of a condition of a linear filter a size $n\times n$.

Considering (2), (4), and (5), we write down figure of merit (3) in an aspect

$$J(e) = M\left\{\sum_{i=0}^{e-1}[z_{i+1} - H\hat{x}_{i+1|i}]^T R^{-1}[z_{i+1} - H\hat{x}_{i+1|i}]\right\} = \sum_{i=0}^{e-1} Sp[R^{-1}HD_{i+1|i}H^T + I], \tag{6}$$

where Sp – a matrix trace, $D_{i+1|i} = M\{[x_{i+1} - \hat{x}_{i+1|i}][x_{i+1} - \hat{x}_{i+1|i}]^T\}$ – a matrix of error variances of extrapolation, I - an identity matrix.

Using (1), (2), (4), (5) and expression for an extrapolation error $\varepsilon_{i+1}^{э} = x_{i+1} - \hat{x}_{i+1|i}$, it is possible to gain a following equation for a matrix of error variances of extrapolation:

$$\begin{aligned} D_{i+1|i} &= \Delta A D_i^x \Delta A^T + A_2(I - K_i^* H)M\{\varepsilon_i^{э} x_i^T\}\Delta A^T + \Delta A M\{x_i \varepsilon_i^{эT}\}(I - K_i^* H)^T A_2^T + \\ &+ A_2(I - K_i^* H)D_{i|i-1}(I - K_i^* H)^T A_2^T + A_2 K_i^* R K_i^{*T} A_2^T + \Gamma Q \Gamma^T, \end{aligned} \tag{7}$$

where

$$\Delta A = A_1 - A_2,\ D_i^x = M\{x_i x_i^T\},$$

$$M\{\varepsilon_{i+1}^{э} x_{i+1}^T\} = \Delta A D_i^x A_1^T + A_2(I - K_{i+1}^* H)M\{\varepsilon_i^{э} x_i^T\}A_1^T + \Gamma Q \Gamma^T,$$

$$M\{x_{i+1}\varepsilon_{i+1}^{эT}\} = [M\{\varepsilon_{i+1}^{э} x_{i+1}^T\}]^T.$$

For the solution of an observed problem it is possible to use a principle of a maximum [3] according to which we write down Hamilton's operator:

$$H[D_{i|i-1}, P_{i+1}, K_i^*] = Sp[D_{i+1|i}P_{i+1}^T], \tag{8}$$

where P_{i+1} – the matrix interfaced variable.

Then on the basis of methods of the theory of a dynamic filtering [1-3] taking into account a necessary condition of a minimum functional (3) and boundary conditions it is possible to come to the equation for P_{i+1}^T a following aspect:

$$P_{i+1}^T - P_i^T = \frac{\partial H[D_{i|i-1}, P_{i+1}, K_i^*]}{\partial D_{i|i-1}} = (I - K_i^* H)^T A_2^T P_{i+1}^T A_2 (I - K_i^* H). \tag{9}$$

From the analysis (9) follows that expressions for P_{i+1}^T and P_{i+1} will be equal and symmetric. Then taking into account symmetry of matrixes P_{i+1} R, $D_{i|i-1}$ the condition of a minimum $J(e)$ becomes

$$\begin{aligned} &\Delta A M\{x_i \varepsilon_i^{эT}\}H^T - \Delta A M\{x_i \varepsilon_i^{эT}\}H^T - A_2 D_{i|i-1}^T H^T - \\ &- A_2 D_{i|i-1} H^T + A_2 K_i^* H D_{i|i-1}^T H^T + A_2 K_i^* H D_{i|i-1} H^T + \\ &+ A_2 K_i^* R^T + A_2 K_i^* R = 0, \end{aligned}$$

where expressions for total K_i^* can be written down in an aspect:

$$K_i^* = A_2^{-1} \Delta A M\{x_i \varepsilon_i^{эT}\} \left(H^T + D_{i|i-1} H^T \right) g_\alpha (H D_{i|i-1} H^T)\,, \qquad (10)$$

$$g_\alpha (H D_{i|i-1} H^T) = [H D_{i|i-1} H^T + R + \alpha I]^{-1}\,,$$

where $g_\alpha (H D_{i|i-1} H^T)$ – generating system of functions for a regularization method, α– regularization parametre.

Here the generating system of functions in (10) is injected for expression stabilization rather K_i^*. In (10) parametre of regularization α it is possible to choose on the basis of a way of modeling (reference) instances or modeling [4]. The essence of this way consists that value α in some initial instance, the equation or problem Π^B is chosen on the basis of the solution of auxiliary modeling instance Π^B or several modeling instances with the known exact solution.

As there is an inaccuracy in the aprioristic information the following statistics is carried out: modeling instances Π_i^B $i = 1,2,\ldots,N$, with various within aprioristic indeterminate form initial data and their implementation are made some Π_i^B $i = 1,2,\ldots,N$. The set of functions $\psi_i(\alpha) = \left\| y_{\alpha_{\Pi_i^B}} - y_{\Pi_i^B} \right\| \Big/ \left\| y_{\Pi_i^B} \right\|$ and magnitudes is as a result gained $\psi_i(\alpha) = \left\| y_{\alpha_{\Pi_i^B}} - y_{\Pi_i^B} \right\| \Big/ \left\| y_{\Pi_i^B} \right\|$ $\alpha_{опт\,\Pi_i^B}$, $i = 1,2,\ldots,N$.

Required value of parametre of regularization α_P is defined one of the formulas

$$\alpha_P = \frac{\sum_{i=1}^{N} \alpha_{опт\,\Pi_i^B}}{N}$$

or

$$\alpha_P = \max_{i=\overline{1,N}} \{\alpha_{опт\,\Pi_i^B}\}\,.$$

The way is most effective in a case when the great number of "close" initial instances dares. In this case force on preliminary formulation and the solution of modeling instances provides sufficient accuracy of a way.

The resulted regular algorithms allow stabilizing procedure of a sizing up of coefficient of amplification Kalman the filter in the conditions of aprioristic indeterminate form at a problem solving of synthesis of adaptive control systems of dynamic installations. The offered adaptive algorithms have been realized programmatically and showed the high efficiency in numerical experiments. Practical implementation of the resulted algorithms in the conditions of concrete technological installation of management in a combination to the algorithms of adaptive identification based on the theory of a sizing up showed the efficiency.

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ANALYSIS OF MODERN DIGITAL SIGNAL PROCESSORS FAMILIES SHARC BASED SUPER HARVARD ARCHITECTURE

B.S. Azamhonov

Tashkent University of Information Technology, Ferghana Branch
86a Ferghana Street, Ferghana, Uzbekistan
Tel.: +998937350300, E-mail: tatuffdek@inbox.uz

***Key words**: super Harvard architecture, processors families SHARC, processors architecture, register.*

One of the most critical to the speed of DSP algorithms factor is the transmission of information to and from memory. This includes not only data, such as sampling the input signal and filter coefficients, but the team program, i.e. binaries entering the program sequencer. For example, suppose that you need to multiply the two numbers, which are somewhere in the memory. To do this, we must take three binary values from memory: the number to be multiplied, plus a command program, indicating that you need to do.

Most modern computers actually built on the von Neumann architecture. Another architecture is only required when you need a very fast processing, and we are willing to pay for it increases the complexity of the device. This requirement meets Harvard architecture. It is so called because of developments made in Harvard University in 1940th under the leadership of Howard Aiken. Aiken insisted on the separation of the memory into two parts: the data memory and program memory with the release of some bus for each of them. Since the buses operate independently, and the team and the data can be selected from the memory and the CPU load at the same time, increasing the speed of processing. Most modern DSPs use this two-bus architecture.

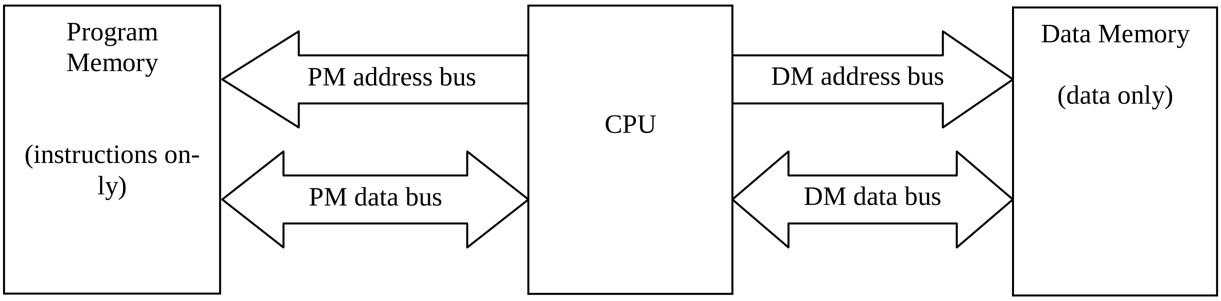
In **Figure 1** the next level of organization Memory super Harvard architecture is shown. This term was introduced by Analog Devices for the description of digital signal processors family ADSP-2106x and ADSP-211xx, manufactured by the company. DSP, built on architecture called SHARC, which is short for Super Harvard Architecture. The idea was to modernize the Harvard architecture, giving it additional features that improve performance.

SHARC DSP architecture optimized for a family of dozens of directions, but two of them is of particular importance is the presence of cache memory commands and I/O controller. First, consider how the presence of cache memory Harvard architecture teams is improving. Shortcomings in basic Harvard architecture are that the memory bus is busy data than memory bus programs. In multiplying two numbers two binary values (numbers) must be received by the CPU via the data bus, and only one binary value (command) is loaded on the bus program. To improve the situation, we'll start with moving the data in the program memory. For example, we can place filter coefficients in the program memory and sample input record is still in the data memory. At first glance, the situation has not been improved. Now we need to pass a single value on the data bus (the input signal) and two values of the bus commands (command, and ratio). If we were doing a random sequence of commands, then it would indeed be the case.

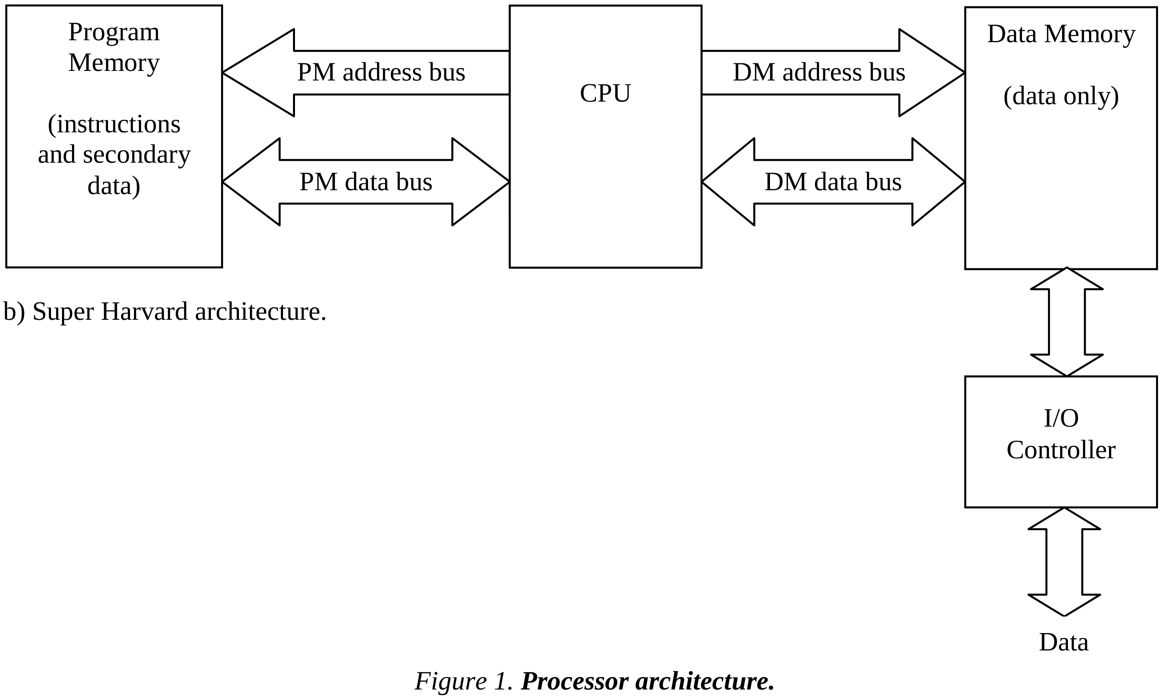
In **Figure 2** SHARC architecture is shown in greater details. The architecture of these processors includes I/O controller connected to a data memory and organizing input signals in and out of it. In particular, the exchange of data with external devices SHARC DSP family contains both parallel and serial ports, providing a very high rate. For example, if the CPU clock speed 40 MHz, two serial ports provide a transfer rate of 40 Mbit/s each, and six parallel ports, 40 MB/s. When all six parallel ports are used together, the data rate is incredible, 240 MB/s.

A number of digital processing algorithms are implemented effectively if they are broken down into several stages. For example, IIR filters are more stable, if implemented as a series connection of several biquad. The presence of several processing steps requires the same number of circular buffers to allow the fastest implementation of the algorithm. With the ability to support a large number of circular buffers, data address generators SHARC processors are optimized for the effective execution of the algorithm Fast Fourier Transform (FFT). They can help you reach the circular buffer mode bit-reverse addressing, which is necessary for the implementation of the FFT. Note that a large number of circular buffers simplify the process of generating code in the case of its design manual (programmer) and the automatic code generation tools Compiler high-level languages, such as C language. Mathematical processing of the processor implemented in three computing units: multiplier, an arithmetic logic device (ALD) and a parallel shifter. Multiplier loads two operands from registers, finds their work and the result is written into the register. ALD is used to perform the operations of addition, subtraction, module, logical operations, convert numbers to fixed-point format to floating point, or vice versa, and other functions. Elementary binary operations are performed in parallel shifter. These include: the shift, cyclic shift, extract fragments of speech or writing data. An important property of processors SHARC makes them really powerful architecture is the possibility of parallel operation of the multiplier and ALD. Per clock multiplier can be processed operands from registers 0 ... 7, and ALD - operands from registers 8 ... 15, and the two results obtained are recorded in any of the 16 registers.

The figure shows a simplified diagram of one of the SHARC processor family from Analog Devices.



a) Harvard architecture.



b) Super Harvard architecture.

Figure 1. ***Processor architecture.***

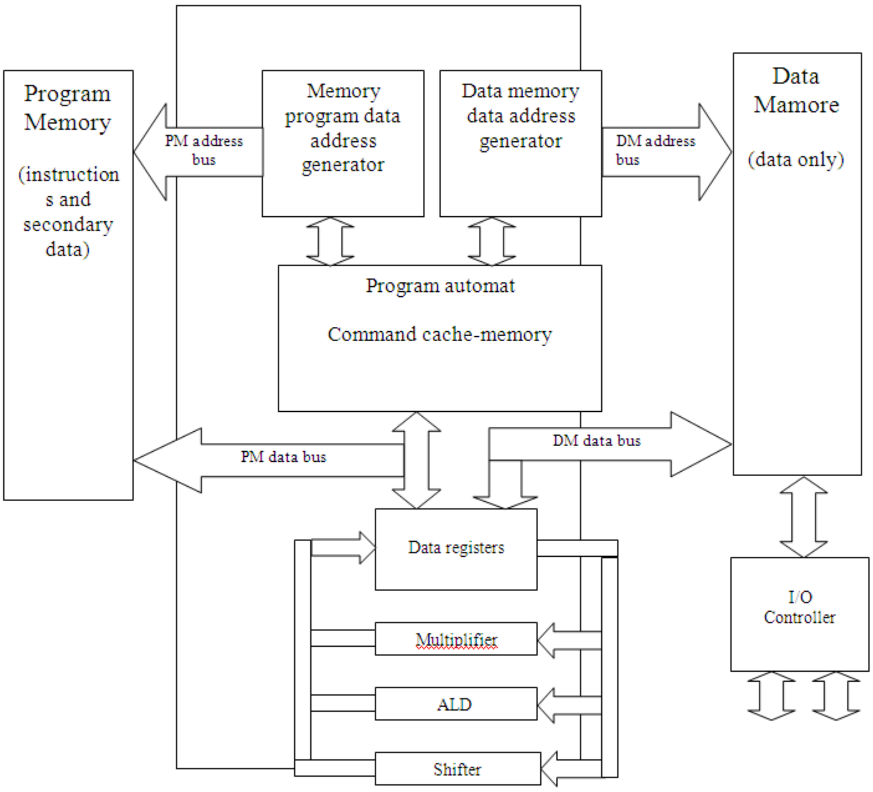


Figure 2. ***Typical Architecture DSPs.***

Development of the basic architecture of SHARC ADSP-2106x family of processors is the SHARC ADSP-2116x, and the platform is ADSP-TS101 TigerSHARC. These processors are based on the so-called SIMD-architecture (Single Instruction Multiple Data: one team - a lot of data). SIMD principle is that the same instructions are executed simultaneously for different data sets. Further improvement of the architecture is support for the regime MIMD (Multiple Instruction Multiple Data: a lot of teams - a lot of data). In this mode, the computing devices perform different streams of commands on different sets of data within one clock cycle. This mode is specific only for the processors ADSP-TS101 TigerSHARC firm Analog Devices (SIMD mode is also supported by them as a special case MIMD-mode). Other high-performed DSP family firm Analog Devices-family Blackfin-designed so that a single cycle runs in parallel many mathematical operations. Heart Blackfin architecture is a block of arithmetic operations on the data, which includes two 16-bit multiplier-accumulators (MAC), two 40-bit ALDs, four 8-bit video ALDs and one 40-bit parallel shifter. With this architecture, processing of 8, 16 or 32-bit data is done with maximum efficiency.

Comparing these different architectures, you can draw some conclusions. It is known that the majority of DSP algorithms required to perform 4 ... 400 teams that SHARC processors equivalent to 4 ... 400 beats to perform processing in one sample the input signal. Then, for the second-generation DSP SHARC ADSP-2116x, running at 100 MHz, will be characterized by the processing speed of 25 thousand to 25 million samples per second. Similarly, for the DSP SHARC ADSP-TS101 at 250 MHz data will be processed at a rate of 625,000 to 62.5 million counts per second. Before I finish this article I would like to point out that a family of SHARC ADSP-TS101 are among the most suitable for the demonstration of how the estimated time of various tasks. The fact is that the multiplication and accumulation produced in these processors in a single clock cycle.

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AUTOMATED SYSTEM OF CORPORATIVE INFORMATION CENTERS

U.F. Karimov, K.A. Gaffarov

Tashkent University of Information Technologies,
Tashkent Amir Temur st. 108

Keywords*: corporative information centers, automated library-information systems, cataloguer, administrator, librarians.*

Decree of President of Republic of Uzbekistan "About the organization of a library-information of the population of republic " created big way to organizes new type information resource and information resource centers in Uzbekistan, new law which accepted in 13th April in 2011 "About activity of information-library centers of republic of Uzbekistan " supported to improve infrastructure of library-information organizations [1]. Decree of President of Republic of Uzbekistan which accepted 23rd February in 2011 №PQ-1487 "About remedies of improvement of services with library-information and information resources in based new information communication technologies in 2011-2015 years" is planned to developing this specialty [2]. We have to create automated library-information systems and engraft to library-information organizations for discharging present decrees, laws and government program. Follow part of this paper we overview programming supplement for library-information organizations.

Automated system of corporative information centers contains 6 automatic working place (AWP), there are:

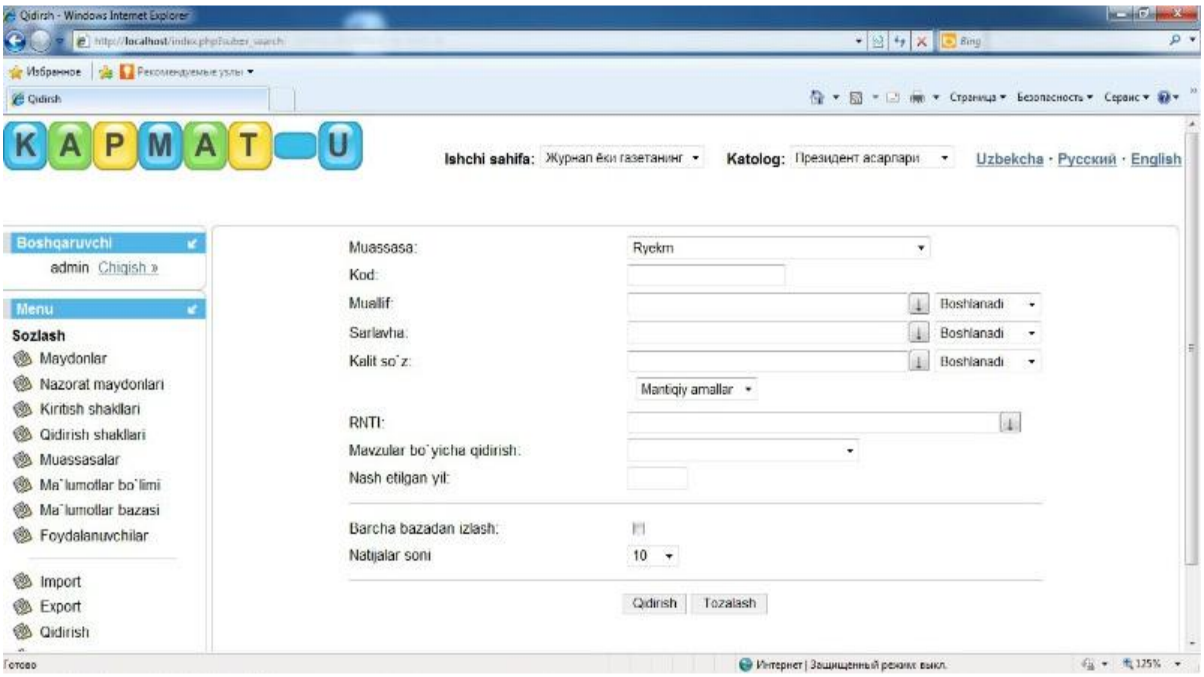
- "Administrator" AWP
- "Cataloguer" AWP
- "User" AWP
- "Librarians" AWP
- "Acquisition" AWP
- "Seasonticket (by library-information organizations)" AWP

Nowadays 4 parts of the system are working and 2 parts are experimental process.

Interface of system has three language (uzbek, russian, english)

"Administrator" AWP of the system can do following functions

- Create and delete databases.
- Import/export bibliographic records
- Create field MARC21 and subfields with "Constructor" of the system
- Registered and give login and password for organization and users of system



Img. 1. ***Overview of administrator AWP.***

“Cataloguer” AWP can do following functions

- Formed electron catalog of the system
- Registered users of the system and also them are give login and password
- Formed references of the system
- Bibliographic records are copied from one database to another database
- Supply exchange bibliographic records between members of corporation
- Can search by all datasets of member library organization of corporation and have a opportunity copying bibliographic records to database himself

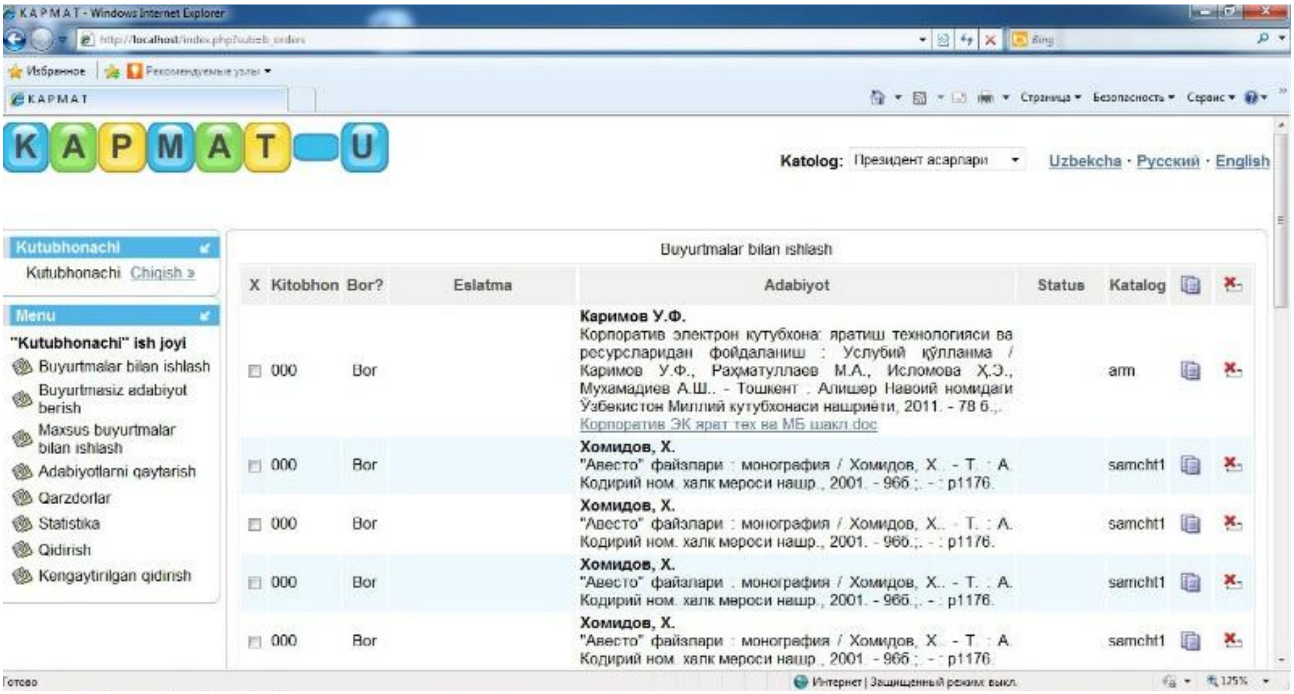
“User” AWP can do following functions

- Doing “simple” and “extended” search from database. Ordering to founded books, taking information about ordered books
- Take information about taken and given back books from information resource center
- View full text information’s and download allowances

Img. 2. ***Overview of readers awp which users of library.***

“Librarians” AWP can do following functions:

- Accept orders, have done and sending information to users about it. Doing special orders
- Doing orders which ordered without using electron catalog
- Give back given books
- Find debtors
- Manage statistics of information resource center



Img. 3. ***Overview of Librarians AWP.***

The system is very easy and have following comforts

1. We can form database of electron catalogue fast with using technology of corporative cataloging
2. readers can use electron catalog by distance (place books, show accepted indents and take information about accomplished demands).
3. The system respects to system of standards of Uzbekistan for creating bibliographic description
4. Working in the system is very easy and it is created which considered experience and practice of librarians of Uzbekistan nowadays
5. Created simple and multimedia user's manual for system users.
6. Implementing of the system, LIS, LRS and organizing special courses for employer of libraries to teaching of the system. Hereafter planed float system of teaching by distance.
7. The system has a "Konstructor" for creating special fields and "Konstructor" can make arbitrary type fields.
8. Given information as a help for cataloguer about filling fields. Filling information's showed by examples.
9. Using dynamic databases in organizing database of electron catalogue is accelerate process of filling and decrease mistakes.
10. The system espouse international library-bibliographic and communicative formats, specification systems and coding rules in input information to "AKAT" database and communicating by network.
11. The system has specific technology for input many volume books and serial editions

Conclusion

1. We can apply the system to every library-information organizations
2. The system can automated main information process (collecting information, save, refinement, searching and communicating to users) in library-information organizations.
3. We can create e-library with the system.
4. Created multimedia user's manual for new users.

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ADAPTIVE ESTIMATION OF THE CONDITION VECTOR IN THE APRIORISTIC UNCERTAINTY COVARIANCE MATRIXES OF OBJECT NOISE AND THE MEASUREMENTS HINDRANCE

O.O. Zaripov, Yu.M. Abdurahmanova, Ch.X. Umarova

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitety st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45, E-mail: uz3121@mail.ru

Keywords: *dynamic system, adaptive filtration, regularization, regularization parameter.*

Creation of control systems by technological objects demands existence large volume of information both on the object, and about its entrance and target variables. This information is necessary for creation of adequate model of a control system on the basis of which management process can be carried effectively out. Usually for difficult objects there is no necessary for control system creation a model, and the problem of management should be solved in the conditions of insufficient or at all absent aprioristic information on object. In such cases it is necessary to resort to automatic control with the adaptation, allowing to provide steady and effective work of all system as a whole [1-4]. It is reached by means of adaptive algorithms which as a processing result of available supervision finally properly change actuation device parameters so that the control system as a whole provided a minimum of this or that criterion of functioning system quality. Thus, the researches directed on development of condition estimation algorithms of dynamic objects management on the basis concepts of an adaptive filtration, are represented actual.

On the basis of methods an optimum dynamic filtration when using models of the object having constant factors both non-stationary noise and hindrances of measurements with unknown correlation matrixes, it is possible to synthesize adaptive algorithms of estimation also. For this purpose for models

$$x_{i+1} = Ax_i + \Gamma w_i , \tag{1}$$

$$z_i = Hx_i + v_i , \tag{2}$$

let's write down expression for updated process

$$\nu_{i+l|i} = z_{i+l} - H\hat{x}_{i+l|i} , \tag{3}$$

where x_i – vector of a dimension condition system *n;* z_i – vector of supervision dimension *m;* w_i and v_i – vectors of object noise and a supervision dimension hindrance *q* and *p* accordingly, being sequence of a kind Gauss white noise with characteristics $E[w_i] = 0$, $E[w_i w_k^T] = Q\delta_{ik}$, $E[v_i] = 0$, $E[v_i v_k^T] = R\delta_{ik}$, $E[w_i v_k^T] = 0$; A, Γ and H – matrixes of corresponding dimensions; $\hat{x}_{i+l|i} = A_{i+l,i}\hat{x}_i = A_i^l \hat{x}_i$.

Then

$$\begin{aligned} v_{i+l|i} &= Hx_{i+l} + R_{i+l} - HA_i^{l-1}\hat{x}_{i+l|i} = \\ &= H\left[A_i^{l-1}x_{i+l} + A_i^{l-2}w'_{i+1} + A_i^{l-3}w'_{i+2} + \ldots + w'_{i+l-1}\right] + R_{i+l} - HA_i^{l-1}\hat{x}_{i+l|i} = \\ &= HA_i^{l-1}\tilde{x}_{i+l|i} + H\sum_{j=2}^{l} A_i^{l-1}w'_{i+j-1} + R_{i+l}\,,\ w'_i = \tilde{A}w_i\,,\ \tilde{x}_{i+1|i} = x_{i+1} - \hat{x}_{i+1|i}. \end{aligned} \tag{4}$$

Let's consider the following sequence of mutual covariance matrixes $M\left(v_{i+j|i}v_{i+1|i}^2\right), j = 2,\ldots,l$. In view of expression (4) it is possible to write

$$M\left(v_{i+j|i}v_{i+1|i}^2\right) = HA_i^{j-1}{}_i P_{i+1|i}H^T,\ j = 2,\ldots,l, \tag{5}$$

where $P_{i+1|i} = M\left(\tilde{x}_{i+1|i}\tilde{x}_{i+1|i}^T\right)$.

The equation (5) can be written down in a matrix form

$$Y_v = SP_{i+1|i}H^T, \tag{6}$$

where

$$Y_v = \begin{bmatrix} M(v_{i+2|i}v_{i+1|i}^T) \\ \hdashline M(v_{i+3|i}v_{i+1|i}^T) \\ \hdashline M(v_{i+4|i}v_{i+1|i}^T) \\ \hdashline \ldots\ldots\ldots\ldots \\ \hdashline M(v_{i+l|i}v_{i+1|i}^T) \end{bmatrix},\ S = \begin{bmatrix} H \\ \hdashline HA_i \\ \hdashline HA_i^2 \\ \hdashline \ldots\ldots \\ \hdashline HA_i^{l-2} \end{bmatrix} A_i\,. \tag{7}$$

Assessment of a covariance matrix of measuring noise we will determine by a formula

$$\hat{R}_{i+1} = M\left(v_{i+1|i}v_{i+1|i}^T\right) - H\left(P_{i+1|i}H^T\right). \tag{8}$$

Then the equation for a matrix of K_{i+1} strengthening of the filter will become

$$K_{i+1} = \left(P_{i+1|i}H^T\right)\left[M\left(v_{i+1|i}v_{i+1|i}^T\right)\right]^{-1}. \tag{9}$$

Let's create from vectors sequence $v_{i+1|i}, v_{i+2|i},\ldots,v_{i+l|i}$ vector of a look:

$$\vartheta_l = \left[v_{i+1|i} \,\vdots\, v_{i+2|i} \,\vdots\, v_{i+3|i} \,\vdots\, \ldots \,\vdots\, v_{i+l|i}\right]^T. \tag{10}$$

It is possible to show [2,4] that the density of probability ϑ_l will be maximum, if

$$M\left(\vartheta_l\vartheta_l^T\right) = \vartheta_l\vartheta_l^T. \tag{11}$$

On the basis of (11) matrixes Y_v and S in the equation (6) will become:

$$Y_v = \begin{bmatrix} v_{i+2|i}v_{i+1|i}^T \\ \hdashline v_{i+3|i}v_{i+1|i}^T \\ \hdashline v_{i+4|i}v_{i+1|i}^T \\ \hdashline \ldots\ldots\ldots \\ \hdashline v_{i+l|i}v_{i+1|i}^T \end{bmatrix}, \tag{12}$$

$$K_{i+1} = \left(P_{i+1|i}H^T\right)\left(v_{i+1|i}v_{i+1|i}^T\right)^{-1}. \tag{13}$$

In case the covariance matrix R_i hindrance of measurements is known, expressions for Y_v, K_{i+1} and S will register in a look:

$$Y_v = \begin{bmatrix} v_{i+1|i}v_{i+1|i}^T - R_{i+1} \\ \hdashline v_{i+2|i}v_{i+1|i}^T \\ \hdashline v_{i+3|i}v_{i+1|i}^T \\ \hdashline \cdots\cdots \\ \hdashline v_{i+l|i}v_{i+1|i}^T \end{bmatrix},\ K_{i+1} = (P_{i+1|i}H^T)\left[HP_{i+1|i}H^T + R_{i+1}\right]^{-1},\ S_i = \begin{bmatrix} H \\ \hdashline HA_i \\ \hdashline HA_i^2 \\ \hdashline \cdots \\ \hdashline HA_i^{l-2} \end{bmatrix}. \quad (14)$$

For synthesis of the adaptive filter in considered statement it is necessary to calculate a matrix $P_{i+1|i}H^T$. The matrix $P_{i+1|i}H^T$ can be calculated on the basis of expression (6) with use various ways (7), (12), (14) formation of matrixes Y_v and S. When developing regular solution algorithm of a considered task further we will use representations (7) and (12) for matrixes of S and Y_v respectively.

Accepting more realistic point of view we will believe that the right member of equation (6) is set with some error caused by noise existence of object model and a hindrance of measurements in (1) and (2).

Thus, instead of (6) we will consider the look equation

$$Y_v = SP_{i+1|i}H^T. \quad (15)$$

From the realistic point of view the equation (15) we will write down in a look

$$Y_{\delta(v)} = S_h P_{i+1|i}H^T, \quad (16)$$

where $Y_{\delta(v)}$, S_h – really observable matrixes of basic data.

For simplification of further calculations we will copy the equation (16) in a look

$$Y_{\delta(v)} = S_h D_i, \quad (17)$$

where $D_i = P_{i+1|i}H_i^T$.

Let's write down the equation (17) in component-wiseform

$$y_{\delta(v,j)} = S_h d_j, \quad (18)$$

where d_j - j-st column of a matrix D, $y_{\delta(v,j)}$ – j-st column of a matrix $Y_{\delta(v)}$, j $(j = 1,2,...,m)$.

One of the computing difficulties connected with this method, consists in a vacuous or bad conditionality of a matrix S_h. The specified circumstance predetermines need of application at the considered problem solution of regularization methods [5-8]. Element d_j search on the basis of regular methods is connected with value calculation of display $G = S_h^+$, $S_h^+ y_{\delta(v,j)}$ – a prototype $y_{\delta(v,j)}$ at display S_h. As display $G = S_h^+$, connected with a task (18), generally speaking, is multiple-valued (it is not supposed that $\ker S_h = 0$), it is possible to assume, that the designed family of linear continuous operators R_α possessed such property: if $y_{\delta(v,j)} \in R(S_h)$, $R_\alpha y_{\delta(v,j)} \to d_{1,j}$ at $\alpha \to 0$, where $d_{1,j}$ – any solution of the equation (18), α – regularization parameter.

In practice basic data $\{S_h, y_{\delta(v,j)}\}$ in the equation (18) are known usually only approximately. Therefore instead of the exact equation (18) we will consider the equation with approximate basic data

$$y_{\delta(v,j)} = S_h d_j,\ d_j \in \mathrm{T},\ y_{\delta(v,j)} \in U, \quad (19)$$

where $S_h : \mathrm{T} \to U$ – the linear matrix operator from some family of approximating operators with conditions of approximation a look:

$$\|S_h - S\| \le h, \quad \|y_{\delta(v,j)} - y_{v,j}\| \le \delta . \tag{20}$$

On the basis of [7] it is possible to write the following estimates for norms of operators

$$\left\|S_h \left(S_h^T S_h + \alpha I\right)^{-1}\right\| \le 1, \quad \left\|\left(S_h^T S_h + \alpha I\right)^{-1}\right\| \le 1/\alpha , \tag{21}$$

where $\alpha > 0$ – regularization parameter, I – the individual operator.

Then taking into account (20) and (21) it is possible to come to look expression

$$\begin{gathered}\|Sd_{0,j} - S[d_j]_h^\alpha\| \le \left\{\left\|\left(S - S_h\right)\left(S_h^T S_h + \alpha I\right)^{-1}\right\| + \left\|S_h \left(S_h^T S_h + \alpha I\right)^{-1}\right\|\right\} \times \\ \times \left(h + \alpha\right)\|d_{0,j}\| \le \left(h/\alpha + 1\right)\left(h + \alpha\right)\|d_{0,j}\|.\end{gathered} \tag{22}$$

From (22) it is possible to conclude that at $\alpha \to 0,\ h/\alpha \to 0$ convergence $Sd_j \to Sd_{0,j}$ takes place.

Thus, the regularization equation $\left(S_h^T S_h + \alpha I\right)d_j = y_{\delta(v,j)}^{i+1}$ let's resolve for any $S_h, y_{\delta(v,j)}^{i+1},\ \alpha > 0$ and decisions $[d_j]_\Delta^\alpha$ meet to the solution of the equation (19) with the right part $y_{v,j}^{i+1} = y_0^{i+1}$: $[d_j]_\Delta^\alpha \to d_{0,j} = S^+ y_0^{i+1}$, when $\Delta \to 0$ and $\alpha \to 0$ at communication $\left(h + \delta\right)/\alpha\left(\delta, h\right) \to 0$, i.e. $\{[d_j]_\Delta^{\alpha(\Delta)}\}$ – regularization family of approximate decisions, and $R^\alpha\left(S_h, y_{\delta(v,j)}^{i+1}\right) = \left(S_h^T S_h + \alpha I\right)^{-1} y_{\delta(v,j)}^{i+1}$ – regularization family of operators task (19) in a point $\{S_h, y_0^{i+1}\}$, where $\Delta = (\delta, h)$ - exact vector.

α it is possible to define parameter of regularization from a condition $\|S_h[d_j]^{\alpha,\Delta} - y_{v,j}^{i+1}\| = 2\left(h\|[d_j]^{\alpha,\Delta}\| + \delta\right) + \mu$, where $\mu = \inf\|S_h d_{0,j} - y_{v,j}^{i+1}\|$ – characterizes degeneration of a matrix S_h.

Thus, when using a regularization method in a considered problem of estimation the following limiting ratio takes place: $\lim\limits_{\Delta \to 0}\|d_{0,j} - [d_j]^{\alpha,\Delta}\| = 0$, where $d_{0,j}$ – the normal decision of equations system (19) with exact basic data.

The given computing procedures allow regularization a considered problem of operated objects estimation on the basis of a quasi linearization method and to realize steady finding of an entry condition by which new approach to a true movement trajectory of system is determined.

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REGULARIZATION ALGORITHMS OF THE ADAPTIVE FILTRATION ON SEQUENCE OF SCALAR MEASUREMENTS

O.O.Zaripov, A.X.Abduganiev, O.P.Shukurova, J.B.Sherbutaev

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitety st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45, E-mail: uz3121@mail.ru

***Keywords**: dynamic system, estimation, adaptive filtration, regularization, regularization parameter.*

At creation of control systems by dynamic systems methods of a Kalman's filtration [1,2] are widely applied. It is known that creation of Kalman filters possibly if all characteristics of system and noise are completely defined. In the majority of practical cases these characteristics either are unknown, or are known partially, or remaining invariable during long intervals of time, change in an unforeseen way upon transition from one interval to another. Use of inexact characteristics can lead to increase or even to a divergence of filtration errors. In these cases it is expedient to pass to creation of steady adaptive procedures of the dynamic filtration intended for minimization or restriction of mistakes in problems of adaptive management creation systems of [1-3].

Recently there were schemes of the Kalman filter, having for an object to bypass this difficulty. These schemes usually call «adaptive filters». In the theory and practice of estimation condition of dynamic systems, there is a set of options and computing schemes of synthesis algorithms an adaptive filtration, each of which can be used for estimation and formation of operating influences with reference to concrete dynamic object. The choice of option of dynamic estimation condition depends on properties of operated object and those main objectives of management which should be reached [2-4].

Practical realization parametrically adaptive algorithms of estimation meets the considerable difficulties of computing character connected with that circumstance that at their formation it is necessary to consider the tasks which decisions are unstable to small changes of basic data. They are characterized by that as much as small changes of basic data can lead to any way big changes of decisions. Tasks of this kind, in essence, are badly caused. They belong to a class incorrectly objectives [5-7]. If basic data are known approximately, the mentioned instability results in practical non-uniqueness of the decision within the set accuracy and to great difficulties in clarification sense of the received approximate decision. Therefore it is expedient to consider various possible approaches to the solution of accuracy increase condition calculation problems of dynamic systems methods of regularization and to reveal the most perspective for practical use methods and algorithms of the incorrectly objectives decision.

Very often in the theory and practice of a filtration the covariance matrix of a measurements hindrance is known proceeding from results of the preliminary analysis of measuring device statistical characteristics. In such cases very effective the approach [3,4] based on an assessment of a covariance noise matrix of object is represented. Let's assume that a covariance matrix of entrance noise it is possible to present in the form of $Q = qI$, and that measurements – a scalar. This assumption doesn't influence a community of the task solution as there is a possibility application method of a consecutive filtration when the vector of measurements is processed consistently a component behind the component. It is necessary to define such value q which will provide at most a density of emergence probability of updated sequence.

Let's consider the linear dynamic system described by the equations

$$x_{i+1} = Ax_i + \Gamma w_i, \tag{1}$$

$$z_i = Hx_i + v_i, \tag{2}$$

with aprioristic data:

$$w_i \sim N(0, Q_i), v_{i+1} \sim N(0, R_{i+1}), x_0 \sim N(x(0|0), P_0),$$

$$Q_i = \begin{cases} q_i, & if \quad i = j, \\ 0, & if \quad i \neq j, \qquad i, j = \overline{1, p} \end{cases} \tag{3}$$

$$\operatorname{cov}(v_i, v_j) = \operatorname{cov}(x_0, w_i) = \operatorname{cov}(x_0, v_j) = 0,$$

where x_i – vector of a dimension condition system *n*, z_i – vector of supervision dimension *m*, w_i and v_i – vectors of object noise and a supervision of dimension hindrance *q* and *p* accordingly, being sequence of a kind Gauss white noise with characteristics $E[w_i] = 0$, $E[w_i w_k^T] = Q\delta_{ik}$, $E[v_i] = 0$, $E[v_i v_k^T] = R\delta_{ik}$, $E[w_i v_k^T] = 0$; *A, Γ* and *H* – matrixes of corresponding dimensions.

For estimation of a condition vector x_i dynamic system (1), (2) the traditional equations of the Kalman's filter [2,3] are usually used.

Let's calculate the updated parameter $v_i = z_{i+1} - H_i x_{i+1|i}$ and we will find its interrelation with required parameters of a covariance matrix $q_1,...,q_p$. On the basis of a ratio (1) it is possible to write down

$$x_i = A_{i|0} x_0 + \sum_{j=1}^{i} A_{i|j} \Gamma_{j|j-1} w_{j-1}, \tag{4}$$

where

$$A_{i|0} = A_{i|i-1} A_{i-1|i-2} \ldots A_{1|0}, \; A_{i|j} = A_{i|i-1} A_{i-1|i-2} \ldots A_{j+1|j}.$$

Substituting in a ratio (2) at *k=i* the value x_i, taken from (4), we find

$$z_i = H_i x_i + v_i = H_i A_{i|0} x_0 + \sum_{j=1}^{i} H_i A_{i|j} \Gamma_{j|j-2} w_{j-1} + v_i. \tag{5}$$

Owing to a ratio (5) and aprioristic data (3) be nonviscous v_i can it is calculated the next way:

$$v_i = z_i - H_i x_{i|0} = z_i - H_i A_{i|0} x_{0|0}. \tag{6}$$

Let's transform the right part of a ratio (6), having substituted expression from (5)

$$v_i = H_i A_{i|0} (x_0 - x_{0|0}) + \sum_{j=1}^{i} H_i A_{i|j} \Gamma_{j|j-1} w_{j-1} + v_i. \tag{7}$$

From (7) and aprioristic data (3) it is possible to write down:

$$\begin{aligned} M(v_i^2 \,|\, x_{0|0}, Q) &= H_i A_{i|0} P_{0|0} A_{i|0}^T H_i^T + H_i \left[\sum_{j=1}^{i} A_{i|j} \Gamma_{j|j-1} Q \Gamma_{j|j-1}^T A_{i|j} \right] H_i^T + R_i = \\ &= H_i A_{i|0} P_{0|0} A_{i|0}^T H_i^T + \sum_{l=1}^{r} q_l \sum_{j=1}^{i} (H_i A_{i|j} \Gamma_{j|j-1})_l^2 + R_i, \end{aligned} \tag{8}$$

where

$$(H_i A_{i|j} \Gamma_{j|j-1})_l \text{ – element of a line } H_i A_{i|j} \Gamma_{j|j-1}.$$

On the basis (8) using necessary conditions of an extremum it is possible to come to the look equation

$$v_i^2 = M(v_i^2 \,|\, x_{0|0}, P_{0|0}, Q).$$

Having substituted in (8) instead of $M(v_i^2 \,|\, x_{0|0}, P_{0|0}, Q)$ value v_i^2, we will receive

$$v_i^2 = H_i A_{i|0} P_{0|0} A_{i|0}^T H_i^T + \sum_{l=1}^{p} q_l \sum_{j=1}^{i} \left(H_i A_{i|j} \Gamma_{j|j-1}\right)^2 + R_i . \qquad (9)$$

As the system (9) is linear concerning parameters q_l, $l = \overline{1, p}$, for finding of these parameters enough $p \le k$ independent is nonviscous v_i. Since number of measurement $p+1$, the vector of a condition can be estimated already *x*.

Let's designate

$$\sum_{j=1}^{l} \left(H_i A_{i|j} \Gamma_{j|j-1}\right)^2 = a_{il}, \; i = \overline{1,k}, \; l = \overline{1, p},$$

$$q = \left[q_1, \ldots, q_p\right]^T,$$

$$\varepsilon_i = v_i^2 - H_i A_{i|0} P_{0|0} A_{i|0}^T H_i^T - R_i ,$$

$$\varepsilon = \left[\varepsilon_1, \ldots, \varepsilon_k\right]^T,$$

$$D = \left\| a_{il} \right\|_{k \times p} .$$

In this case the system of the equations (9) becomes

$$Dq = \varepsilon . \qquad (10)$$

The system of the equations (10) can be badly caused, i.e. big changes of the decision can answer small changes of basic data. Noted circumstance at the solution of this equation results in need of application regularization methods[5-7]. For regularization of the equation solution (10) we will use a method of regularization of Tikhonov

$\hat{q} = \arg\min_q \left\| \varepsilon - Dq \right\|_2 + \alpha \left\| q \right\|_2$, where α – regularization parameter;

and l_1 – minimization [8]

$\hat{q} = \min_q \left\| q \right\|_1$ under condition $\left\| \varepsilon - Dq \right\|_2 \le \varsigma$,

where ς – accuracy of approximation.

For ensuring stability of various methods and, in particular, l_1 – minimization, the approach [9,10] which provides correction of properties operator by the *D* way of its multiplication to a matrix a projector recently is used. As a matrix of a projector we will use a matrix which columns are created by random variables with the normal law of distribution.

For the purpose of comparison results of recovery the required decision q we will increase both parts of the initial equation $Dq = \varepsilon$ by a matrix $G \in \mathsf{G}^{k \times n}$, $k \le n$. Then:

$$GDq = G\varepsilon , \; GD = S , \; S \in \mathsf{G}^{k \times n} , \; G\varepsilon = b , \; b \in \mathsf{G}^{k} .$$

Taking into account operation of multiplication we will receive:

Recovery of the decision by a regularization method of Tikhonov:

$$\hat{q} = \arg\min_q \left\| G\varepsilon - GDq \right\|_2 + \alpha \left\| q \right\|_2 .$$

Recovery of the decision by l_1-minimization method:

$\hat{q} = \min_q \left\| q \right\|_1$ under condition $\left\| G\varepsilon - GDq \right\|_2 \le \varsigma$.

Dependence a relative error recovery of the solution of q ($d = \| q - \hat{q} \| / \| q \|$) on number of lines *k* in *G* matrix was investigated at various levels of additive noise in a signal at (for noise levels *1e-4 ÷ 1e-2*).

Accuracy of recovery of the decision a regularization method of Tikhonov depends on selection parameter correctness of regularization. For selection of regularization parameter were used a method of Tikhonov regularization with the parameter of regularization received on a way of the cross importance; with the parameter of regularization received on a way of a quasioptimality; with the parameter of regularization received on a method of a *L*-curve [11].

Modeling examples show that all methods of regular estimation without multiplication to a matrix of *G* yield approximately identical results ($0.71<d<0.93$) with insignificant advantage of a regularization method with a choice of regularization parameter on the basis of a *L*-curve. Regularization methods of the solution considered incorrect task, connected with multiplication to *G* matrix, lead to more best results ($0.34<d<0.62$). Here the best quality is provided by the methods using a choice of regularization parameter on the basis ways of the cross importance and a *L*-curve.

Thus, matrix projector use in a certain measure lowers a measure of conditionality the matrix operator of a considered task and increases accuracy of estimation the required decision.

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ANTIJAMMING ALGORITHM OF ADAPTIVE AUTHENTICATION OF MANAGEMENT OBJECTS

J.U. Sevinov, B.A. Holkhodjaev, D.R. Karimov

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan
Phone: 246-03-45, (+99893) 398-56-68, E-mail: jasur_72@rambler.ru

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In the numerous tasks of management it is necessary to have in an order a model of the system, able to work real-time. Thus a model must not be base on future measuring. A necessity for forming of such models usually arises up because a model is needed for taking away of some judgments about the system during her functioning. The methods intended for the decision of similar tasks with the use of the influenced models of some type are usually named adaptive [1,2]. In this sense it is talked about adaptive control, adaptive filtration, adaptive treatment of signals and adaptive prediction. The calculation of job of model performances real-time must be produced so that treatment of measuring on every step was always completed to beginning of next step. Otherwise, the built model will not be able to manage with a stream.

We will consider the multidimensional system, when an entrance signal of $u(t)$ is m-by a measure vector, and output signal of $y(t)$ - l-by a measure vector:

$$y(t)+A_1y(t-1)+\ldots+A_py(t-n_a)=B_1u(t-1)+\ldots+B_qu(t-n_b)+v(t), \qquad (1)$$

where A_i -($l\times l$) are matrices, a B_i -($l\times m$) are matrices, $v(t)$ is a measuring hindrance with the variance-covariance matrix of R.

To solve the problem of identification is necessary to make the parameterization of equation (1). To do this, you can include all the elements of (1) the total number $(pl + qm)l$ units in the parameter vector θ. Then we can define $((pl + qm) \times l)$ - matrix

$$\theta=[A_1, A_2, \ldots, A_p, B_1, \ldots, B_q]^T$$

and $(pl + qm)$ - dimensional column vector

$$\varphi(t)=\begin{bmatrix} -y(t-1) \\ \vdots \\ -y(t-p) \\ u(t-1) \\ \vdots \\ u(t-q) \end{bmatrix},$$

and rewrite (1) as

$$y(t)=\theta^T\varphi(t)+v(t). \qquad (2)$$

When the parameterization imposed additional structure appropriate form such d-dimensional column vector θ and ($l\times d$) - matrix $\varphi^T(t)$, to represent (1) in the form

$$y(t)=\varphi^T(t)\theta+v(t). \qquad (3)$$

It can be shown [3] that (2) and (3) are related by

$$\theta = col\,\theta^T,$$

$$\varphi(t)=\varphi(t)\otimes I_l,$$

where I_l - the unit ($l\times l$)-matrix is, $\otimes$ -symbol kronekkerova works.

Another alternative parameterization of equation (1) is a representation of the form [4]:

$$\mathrm{y}_i(t)=\bar{z}_i^T(t-1)\theta_i+\xi_i(t), \quad i=1,2,\ldots,l,$$

or

$$\mathrm{y}(t)=\bar{Z}(t-1)\theta+\xi(t),$$

where $\bar{z}_i$ is the dimension n_i and is composed of the components of

$$\bar{z}_i(t-1)=\left[\mathrm{y}_i(t-1),\ldots,\mathrm{y}_i(t-p),\mathrm{u}^T(t-1),\ldots,\mathrm{u}^T(t-q)\right]^T,$$

$$\bar{Z}(t-1)=\left[\begin{array}{c:c:c:c} \bar{z}_1^T(t-1) & 0 & \ldots & 0 \\ \hdashline 0 & \bar{z}_2^T(t-1) & \ldots & 0 \\ \hdashline \ldots & \ldots & \ldots & \ldots \\ \hdashline 0 & 0 & \ldots & \bar{z}_l^T(t-1) \end{array}\right].$$

Vector parameter $\theta=\left[\theta_1^T \;\vdots\; \ldots \;\vdots\; \theta_l^T\right]$, $n_0=\sum_{i=1}^{l}n_i$, $n_0=l(lp+mq)$, is made up of all the elements of the matrix $\mathrm{A}_j,\ j=1, 2, \ldots, p$; $\mathrm{B}_j,\ j=1, 2, \ldots, q$.

We will consider the model structure (3). This structure is the most common and very useful for solving the problem of identification. For the estimation of the parameters of the object should be used Kalman filter type [3-6]. To isolate supplement (3) is the equation:

$$\theta(t+1) = \theta(t) + w(t)\,, \tag{4}$$

where $w(t)$ -object state noise with covariance matrix Q.

Then to identify the object, described by equations (3), (4), we can use the following expression:

$$\begin{gathered} \theta(t) = \theta(t-1) + K(t)[y(t) - \varphi^T(t)\theta(t-1)]\,, \\ K(t) = P_{\text{Э}}(t)\varphi(t)[D(t)]^{-1},\ D(t) = \varphi^T(t)P_{\text{Э}}(t)\varphi(t) + R\,, \\ P_{\text{Э}}(t) = P(t-1) + Q\,,\ P(t) = [I - K(t)\varphi^T(t)]P_{\text{Э}}(t)\,. \end{gathered} \tag{5}$$

Very often in the real operation of the facility of interference may vary. We will look at estimating the covariance matrix of the measurement noise. Based on [5,6] evaluation matrix additive noise intensity can be calculated on the basis of the following relationship:

$$\left\{\sum_{j=1}^{t} [G(j,R)]^{-1} - \sum_{j=1}^{t} [G(j,R)]^{-1} [y(j) - \varphi^T\theta(j-1)][y(j) - \varphi^T\theta(j-1)]^T [G(j,R)]^{-1}\right\}_{R=R_0} = 0, \tag{6}$$

where $G(j,R) = R + \varphi^T P_{\text{э}}(j,R)\varphi$.

If the sample size increases, for a sample of y^{t+1} can write an equation of the form:

$$\begin{gathered} \Big\{R_0(t+1) + \varphi^T P_{\text{э}}(R_0(t+1))\varphi = \frac{1}{t+1}\sum_{j=1}^{t+1} [y(j) - \varphi^T\theta(j-1, R_0(t+1))] \times \\ \times [y(j) - \varphi^T\theta(j-1,\ R_0(t+1))]^T\,. \end{gathered} \tag{7}$$

In (7) in the evaluation of R_0 using the time index $t+1$, showing that the score is determined by the results of processing the sample y^{t+1}. Then estimate R_0 to be understood as $R_0(t)$, i.e. resulting from the treatment of the sample y^t.

Given the conditions on the basis of steady-state $P_{\text{э}}(j,R)$ (6) and (7) we can write sat the following expression:

$$R_0(t+1) = R_0(t) + \frac{1}{t+1}\Big[[y(t+1) - \varphi^T\theta(t,R_0(t))][y(t+1) - \varphi^T\theta(t,\ R_0(t))]^T - \varphi^T\varphi - R_0(t)\Big]. \tag{8}$$

(8) is a recurrent algorithm of forming estimates of the intensity of the additive noise.

In solving the equations (5) and (6) at each step necessary to calculate the inverse matrix. When the matrix is ill-conditioned, calculate its inverse matrix is not possible and, therefore, not possible to construct the optimal estimate. For this reason it is advisable to (5) in place of $D(t)$ to use

$$D_\alpha(t) = \varphi^T(t)P_{\text{Э}}(t)\varphi(t) + R + \alpha I\,.$$

Based on the methods of the theory of optimal filtering and methods of solving ill-posed problems [5-8], it can be shown that the appropriate choice of parameters α unbiased estimate $\hat{\theta}_\alpha(t)$ at $D(t) = D_\alpha(t)$ will be close to optimal estimate $\hat{\theta}^o(t)$. Here it is advisable to assign a priori value of $\alpha_i = \alpha$, providing the order of decrease of $\alpha(w_0, v_0)$, sufficient for the construction of a regularizing algorithm, in particular, we can set $\alpha = w_0^2 + v_0^2$, where $\|w_t\|^2 \le w_0^2$, $\|v_t\|^2 \le v_0^2$, w_0^2 and v_0^2 - given numbers. In this case, the estimate of $\hat{\theta}(t)$ will not be worse than the most unfavorable noise conditions. Similarly, when a re-shenii (6) should be used instead of $G(j,R)$ expression of the form:

$$G_\alpha(j,R) = R + \varphi^T P_{\text{э}}(j,R)\varphi + \alpha I\,.$$

Thus, the above expressions can synthesize optimal or sub-optimal in the mean filtering algorithms that have the properties of convergence of estimates of stability with respect to rounding errors and approximation schemes.

The algorithms received above appear also very effective at the solution of problems of control with predicting model in the presence of delay on control. It is caused by that use in practice of construction and operation of control systems serves relative simplicity of the base scheme of formation of the feedback, being combined with high adaptive properties. The last circumstance allows to operate multidimensional and multicoherent objects with difficult structure, to optimize processes in real time within restrictions on operating and operated variables, to consider uncertainty in a task of objects and indignations.

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STABLE ALGORITHMS FOR IDENTIFICATION OF CONTROL TECHNOLOGICAL OBJECTS

J.U.Sevinov, A.G. Abdurakhmanov, D.T.Kodirov, R.Turgunov

Tashkent State Technical University, Department of Electronic and Automatic
2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan
Phone: (+99893) 398-56-68

Key words: *dynamic system, estimation, identification, regularization.*

Production processes are now fairly well established, and the usual management by exception is ineffective because of low performance. Increase the effectiveness of management in such industrial applications, you can use the control on the perturbation. However, such management requires accurate knowledge of the mathematical model of the object. Even minor errors in the model can lead to large errors in the prediction and management. Management in such a setting is a difficult task because it requires simultaneously with development of performance management study to identify the object. The task can be greatly simplified by separating the processes of identification and production control. This may lead to some losses, but the algorithm of the system dramatically simpler. This kind of management system called adaptive systems with ID. Management system with the ID in the closed loop enable speedily compensate the current changes occurring characteristics of the object.

Adaptive control systems with an identifier in the feedback received at the present time, a significant development. Various algorithms for the identification and synthesis of control actions in these systems [1]. In this paper we present algorithms for regular identification of linear stochastic control objects on the basis of the methods of dynamic filtering.

Consider the object of control in linear difference equation:

$$x_{t+1} = a_0 + \sum_{i=1}^{n} a_i x_{t+1-i} + \sum_{j=1}^{m} a_{n+j} u_{t+1-j} + \xi_t \,, \; t \geq 0 \,, \tag{1}$$

where x - coordinate of the object's state, u - control, ξ_t - disturbance, $a_i (i = 0,..., n + m)$ - constant unknown parameters of the object. We assume that $|\xi_t| \leq \xi_1;\; u_1 \leq u_t \leq u_2$.

For identification of the object we write (1) in the following matrix form:

$$Y_t = Z_{t-1} a_t \,,$$

$$Y_t = \left(y_t \mid \cdots \mid y_{t-p+1} \right)^T,$$

$$Z_{t-1} = \left(z_{t-1} \mid \cdots \mid z_{t-p} \right)^T,$$

where

$$y_k = z_{k-1} a_t, \quad k = t,\, t-1, ...,\, t-p+1,$$

$$z_k = \left(x_k, ..., x_{k+1-n}, x_{k-n}, u_k, ..., u_{k+1-m} \right),$$

$$a_t^T = (a_0, a_1, ..., a_{n+m}) \,,$$

$p \geq 1$ - which defines the depth of the memory in the algorithm of identification.

Parameter vector a_t will be defined as

$$a_t = a_{t-1} + \Delta a_t \,,$$

where a_{t-1} - the value of the required vector a_t on the previous step, Δa_t - vector for this parameter a_t.

Increment parameter

$$\Delta a_t = a_t - a_{t-1}$$

will find according to criteria

$$\begin{aligned} \left\| e_t^0 - Z_{t-1} \Delta a_t \right\|^2 &= \min, \\ \left\| \Delta a_t \right\|^2 &= \min, \end{aligned} \;,$$

where

$$e_t^0 = x_t - Z_{t-1} a_{t-1},$$

$$x_t = \left(x_t \mid \cdots \mid x_{t-p+1} \right)^T.$$

To calculate the vector for this parameter Δa_t write a dynamic process model, appropriate to the task

$$\Delta a_{t+1} = \Delta a_t \,,$$

$$e_t^0 = Z_{t-1} \Delta a_t + v_t \,,$$

where interference measurement v_t has zero mean and non-negative definite covariance matrix R_t.

Vector for this parameter can retrieve Δa_t as the solution of the system of linear algebraic equations:

$$p_t \, \Delta a_t = b_t \,,$$

where

$$p_t \stackrel{\Delta}{=} Z_t^T V_t^{-1} Z_t \,,$$

$$b_t \stackrel{\Delta}{=} Z_t^T V_t^{-1} e_t^0 \,,$$

$$V_t = E\{v_t, v_t^T\}.$$

Suppose that Z_t is a matrix of full rank. The condition

$$M_0 = E\{(\Delta a_0 - \overline{\Delta a_0})(\Delta a_0 - \overline{\Delta a_0})^T\} > 0,$$

$$R_{tt} = E\{v_t v_t^T\} > 0 \ \forall t,$$

not guarantee nondegeneracy V_t, and the more and the nondegeneracy p_t. If

$$K_{\Delta av}(t) = E\{(\Delta a_0 - \overline{\Delta a_0})\} = 0,$$

$$R_{tj} = E\{v_t, v_t^T\} = 0 \ \forall t, j, t \neq j,$$

i.e. if there is no correlation, then this condition is sufficient for nondegeneracy V_t. Thus, the condition correlated input noise increases the practical significance of the problem. Therefore, when correlated noise is particularly important to develop stable algorithms for identification of dynamic management objects.

Applying to the problem in dynamic filtering methods [2,3] can arrive at the following system of recurrent equations:

$$\Delta a_{t+1}^{\alpha,\gamma} = \overline{\Delta a}_{t+1}^{\alpha,\gamma} + K_{t+1}^{\alpha,\gamma}\left[y_{t+1}^0 - Z_t\,\overline{\Delta a}_{t+1}^{\alpha,\gamma} + \Delta_{t+1}^{\alpha,\gamma} e_t^0\right],$$

$$\overline{\Delta a}_{t+1}^{\alpha,\gamma} = g_\alpha(p_{t+1})\, b_{t+1},$$

$$K_{t+1}^{\alpha,\gamma} = \left(P_{t+1}^{\alpha,\gamma} Z_t^T - N_{t+1}^{\alpha,\gamma}\right)\left(\Sigma_{t+1}^{\alpha,\gamma}\right)^{-1},$$

$$P_{t+1}^{\alpha,\gamma} = g_\alpha(p_{t+1}),$$

$$N_{t+1}^{\alpha,\gamma} = P_{t+1}^{\alpha,\gamma} Z_t^T V_{t+1}^{-1} K_{t+1},$$

$$g_\alpha(p_{t+1}) = P_{t+1}^{\alpha,\gamma} - K_{t+1}^{\alpha,\gamma}\left[P_{t+1}^{\alpha,\gamma} Z_t^T - N_{t+1}^{\alpha,\gamma}\right]^T,$$

$$\Sigma_{t+1}^{\alpha,\gamma} = \tilde{\Sigma}_{t+1}^{\alpha,\gamma} + \Delta\Sigma_{t+1}^{\alpha,\gamma},$$

$$\tilde{\Sigma}_{t+1}^{\alpha,\gamma} = Z_t P_{t+1}^{\alpha,\gamma} Z_t^T + R_{t+1} - Z_t N_{t+1}^{\alpha,\gamma} - \left(Z_t N_{t+1}^{\alpha,\gamma}\right)^T,$$

$$\Delta\Sigma_{t+1}^{\alpha,\gamma} = \Delta_{t+1}^{\alpha,\gamma} K_t = K_t^T\left(V_t^{-1} Z_t P_{t+1}^{\alpha,\gamma} Z_t^T V_t^{-1} - V_t^{-1}\right)K_t,$$

where - $g_\alpha(p_t) = (p_t^T p_t + \alpha I)^{-1}$ - generating system functions for the regularization method, $\alpha>0$ - the regularization parameter, $\gamma=[h,\delta]$ - the precision vector, $\|p_t - \bar{p}_t\| \le h$, $\|b_t - \bar{b}_t\| \le \delta$, $\bar{p}_t$ and $\bar{b}_t$ - the exact values of matrix p_t and vector b_t.

The choice of the regularization parameter α is advisable to carry out on the basis of model examples [4].

Reduced regular identification algorithms are well sold in the equation and the computer can be used in problems of synthesis of control actions in terms of correlated noise.

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MICROPROCESSOR SYSTEM OF AUTOMATIC CONTROL OF TECHNOLOGICAL PROCESS LINTERING OF COTTON SEEDS

N.Z.Kamalov, Sh.Z.Kamalov, D.R.Karimov

Open joint-stock company "Pakhtasanoat ilmiy markazi"
Street Shota Rustaveli, 8
100070, Tashkent, Uzbekistan
Phone: 256 04 21, 256 14 46

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Now achievement of high rates of an intensification of technological processes of primary processing of a seed cotton, improvement of quality of production, economy of material, power and labour resources, increasing of work reliability of the technological equipment, protection of environment and improvement of important technical and economic indicators of product process are impossible without creation and perfection of control systems. Therefore automation of manufacture of primary processing of seed cotton on the basis of using of modern means computing including the microprocessor systems is the most perspective direction of scientific and technical progress [1].

The modern technological processes which make a basis of the industrial manufactures of seed cotton primary processing are various in cotton cleaning industry it is seed cotton preparation and storage, drying cotton seed and clearing, ginning and fiber cleaning, lintering and lint cleaner, pressing of cotton production, etc. Each of these technological processes is carried out on its specific unit (group of units), regulated manually either automatically by serial or special control mean [2].

Technological process of lintering cotton seeds is one of the basic processes of primary processing of the seed cotton, defining its productivity, and quality of cotton lint, sowing and technical seeds. It is characterised by an insufficient level of scrutiny from the point of view of modelling and management problems. It explains semi empirical search of lintering modes that is carried out.

The experiments and experimental works carried out at the cotton cleaning factories show that the basic indicators of work lintering the unit: the weight of the seed platen, productivity, a contamination of lint, damaging of cotton seeds, cotton seeds after lintering depends on a great number of parameters which characterise the quality and economic efficiency of lintering process. These parameters are in close interrelation with each other, frequently have casual character that complicates application of the determined methods of research to lintering process.

Besides, revolting influence on process lintering or object noise has a great influence.

Revolting influence or object noise arises because of uncontrollable deterioration of sawing cylinder, instability weight of the seed platen, pressure of a surface to sawing teeth fluctuations of cotton seeds submission.

All it leads that object parameters change arbitrarily in time. There is an uncontrollable drift of object characteristics.

Quality of received cotton lint and cotton seeds is formed in lintering process. At the result of non-uniformity of cotton seeds submission in the working chamber of linter and the most technological process, considerable fluctuations of weight and density of the seed platen are often observed. Density reduction reduces of productivity and in a limiting case there is a disintegration of the seed platen, and lintering process stops. Increase of density of the seed platen allows raising productivity of lintering machine, but on the other hand worsens quality indicators lint and seeds, promotes damage of seeds, occurrence of a thin skin with a fibre, increases residual lowering cotton seeds. In a limiting case there is a reconsolidation of the seed platen, failure lintering machine.

Thus, the density of the seed platen is one of process key parameters of lintering and influences on qualitative and quantity indicators of processing of cotton seeds.

Technological process is combined enough also its characteristics, especially characteristics of elements, change in time and in advance by unforeseen image and so consequently stochastic statement of management is an actual problem. Solutions of this problem is possible by using of the device of the statistical theory of optimum processes, probability theory, the system approach, methods of planning of experiment and other methods with use of microprocessor technique.

It is necessary to notice that existing control systems of lintering process of cotton seeds do not meet modern requirements both technical, and with aesthetic the points of view.

The systems of automatic control constructed until recently, on the basis of relay-contact schemes and elements of discrete electronics (diodes, transistors etc.), do not give now possibility to solve a problem of automation of technological processes of processing of a cotton seed in communication by bulkiness of means and not qualitative static and dynamic characteristics [3].

Application of mechanical variators or the direct current engine on drive feeding platens differs extreme unreliability, therefore are everywhere deduced from work. Regulation of speed of rotation of a pulse variator is conducted in a manual mode.

The electric motor sawing cylinder lintering machine is started up directly, thus starting currents reach not less than 6-7 multiple rating values. It negatively affects quality of operation of the electric motor. Besides, direct start-up conducts to the raised deterioration of the mechanical equipment. The quantity of consecutive start-up is limited, as there is an overheat of the electric motor and protection operation. On occasion because of frequent start-up electric motors, especially big capacity, fail. There is no system of intensive adjustable braking of the electric motor sawing cylinder of lintering machine at emergency situations that leads to an industrial traumatism.

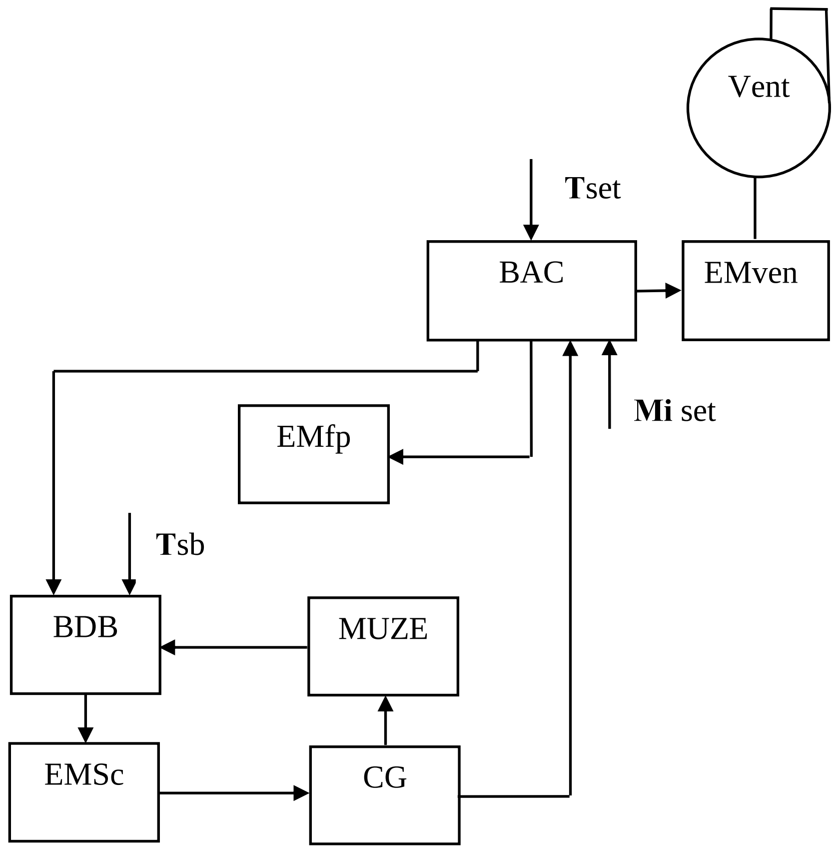
The element base of existing systems is executed on relay-contactor the equipment with separate application of electronic devices that leads to tightening to time of reaction for a technological situation. It does impossible automation process.

Equipment maintained sawing linter microprocessor automation systems of regulation of a food by cotton seeds depending on electric motor loading sawing cylinder, automatic inclusion and switching-off of electric motors линтера in demanded sequence depending on presence or absence of giving of cotton seeds in linter, automatic protection of the electric motor sawing cylinder, the fast stop sawing cylinder with intensive braking allows to keep natural properties cotton lint, to raise quality indicators of cotton production and productivity sawing linter depending on a condition of processed raw materials [4].

Starting with above told said, the microprocessor system of automatic control of process lintering cotton seeds is offered. The microprocessor system offered in work consists from [Fig]:

- The adjustable electric drive of feeding platens executed on the basis of the asynchronous electric motor of an alternating current with S.C. rotor of common industrial execution and the device of transformation of frequency;
- Devices of smooth start-up with adjustable intensive braking for management of the electric motor sawing cylinder of linter;
- Devices of measurement of power consumption (the electric power expense) the electric motor sawing cylinder of linter;
- The block of microprocessor processing of the information and development of signals of management.

As the microprocessor device use of industrial controller "SPEKON", for adjustable drives of feeding platens converters of frequency E2-8300 VESPER, devices of smooth start-up АТИ-СТ-380/75-М112 with necessary completion of the software is offered.



Vent – ventilator; Tset - Time of a delay of switching-off of the electric motor; BAC - The automatic control and switching-off block; EMven –motor of ventilator; Mi зад- уставки по мощности; EMfp - The electric motor of feeding platens; Tsb - Set time of braking; BDB - The block of dynamic braking; MUZE - The device of protection of electric motors; EMSc - The electric motor sawing the cylinder; CG - The capacity gauge.

Fig. ***The Block diagrams of system of complex automation of technological process lintering a seed cotton.***

That fact is put in a basis of work of microprocessor system that the quantity of the cotton seeds, submitted in linter at optimum work corresponds to certain power consumption (the electric power expense) engine sawing cylinder of linter. At excess of this value (at the electric power over-expenditure) it is necessary to reduce giving of cotton seeds in linter through the regulation block and on the contrary. The information on conditions of loading of the engine (the electric power expense) sawing cylinder of linter turns out from capacity gauges. If necessary the automatic system can be translated in a manual mode.

The operator has the information on following indicators:

- Power consumption (the electric power expense) engine sawing cylinder of linter;
- Speeds of rotation of feeding platens linter(the expense of cotton seeds);
- Emergency switching-off of the engine sawing cylinder of linter;
- Intensive braking of the engine sawing cylinder of linter, etc.

In the given project application of the frequency-regulated electric drive with the asynchronous electric motor with S.C is essentially new. A rotor for feeding platens, the device of smooth start-up for a drive sawing cylinder, direct measurement of power consumption on the main drive, use of last as feedback for a drive of feeding platens.

It is applied original gauges of parameters of technological process the control panel is carried out with application. All data about a condition of technological process is transferred in the higher on hierarchy automatic control system.

Sawing linter, equipped with the above-named microprocessor system and visualisation system, it will be quite competitive in a foreign market in what, without conceding foreign analogues.

As a result of introduction sawing linter, equipped with microprocessor system of automatic control it will be reached:

- Uniform loading lintering cotton seeds;
- Exception of formation of faces;
- Decrease in idle times;
- Exception of work of the equipment at incomplete loading;
- Productivity increase on eating lint;
- Economy of power resources;
- Maintenance of conditions of safety precautions and labour safety;
- Increase of reliability of the equipment and durability of its work.

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THE DEVELOPMENT OF PROGRAM GUIDELINES FOR INSTRUMENTAL EVALUATION OF GRADE OF UZBEK COTTON FIBER ON THE HVI MEASUREMENT SYSTEMS

R.A. Gulyaev, A.A. Akhmedov, E.T. Maksudov, N.A. Mullabaeva

8, Sh. Rustaveli street, Tashkent, 100070, Uzbekistan
Phone/fax: 256-04-21, e-mail: rgsifat@gmail.com
JSC «Pakhtasanoat Ilmiy Markazi»,
109, K.Shark blind alley, M.Uygur street, 100020, Uzbekistan
Phone/fax: 120-59-24, e-mail: science@sifat.uz
Uzbek Center «Sifat» with the Cabinet of Ministers of Republic of Uzbekistan

***Keywords**: cotton, fiber, color chart, HVI, grade, class, standard, measurement, colorimeter, instrument, system, classification*

1. Introduction

The grade of cotton fiber is the key indicator of quality in accordance with national classification. Grade is characterized by color parameters that are currently defined by trained specialists - classers. The national color chart for uzbek cotton are being developed to depart from the subjective human evaluation of fiber quality to instrumental testing methods. The introduction of the domestic color chart in HVI 900 SA will create conditions for the instrumental definition of cotton fiber grade in accordance with the national classification system.

2. Methodology

Color of cotton fiber in all classification systems is an important indicator of quality. In the classification system of the Republic of Uzbekistan in accordance with the color of cotton fiber its grade is determined. According to the national standard of the Republic of Uzbekistan O'z DSt 604:2001 «Cotton Fiber. Technical specifications "[1], depending on appearance, colour and presence of spots cotton fibre of each type is sub-divided into five grades: Birinchi (I), Ikkinchi (II). Uchinchi (III); Turtinchi (IV) and Beshinchi (V) in compliance with the requirements of Table 1 and standards of cotton appearance (boxes), approved by the established procedure.

All varieties are represented by material standards contained in the boxes. Each box describes one variety of cotton and contains cells that represent changes content of defects and trash in the fiber. In the Birinchi and Ikkinchi grade boxes for five cells, representing the classes - Oliy (Highest) Yakhshi (Good), Urta (Medium), Oddiy (Normal) and Iflos (Trashy). The Uchinchi and

Turtinchi grades have for 4 cells, representing the classes - Yakhshi (Good), Urta (Medium), Oddiy (Normal) and Iflos (Trashy). In the Beshinchi grade, only three cells representing the classes - Urta (Medium), Oddiy (Normal) and Iflos (Trashy).

The traditional classification of cotton fiber by grade and class is carried out by specially trained and taught classifiers by comparing test samples with samples of appearance (material standards) or descriptive standard.

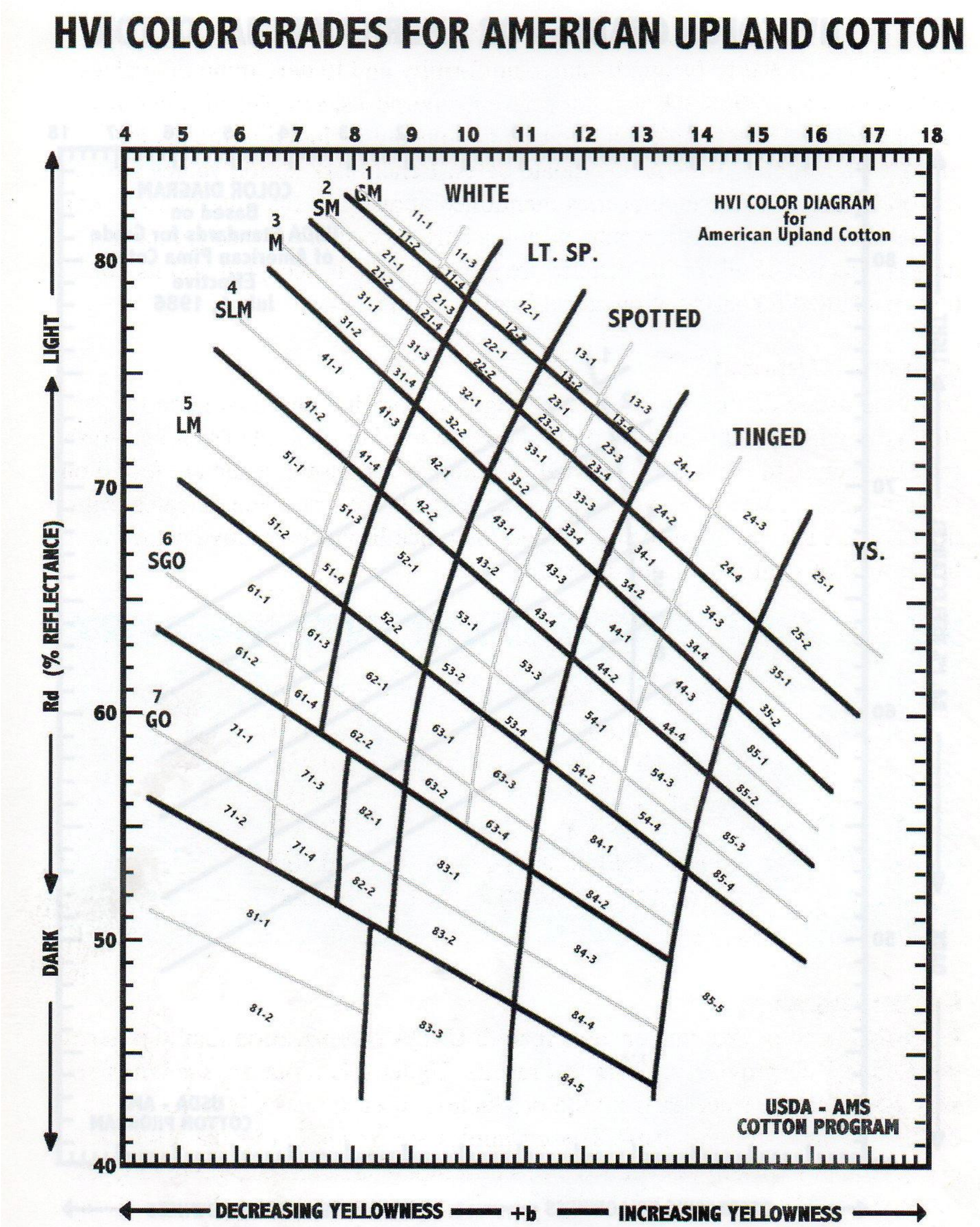
The necessity of tools for estimating the grade is recognized worldwide and is caused by a lack of quantitative data on the color standards used, variability of their color and, mostly, the uncertainty and subjectivity of the visual comparison, implemented by classifiers.

The transition from sensory to instrumental grade assessment demands creation of high-performance and high-precision instruments for measuring the color of the fiber (colorimeters), and systems to ensure consistency of the instrumental and sensory evaluation. The emergence and development of systems of HVI allowed to introduce color chart into their software, interpreting color indicators in performance grade fiber, provided the basis for the introduction of instrumental evaluation of cotton fiber quality.

Table 1

Industrial Grade	Fibre colour and appearance by fibre types	
	la, Ib, 1, 2, 3	4 – 7
I	White, or white with natural creamy shade or creamy according to breeding variety or region of cotton cultivation. Lustrous, silky and dense by appearance.	White, or white with natural creamy shade.
II	From mat-white to creamy with shades and small yellow spots. Lustre, silkiness and density are lower than in case of the sort I.	From mat-white to creamy with light yellow spots.
III	From mat-white to creamy or yellow of uneven coloration with yellow spots. Greyish shade, almost lustreless.	From dull-white to creamy with yellowish spots with mat-greyish shade.
IV	Yellow or light yellow of uneven colouration with grey shade and brown spots. Lustre less.	From dull white and cream-coloured to yellow-creamy with grey shade and brown spots.
V	From brown to yellow with spots. Grey.	Dull-white or dull-creamy to bright yellow with brown sports. Grey.

Color measurements of cotton made in a colorimeter of HVI system, which is part of the color-trash module. During testing the sample of cotton fiber is placed on the window of the module and to create optimum measurement is pressed against the surface by special platform. In the pressed state, the sample illuminated by incandescent lamps, angled 450 to the sample. Light reflected from the sample, before entering in the light guide, mixed on diffuse screen. Light guide - color tube is a well-polished rectangular solid of pure plastic. Multiple reflections within the tube mixes light and divide it equally among the electric vacuum photocells in a thermostatically controlled aluminum block. Filters, mounted under light guide have a certain range of bandwidth. First filter yellow-green - matches the Y and second blue - coordinate Z.



Pic.1.

These values are then recalculated figures Nickerson-Hunter Rd and + b are given by:

$$Rd = Y \qquad (1)$$

$$+b = 70 \cdot fy \cdot (Y - 0.847 \cdot Z) \qquad (2)$$

where $fy = 0{,}51 \cdot \left[\frac{21+20\cdot Y}{1+20\cdot Y}\right]$; Rd - reflectance,%; + b - the degree of yellowness,%.

The principle of the color chart is as follows. Within particular group (selected varieties) cotton fiber with a large measure of reflectance Rd and smaller parameter of yellowness + b is usually of higher quality. Conversely, a smaller figure Rd and greater figure + b is for low quality cotton fiber. Combination of indicators Rd and + b in the corresponding coordinate allows you to create zones and assign them specific indicators of fiber grade. On this principle in accordance with national standards developed the color chart.

In the U.S., since 1998, the official classification of cotton fiber grade has been carried out by the instrumental systems of HVI, the software that is embedded color chart for Upland varieties of medium (Pic.1) and long-fiber - Pima. Nowadays, the color chart, based on national standards, in addition to the U.S. is in China, India, Pakistan and Australia.

3. Results

National classification of cotton fiber in accordance with O'z DSt 604:2001 is differ from cotton fiber classification, existing abroad. Within a variety Uzbek cotton fiber has identical color characteristics with gradually increasing from the highest to the lowest class of contamination. American, or as it's adopted universal classification of cotton fiber provides a different approach to estimate the fiber. Inside one grade cotton fiber depending on the class has different characteristics as color and dockage. In this regard, just borrow foreign color chart is not possible.

The Republic of Uzbekistan develops the national color chart according to the classification of O'z DSt 604:2001. However, the domestic color chart will include exclusively grade estimation. Fiber's classing assessment will be made by the program guidelines on the basis of contamination, issued HVI. Together, this will allow for an instrumental assessment of cotton fiber in accordance with the national classification.

Creation of a national color chart for cotton fiber of medium domestic cotton varieties is getting step by step.

In the first phase will be carried out studies of the theoretical foundations of the science of color, characteristics of human vision, technology and operating principles of modern measuring systems, including direct part of HVI - colorimeter (a device for measuring the color.) The history and the principles of creation of the color charts in the U.S., China, India, and Pakistan planned to study. Will be performed the collection and statistical analysis of data 2000-2011 crop years from all operating HVI systems in the Republic, determination the areas of grades and classes.

In the second stage will be performed the collection and statistical analysis of the data yields of 2011-2012 from all operating HVI systems in the Republic. On their basis the grade zones will be adjusted and modified. On the basis of the quality produced in the calorimeter system HVI 900 SA measurements of national cotton standards of appearance, will be defined the main points of future areas inherent to grades and classes of Uzbek cotton.

In the third phase will be carried out to develop a layout of the national color diagram for cotton fiber, producing software and the introduction of the color chart in HVI. There will also be carried out a series of experiments and comparative trials to evaluate the grade of cotton fiber with the help of HVI and by classer method.

4. Conclusion

Currently, specialists of the Scientific Center «Pakhtasanoat Ilmiy Markazi» and Uzbek Center "Sifat" work together on creating a color chart for the domestic cotton in Uzbekistan. By now, the data of processing more than 25 million samples of cotton fiber is defined. Analysis of data on indicators of bale-grade class received organoleptically in accordance with the classification of O'z DSt 604:2001, data and color characteristics HVI - Rd and + b, allows to have a possibility of a variety of instrumental assessment system based on domestic color chart.

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GEOMETRICAL REASONING AND ITS APPLICATIONS IN DECISION MAKING

R.A. Aliev*, L.A. Gardashova, O.H. Huseynov**, K.R. Aliyeva****

**Joint MBA Program (USA, Azerbaijan) 20 Azadlig Ave., AZ1010 Baku, Azerbaijan,*
Tel: +99412 493 45 38, Fax: +99412 598 45 09, E-mail: raliev@asoa.edu.az
***Azerbaijan Sate Oil Academy, Azadlyg ave., 20, Baku, Azerbaijan*
e-mail: latsham@yandex.ru, oleg_huseynov@yahoo.com, kamala64@rambler.ru

Abstract: *Real-world decision relevant information is perception-based and, as a result, is imperfect. Sometimes it becomes inappropriate to precisiate such information even by using membership functions and a graphical representation of information is more convenient. In the present paper we suggest an approach for decision making with graphically described information. The suggested approach is based on the ideas of the extended fuzzy logic of Prof. L.A. Zadeh. We suggest extended fuzzy logic and fuzzy geometry-based approach to a decision making problem.*

Keywords: *decision making, extended fuzzy logic, fuzzy incidence geometry, if-then rules, Pavelka logic.*

1. Introduction

All works on decision analysis assume availability of numeric or measurement-based information. In other words, the available imperfect information is always considered to admit required precisiation. The fundamental question remains: what if the information is not only imperfect and perception-based, but also unprecisiated?

As stated in [1] while fuzzy logic delivers an important capability to reason precisely in presence of imperfect information, the extended (or unprecisiated) fuzzy logic delivers a unique ability to reason imprecisely with imperfect information. The capability to reason imprecisely is used by human being when precise reasoning is infeasible, excessively costly or not required at all. A typical real-life case example is a case when the only available information is perception-based and no trustworthy precisiation or fuzzy numeric models (e.g. articulated through membership functions) are possible to obtain. As a model of unprecisiated fuzzy logic we consider fuzzy geometry [1] .

The concept of fuzzy geometry is not new. Many authors suggest various versions of fuzzy geometry. Some of well-known ones are the Poston's fuzzy geometry [2], coarse geometry [3], fuzzy geometry of Rosenfeld [4], fuzzy geometry of Buckley and Eslami [5], fuzzy geometry of Mayburov [6], fuzzy geometry of Tzafestas [7], and fuzzy incidence geometry of Wilke [8]. Along this line of thought, many works are devoted to model spatial objects with fuzzy boundaries [9, 10,11].

The study reported in [9] proposes a general framework to represent ill-defined information regarding boundaries of geographical regions by using the concept of relatedness measures for fuzzy sets. Regions are represented as fuzzy sets in a two–dimensional Euclidean space, and the notions of nearness and relative orientation are expressed as fuzzy relations. To support fuzzy spatial reasoning, the authors derive transitivity rules and provide efficient techniques to deal with the complex interactions between nearness and cardinal directions.

The work presented in [11] introduces a geometric model for uncertain lines that is capable of describing all the sources of uncertainty in spatial objects of linear type. Uncertain lines are defined as lines that incorporate uncertainty description both in the boundary and interior and can model all the uncertainty by which spatial data are commonly affected and allow computations in presence of uncertainty without oversimplification of the reality.

Qualitative techniques for spatial reasoning are adopted in [10]. The author formulates a computational model for defining spatial constraints on geographic regions, given a set of imperfect quantitative and qualitative constraints.

What is common in all currently known fuzzy geometries is that the underlying logic is the fuzzy logic. Fuzzy logic implies existence of valid numerical information (qualitative or quantitative) regarding the geometric objects under consideration. In situations, when source information is very unreliable to benefit from application of computationally-intensive mathematical computations of traditional fuzzy logic, some new method is needed. The new fuzzy geometry, the concept of which is proposed by Zadeh and referred to as F-Geometry, could be regarded as a highly suitable vehicle to model unprecisiated or extended fuzzy logic [1].

Of the geometries mentioned above, the fuzzy incidence geometry of Wilke [8] can form a starting point for developing the new F-Geometry. Thus fuzzy incidence geometry extends the Euclidean geometry by providing concepts of extended points and lines as subsets of coordinate space, providing fuzzy version of incidence axioms, and reasoning mechanism by taking into account the positional tolerance and truth degree of relations among primitives. To allow for partially true conclusions from partially true conditions, the graduated reasoning with Rational Pavelka Logic (RPL) is used [11,8].

Application of fuzzy geometry to solving problems of decision making with unprecisiated information is considered in [12,13]. In these papers, decision making is based on treatment If-Then rules in which antecedents and consequents are represented by fuzzy geometrical objects. The considered If-Then rules describe dependence between unprecisiated decision-relevant information and overall evaluation of alternatives. The authors provide application of the suggested approaches to solving benchmark and real-life decision making problems.

In the suggested paper we propose a new approach to decision making with unprecisiated information. The approach is based on a new fuzzy geometry which represents a world of fuzzy geometrical objects – fuzzy points and lines. A fuzzy geometrical object models an unprecisiated information on a value of a variable by truth degrees associated to numerical values of variables. The truth degrees are represented as estimations of confidence of a decision maker (DM) (or an expert).

2. Preliminaries

2.1. Fuzzy primitives

Definition 1. F-mark[12]. An ***F-mark*** A is a bounded subset of $A \subset R^2$, representing a graphical hand-mark drawn by human being to indicate visually a value of a perception-based information granule.

Definition 2. Convex hull. The convex hull of a set A is the smallest convex set containing A and is denoted by $ch(A)$.

Any F-mark, which represents a convex subset A of R^2, can be approximately defined by its center $c=(x_c, y_c)$ (which is a Euclidean point) and two diameters ($\phi_{\min}, \phi_{\max}$)[8]:

$$A = P(c, \phi_{\min}, \phi_{\max}).$$

The center c can be computed as a center of gravity of convex hull: $c=C(ch(A))$ while the two diameters are[8]:

$$\phi_{\min} = \min_t \left| ch(A) \cap \; c + t \cdot R_\alpha (0,1)^T \; \right|$$

$$\phi_{\max} = \max_t \left| ch(A) \cap \; c + t \cdot R_\alpha (0,1)^T \; \right|$$

where $t \in R$ and R_α is the rotation matrix describing rotation by angle α.

The illustration of the concept is presented in Fig. 1.

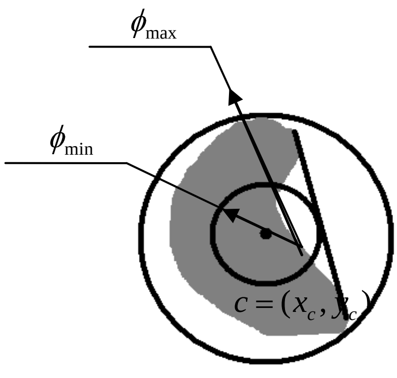


Fig. 1. ***An F-mark with two diameters and its convex hull.***

Definition 3. F-point[12]. The degree to which an F-mark $A = P(c, \phi_{\min}, \phi_{\max})$ is an F-point is determined as follows[8]:

$$p(A) = \phi_{\min} / \phi_{\max}$$

Definition 4. F-line[12]. The degree to which an F-mark A is an F-line is determined as:

$$l(A)=1-p(A).$$

Definition 5. Truth degree. Truth degree of a statement is a measure of truthness of this statement. It may be measured by a numerical value, an interval value, a fuzzy number, or a linguistic label.

Definition 6. Truth degree of an incidence of two f-marks [8]. The truth degree of predicate for the incidence of F-marks A and B is determined as:

$$inc(A,B)=\max\left(\frac{|ch(A)\cap ch(B)|}{|ch(A)|},\frac{|ch(A)\cap ch(B)|}{|ch(B)|}\right),$$

here $|ch(A)|$ is the area covered by $ch(A)$.

Definition 7. Truth degree of an equality of two f-marks [8]. The truth degree of a predicate defining the equality of F-marks A and B, is determined as follows:

$$eq(A,B)=\min\left(\frac{|ch(A)\cap ch(B)|}{|ch(A)|},\frac{|ch(A)\cap ch(B)|}{|ch(B)|}\right)$$

Definition 8. Measure of distinctness of two f-marks[8]. The measure of distinctness of f-marks A and B is determined as:

$$dp(A,B)=\max\left(0,1-\frac{\max\ \phi_{\max}(A),\phi_{\max}(B)}{\phi_{\max}(ch(A\cup B))}\right)$$

Two f-points A and B can generate an f-line L as follows (Fig. 2):

$$L=ch(A\cup B)$$

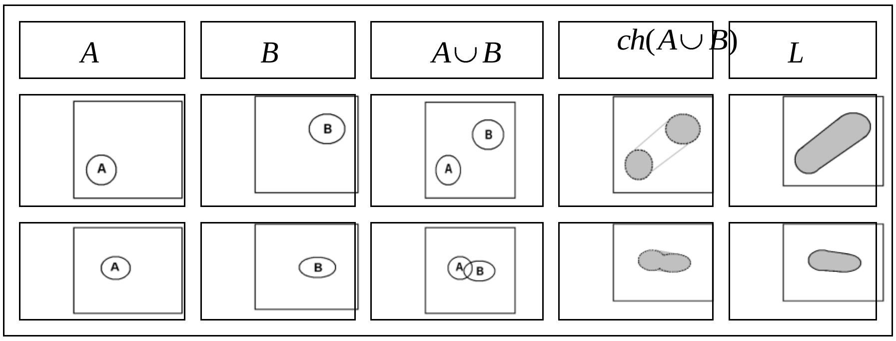


*Fig. 2.**Generation of an f-line from two f-points.***

In the present paper for the purpose of reasoning with the fuzzy geometrical primitives we use the operators of Lukasiewicz logic which are given below.

T-norm:

$$\mu_S(x,y)=\max(0;x+y-1) \tag{1}$$

T-conorm:

$$\mu_R(x,y)=\min(1;x+y) \tag{2}$$

Implication:

$$\mu_S(x,y)=\min(1;1-x+y) \tag{3}$$

2.2 Axioms of the Fuzzy Incidence Geometry

The following axioms formalize the behavior of points and lines in incident geometry[8]:

(A1) For every two distinct points p and q, at least one line l exists that is incident with p and q.

(A2) Such a line is unique.

(A3) Every line is incident with at least two points.

(A4) At least three points exist that are not incident with the same line.

For fuzzy version of incident geometry each of the above axioms may not evaluate to absolute truth for all possible inputs. A fuzzy version of the incident geometry, which is suitable to work with f-points and f-lines can be axiomatized as follows [8]:

$$
\begin{array}{ll}
\text{(A1')} & \left(dp(x,y) \rightarrow \sup_{z} \left[l(z) \otimes inc(x,z) \otimes inc(y,z) \right], r_1 \right) \\
\text{(A2')} & \left(dp(x,y) \rightarrow \left[l(z) \rightarrow \left[inc(x,z) \rightarrow \left[inc(y,z) \rightarrow l(z') \rightarrow \left[inc(x,z') \rightarrow \left[inc(y,z') \rightarrow eq(z,z') \right]\right]\right]\right]\right], r_3 \right) \\
\text{(A3')} & \left(l(z) \rightarrow \sup_{x,y} \left[p(x) \otimes p(y) \otimes \neg eq(x,y) \otimes inc(x,z) \otimes inc(y,z) \right], r_3 \right) \\
\text{(A4')} & \left(\sup_{u,v,w,z} \left[p(u) \otimes p(v) \otimes p(w) \otimes l(z) \rightarrow \neg \left(inc(u,z) \otimes inc(v,z) \otimes inc(w,z) \right)\right], r_4 \right),
\end{array}
\qquad (4)
$$

where *x, y, z, z', u, v,* and *w* are measurable variables to hold f-points and f-marks, $\otimes$ denotes Lukasiewicz t-norm, r_1, r_2, r_3, and r_4 are truth values of the associated axioms.

2.3 Pavelka logic

While we use extended fuzzy logic to reason with partially true statements we need to extend classical logics for partial truth. We consider here only extension at the Lukasewicz logic for partial truth. In order to deal with partial truth Pavelka [14] extended this logic by adding truth constants for all reals in $[0,1]$. Hajek [15] simplified it by adding these truth constants $\bar{r}$ only for each rational $r \in [0,1]$ (so $\bar{r}$ is an atomic formula with truth value *r*). They also added 'book - keeping axioms'

$$\overline{r \Rightarrow s} \equiv \bar{r} \rightarrow \bar{s} \text{ for r, s rational } \in [0,1] \; .$$

This logic is called Rational Pavelka logic (RPL). RPL was introduced in order to reason with partially true statements. In this section we note that this can already be done in Lukasiewicz logic, and that the conservative extension theorems allow us to lift the completeness theorem, that provability degree equals truth degree from RPL to Lukasiewicz logic. This may be regarded as an additional conservative extension theorem, confirming that, even for partial truth, Rational Pavelka logic deals with exactly the same logic as Lukasiewicz logic - but in a very much more convenient way. RPL extends the language of infinite valued Lukasiewicz logic by adding to the truth constants 0 and 1 all rational numbers r of the unit interval $[0,1]$ *A graded formula* is a pair (φ, r) consisting of a formula φ of Lukasiewicz logic and a rational element $r \in [0,1]$, indicating that the truth value of φ is at least r, $\varphi \geq r$ [8]. For example, $p(x), 1/2$ expresses the fact that the truth value of $p(x)$, $x \in Dom$, is at least $1/2$. The inference rules of RPL are the *generalization rule*

$$\frac{\varphi}{(\forall x)(\varphi)},$$

and a modified version of the *modus ponens rule,*

$$\frac{(\varphi, r), (\varphi \rightarrow \psi, s)}{(\psi, r \otimes s)} \qquad (5)$$

Here $\otimes$ denotes the Lukasiewicz t-norm. Rule (5) says that if formula φ holds at least with truth value *r*, and the implication $\varphi \rightarrow \psi$ holds at least with truth value *s*, then formula ψ holds at least with truth value $r \otimes s$. The modified modus ponens rule is derived from the so-called *book-keeping axioms* for the rational truth constants *r*. The book-keeping axioms add to the axioms of Lukasiewicz logic and provide rules for evaluating compound formulas involving rational truth constants [16]. The use of fuzzy reasoning trades accuracy against speed, simplicity and interpretability for lay users. In the context of ubiquitous computing, these characteristics are clearly advantageous.

3. Statement of problem

In an unprecisiated perception-based information setting we consider a decision making problem as a 4-tuple $S,P,X,A,\succsim$ where a set of states of nature S, a set of corresponding probability distributions P, a set of outcomes X are generally considered as spaces of f-lines. Set of actions A is considered then as a set of mappings from S to X. Preferences $\succsim$ in its turn is to be implicit in some knowledge base described as if-then rules which include S,P,X,A-based description of various decision making situations faced before and a DM's or experts' opinion-based evaluations of corresponding values $V(a)$ of alternatives $a \in A$ which are also to be described by f-lines.

The problem of decision making consists in determination of the best alternative as an alternative $a^* \in A$ for which $V(a^*) = \max_{a \in A} V(a)$.

4. Fuzzy geometrical IF-THEN rules for decision making

A current perception-based input information on values of a variables of interest is introduced by a user in form of fuzzy lines. An entered fuzzy line is situated in a 2D space one dimension of which supports a basic (numerical) value of probability and the other dimension supports a truth degree associated with this basic value. Every fuzzy line is approximated by its convex hull which represents a set of basic values of a variable of interest with the associated truth degrees. The truth degree $\alpha \in [0,1]$ of a basic value is defined a thickness of the fuzzy line at a point representing a basic value (see Fig. 3).

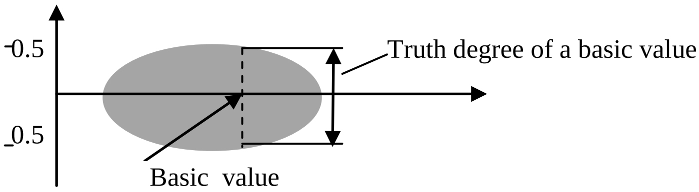
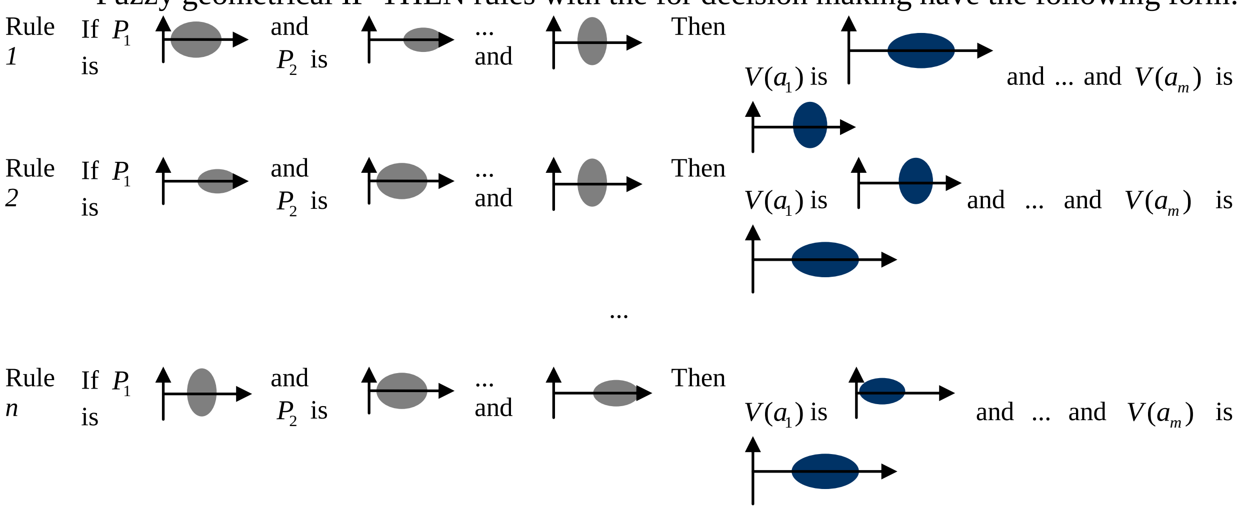


Fig. 3. ***Fuzzy line as a description of a value.***

A truth degree represents a DM's or an expert's confidence-based evaluation of the truthness of a considered basic probability given the available perception-based information.

Fuzzy geometrical IF-THEN rules with the for decision making have the following form:



(6)

Solving of a decision making problem on base of current information on probabilities expressed by fuzzy geometrical primitives consists in performing reasoning with fuzzy geometrical IF-THEN rules base (6), computation of $V(a_i),\ i = 1,...,m$ and determination of the best alternative by ranking $V(a_i),\ i = 1,...,m$.

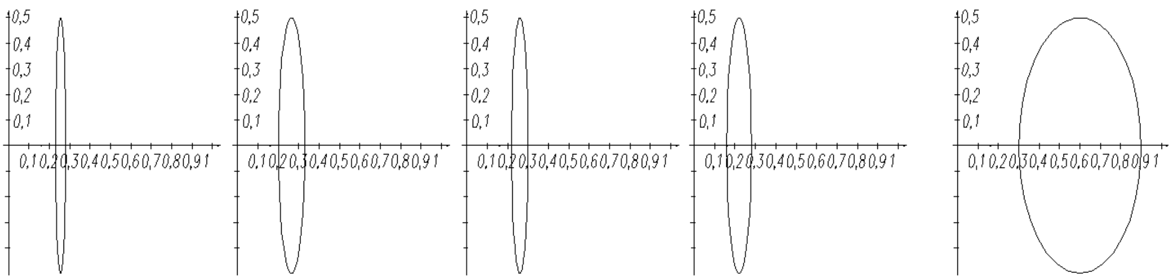
5. Method of solution

Given fuzzy geometrical information provided by a DM it is needed first to verify satisfaction of the axioms of fuzzy incidence geometry (see Section 2.2) for this information by calculating $r_i,\ i = 1,...,4$. A degree $\overline{r} = \min_{i=1,...,4} r_i$ of satisfaction of these axioms is then calculated. If the degree $\overline{r}$ is smaller than some threshold r', for example, $r' = 0.5$ then a user is requested to enter geometrical information again. If the threshold is reached then the entered objects are approximated by convex hulls. For convenience of the further computations, the convex hulls can be replaced by the nearest ellipses. Then the reasoning within the fuzzy geometrical IF-THEN rules is performed on base of Pavelka logic which is an extension of Lukasiewicz logic. We have to mention that fuzzification of incidence geometry suggested in [8] is based on Lukasiewicz logic. The reasoning on base of fuzzy geometrical IF-THEN rules includes the following steps. At the first step, by using Lukasiewicz t-norm (1) we aggregate antecedents of every *i*-th rule. At the second step, given the aggregated antecedent parts and a consequent part of every rule we calculate the relation matrix on base of Lukasiewicz implication (3). At the third step, by using Lukasiewicz t-conorm (2) we aggregate the relations calculated for all the fuzzy geometrical IF-THEN rules and arrive at one resulting relation. A composition of current input information with the resulting relation allows to calculate the geometrical outputs describing values of alternatives. At the third step, the best alternative is determined by performing the ranking of the calculated geometrical outputs.

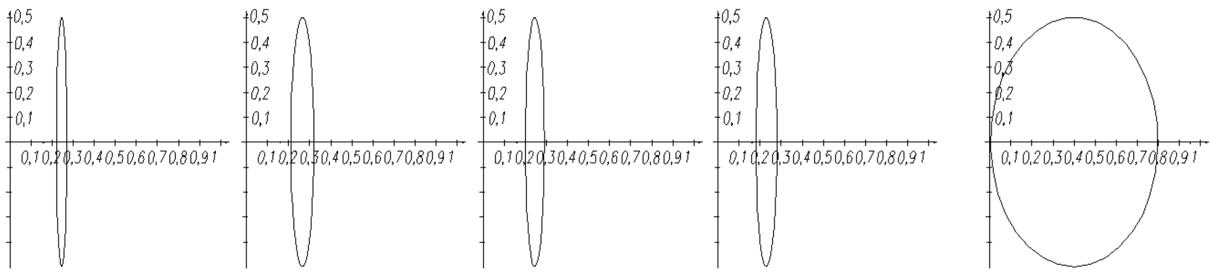
6. Example. An investment problem.

An economic agent considers the following alternatives to make a decision for short-term investment of up to 1 year: common bonds stocks of enterprise and time deposit. Suppose that the agent evaluates each alternative under the following states of economy that may take place during a year: strong growth, moderate growth, stable economy, recession. On the base of the past experience, the economic agent expresses his opinion on the values of the alternatives provided probabilities of the states of economy by using fuzzy geometrical IF-THEN rules base. Let us consider a fragment of this rules base with two rules (for simplicity only values of the first alternative are shown):

Rule 1



Rule 2



The four antecedents as fuzzy geometrical objects in each rule represent perception of the values of probabilities of four states of nature. The consequent of each rule represents the value of the alternative. The problem is to determine the best alternative by applying reasoning within the considered rules given current perception based information on probabilities. The problem is solved as follows.

First, the rules are formalized on the base of Pavelka logic as follows. Inputs in each rule are aggregated into one input by using Lukasievicz t-norm (Tables 1 and 2):

Table 1

Aggregation of inputs of the first rule

BASIC VALUE	TRUTH DEGREES OF THE INPUTS				Aggregation results (truth degrees)
	A1	A2	A3	A4	
0,21	0,54	0	0,98	0	0
0,22	0,72	0	1	0	0
0,23	0,84	0,66	0,98	0	0,52
0,24	0,92	0,86	0,94	0,8	0,672
0,25	0,992	0,96	0,86	0,86	0,478
0,26	0,998	1	0,74	0,74	0,078
0,27	0,998	0,96	0,56	0,56	0
0,28	0,972	0,86	0	0	0
0,29	0,92	0,66	0	0	0
0,3	0,84	0	0	0	0

Table 2

Aggregation of inputs of the second rule

BASIC VALUE	TRUTH DEGREES OF THE INPUTS				AGGREGATION RESULTS (TRUTH DEGREES)
	A1	A2	A3	A4	
0,21	0	0	0,62	0,92	0
0,22	0	0,58	0,84	0,98	0
0,23	0,8	0,78	0,94	1	0,52
0,24	0,98	0,9	0,994	0,98	0,854
0,25	0,98	0,96	0,994	0,92	0,854
0,26	0,8	0,996	0,94	0,8	0,536
0,27	0	0,996	0,84	0,6	0
0,28	0	0,96	0,62	0	0
0,29	0	0,9	0	0	0
0,3	0	0,78	0	0	0

Given the aggregated inputs we construct the fuzzy geometrical relation matrices of the rules R_1 (1st rule) and R_2 (2nd rule) by using Lukasiewicz implication (Tables 3 and 4).

Table 3

Fuzzy geometrical relation matrix R_1

	0	0	0	0	0,74	0,94	1	0,94	0,74	0
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,52	0,480	0,480	0,480	0,480	1,000	1,000	1,000	1,000	1,000	0,480
0,672	0,328	0,328	0,328	0,328	1,000	1,000	1,000	1,000	1,000	0,328
0,478	0,522	0,522	0,522	0,522	1,000	1,000	1,000	1,000	1,000	0,522
0,078	0,922	0,922	0,922	0,922	1,000	1,000	1,000	1,000	1,000	0,922
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table 4

Fuzzy geometrical relation matrix R_2

	0,000	0,680	0,884	0,980	1,000	0,980	0,884	0,680	0,000	0,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,52	0,480	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,480	0,480
0,854	0,146	0,826	1,000	1,000	1,000	1,000	1,000	0,826	0,146	0,146
0,854	0,146	0,826	1,000	1,000	1,000	1,000	1,000	0,826	0,146	0,146
0,536	0,464	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,464	0,464
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

At the next step, we determine an aggregated fuzzy relation matrix R for two rules as the union $R = R_1 \cup R_2$ by using Lukasiewicz t-conorm (Table 5).

Table 5

Aggregated fuzzy relation matrix

1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,626	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,626
0,474	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,474
0,986	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,986
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Assume now a DM graphically enters his current perception-based description of probabilities (Fig. 4):

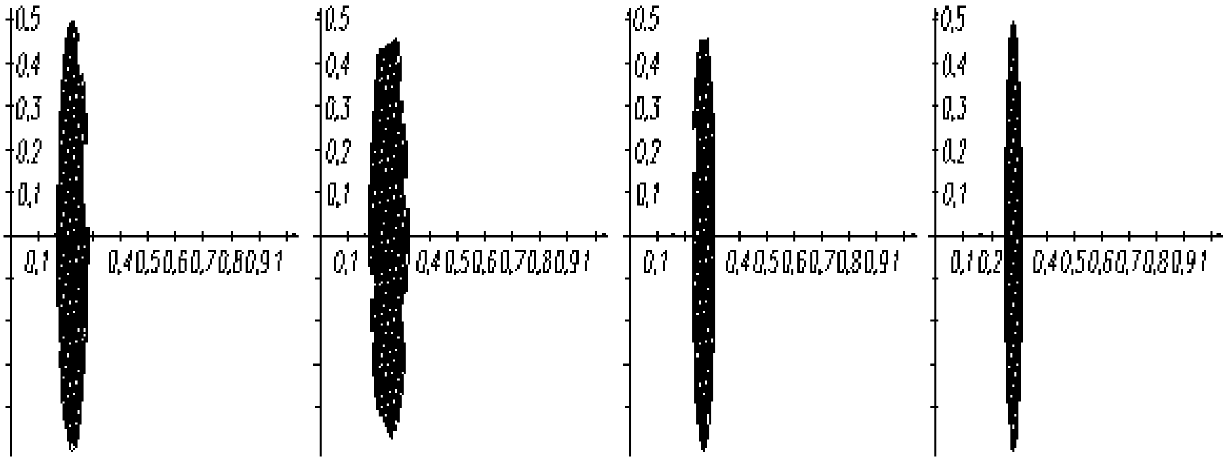


Fig. 4. ***Graphically entered information.***

For the entered objects satisfaction of the axioms (4) at the required threshold is verified and the objects are then approximated by ellipses (Fig. 5):

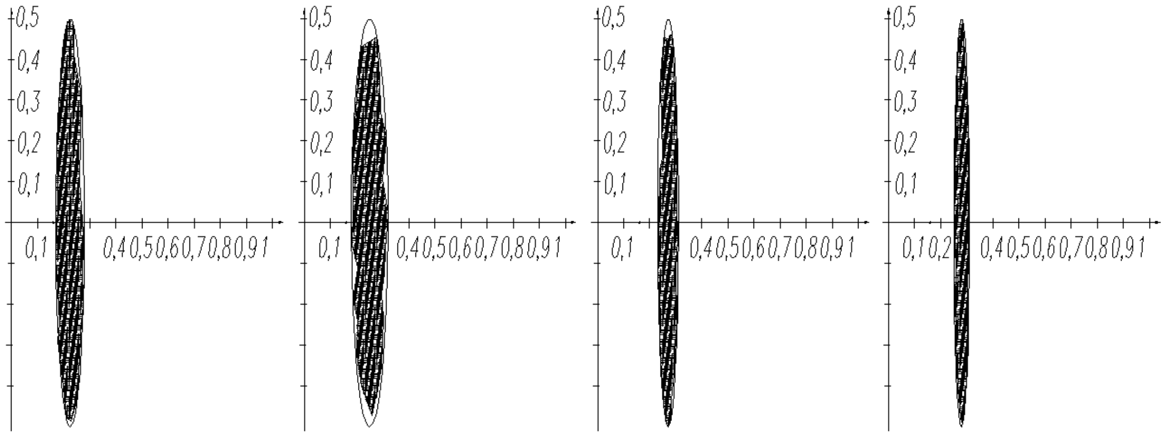


Fig.5. ***Entered information approximated as ellipses.***

Now it is needed to aggregate these ellipses to use them in the further computations. The aggregation of these inputs is shown in Table 6.

Table 6

Aggregation of the current inputs

BASIC VALUES	TRUTH DEGREES OF THE INPUTS				Aggregation results on the inputs
	A1'	A2'	A3'	A4'	
0,21	0,96	0,82	0	0	0
0,22	0,996	0,9	0	0	0
0,23	0,996	0,96	0	0	0
0,24	0,96	0,98	0,66	0	0
0,25	0,9	1	0,86	0	0
0,26	0,78	0,98	0,96	0,74	0,46
0,27	0,58	0,96	1	0,94	0,48
0,28	0	0,9	0,96	1	0
0,29	0	0,82	0,86	0,94	0
0,3	0	0,7	0,66	0,74	0

At the next step we compute maximin composition of the aggregated current inputs and arrive at a resulting output for the rules (Table 7).

Table 7

Calculation of the resulting output

0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	0,626	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,626
0	0,474	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,474
0,46	0,986	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,986
0,48	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	0,480	**0,480**	**0,480**	**0,480**	**0,480**	**0,480**	**0,480**	**0,480**	**0,480**	**0,480**

Thus we get the resulting output as the overall value of the considered alternative:

$$\alpha(y) = 0.48/0.1 + 0.48/0.2 + 0.48/0.3 + 0.48/0.4 + 0.48/0.5 + 0.48/0.6 + 0.48/0.7 + 0.48/0.8 + 0.48/0.9 + 0.48/1$$

Graphical representations of the current fuzzy geometrical information entered by a DM and the computed overall value of an alternative are shown below (Fig. 6):

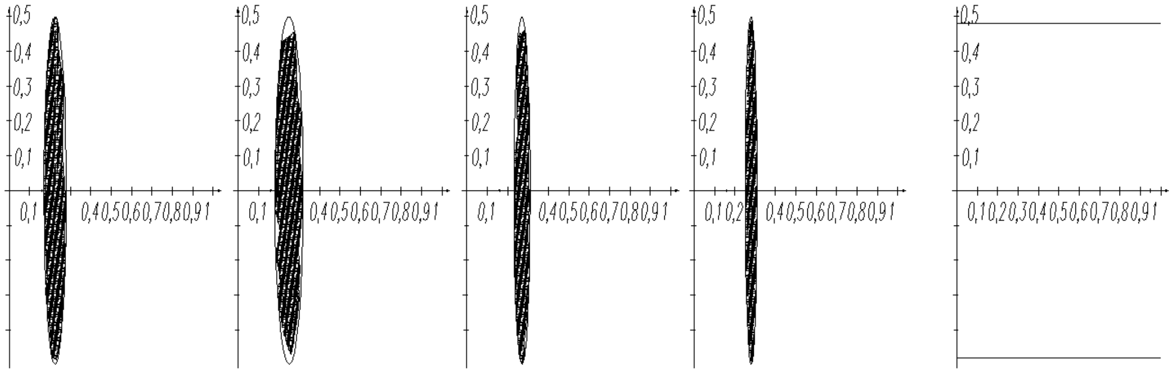


Fig.6. ***Approximated current inputs and the computed output***

The fuzzy geometrical values of the other two alternatives can be calculated analogously. The best alternative may be determined on the base of comparison of the fuzzy geometrical values.

Conclusion

For situations with unprecisiated information the use of the existing methods is not possible. We suggest an approach to decision making under unprecisiated imperfect information which is based on Zadeh’s extended fuzzy logic. The results obtained in the considered example shows validity of the suggested approach.

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