ISSN 1407-5806

COMPUTER MODELLING AND NEW TECHNOLOGIES

Volume 9
No 2

2005

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Computer Modelling and New Technologies

Volume 9, No.2 – 2005

ISSN 1407-5806
ISSN 1407-5814
(On-line: www.tsi.lv)

Riga – 2005

THE JOURNAL IS DESIGNED FOR PUBLISHING PAPERS CONCERNING THE FOLLOWING FIELDS OF RESEARCH:

- mathematical and computer modelling
- mathematical methods in natural and engineering sciences
- physical and technical sciences
- computer sciences and technologies
- semiconductor electronics and semiconductor technologies
- aviation and aerospace technologies
- electronics and telecommunication
- navigation and radar systems
- telematics and information technologies
- transport and logistics
- economics and management
- social sciences

Articles can be presented in journal in English (preferably), Russian, German and Latvian (at the option of authors). All articles are reviewed.

EDITORIAL CORRESPONDENCE
Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)-7100593. Fax: (+371)-7100535.
E-mail: journal@tsi.lv, http:// www.tsi.lv

COMPUTER MODELLING AND NEW TECHNOLOGIES, 2005, Vol.9, No2
ISSN 1407-5806, **ISSN** 1407-5814 (on-line: www.tsi.lv)
Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

CONTENTS

Editors' Remarks

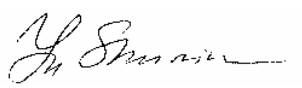
Greatness in Little

.......Nature, who with like state, and equal pride,
Her great works does in height and distance hide,
And shuts up her minuter bodies all
In curious frames, imperceptibly small.
Thus still incognito, she seeks recess
In greatness half-seen, or dim littleness.
Ah, happy littleness! that art thus blest,
That greatest glories aspire to seem least.
Even those installed in a higher sphere,
The higher they are raised, the less appear,
And in their exaltation emulate
Thy humble grandeur and thy modest state.
Nor is this all thy praise, though not the least,
That greatness is thy counterfeit at best.
Those swelling honours, which in that we prize,
Thou dost contain in thy more thrifty size;
And hast that pomp, magnificence does boast,
Though in thy stature and dimensions lost.
Those rugged little bodies whose parts rise
And fall in various inequalities,
Hills in the risings of their surface show,
As valleys in their hollow pits below.
Pompous these lesser things, but yet less rude
Than uncompact and looser magnitude.
What *Skill* is in the *frame* of *Insects* shown?
How *fine* the *Threds*, in their small *Textures* spun?
How *close* those *Instruments* and *Engines* knit,
Which *Motion*, and their *slender Sense* transmit?
Like *living Watches*, each of these conceals
A thousand *Springs of Life*, and *moving wheels*.
Each *ligature* a *Lab'rynth* seems, each *part*
All *wonder* is, all *Workmanship* and *Art*.
Rather let me this *little Greatness* know,
Then all the *Mighty Acts* of *Great Ones* do.
These *Engines* understand, rather than prove
An *Archimedes*, and the *Earth* remove.
These *Atom-Worlds* found out, I would despise
Colombus, and his vast *Discoveries*.

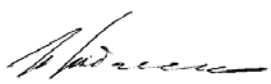
Richard Leigh[1]

This 9th volume No.2 continues our main activities in applied statistics and computer modelling. A special attention is paid to statistical methods in computer simulation. This field of applied science demonstrate some ideas how to find causality in phenomena chaos and non-regularity. This edition is the continuation of our publishing activities. We hope our journal will be interesting for research community, and we are open for collaboration both in research and publishing.

EDITORS



Yu. N. Shunin



I.V. Kabashkin

[1] **Richard Leigh (1649-1728)** was a poet of the seventeenth century who managed to excel himself in this particular poem of 1675 with his interesting analogy of an insect as a working machine.

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 7-16
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

SIMULATION OF MULTI-CRITERIA SELECTION OF BUILDINGS' MAINTENANCE CONTRACTOR USING THE GAME THEORY

E.K. ZAVADSKAS, Z. TURSKIS, T. VILUTIENĖ

Vilnius Gediminas Technical University, Faculty of Civil Engineering,
Saulėtekio al. 11, LT–10223 Vilnius, Lithuania
E-mail: Edmundas.Zavadskas@adm.vtu.lt, Zenonas.Turskis@st.vtu.lt, Tatjana.Vilutiene@st.vtu.lt

In the paper the comparative analysis of dwelling maintenance contractors by applying the methods of game theory is presented. The decision-making methods Wald's rule and Bayes's rule for solving different problems with incomplete information are applied in the research. To illustrate the application of the aforementioned methods, we consider the problem of maintenance contractor selection. To compare the performance of various maintenance contractors, the data from 15 dwelling maintenance organizations are used. Contractors are evaluated by a set of criteria characterizing them from various perspectives. The analysis is made taking into account the standpoints of building owners. Experts determine the initial weights of criteria. Multi-criteria analysis of the performance of maintenance contractors allows us to determine the importance of particular contractor characteristics for achieving the aim to meet the needs of different participants of the maintenance process.

Keywords: *game theory, multi-criteria selection, decision-making methods, efficiency*

Introduction

Decision-maker all time is into collision with series of choices or mistakes upon an effect of various conditions. The problem's solution depends on information one possess, problem's aim and object's model. Decision-maker tries to plan beforehand actions necessary to solve the problems. The decision is made by the way of comparison between merits and demerits of the possible variant under various states of environmental conditions.

At present time mainly achievements are in the field of modelling (simulation). More exactly determined simulation according to different methods gives various classes' numerical approximations of integrals [1]. Advantages or disadvantages are very important to choose solution method for individual problem. Otherwise, data must be computer processed to implement new methods.

If we scrutinize standard decisions in different fields, we shall become certain that deficiency of information is very often ignored. Experts make use of unfavourable initial data, their values applied are exaggerated, work is executed with poor quality determined models which, in case of need, are a bit corrected on the basis of practical experience, however reflect the actual situation insufficiently. Acting in such a way, experts make allowable decisions, but most often these decisions are unfavourable. For example, insufficient substantiation of projects efficiency under increased risk (open market) holds potential investments. State, private businessman, credit institutions financing real investment projects is concerned in qualitative evaluation of projects. The main problem of projects efficiency evaluation is to determine and to ground them (defined civil, financial and similar designed solutions) implanting due to definite reasons is "useful", "profitable" or contrary "useless", "unprofitable", "irrational".

While researching into regularities, deficiency of information is attempted to evade. Application of regularities enables to evaluate results of necessary actions and to present the direction of their selection. Simple evaluation of all possible actions is not always sufficient. Each action may cause several results sometimes contradicting one another. As the actual result is not known, solution criteria are necessary, which can take into consideration the totality of possible results. Various solution rules are proposed for optimisation in the presence of indefiniteness, on which basis the most favourable solution is selected out of the great number of possible solutions. All these calculations are fulfilled with LEVI 3.0 program applied in this work. The aim of this paper is to show the possibilities to apply methods of Game theory for modelling and simulation of decisions in different fields. This paper analyses the application of aforementioned methods to maintenance field.

1. A review of MCDM methods applied to solve multi-objective problems

Classical methods of multi-criteria optimisation and determination of priority and utility function were first applied by V. Pareto [2] in 1896. Debreu improved them in 1959 [3]. These methods were strongly related to economical theory, concerning the averages of thousands of decisions. Methods of multi-criteria analysis were developed in the 1960's to meet the increasing requirements of human society and the environment. In 1980 F. Seo [4] suggested a multi-criteria decision-making method that was concerned with balancing some conflicting objectives in a hierarchical structure. In 1980 T. Tanino *et al* [5] analysed the problem of the coordination of different goals and objectives of various interested parties.

R. L. Keeney and H. Raiffa [6] offered the representation theorems for determining multi-criteria utility functions under preferential and utility independence assumptions. R. L. Keeney [7] outlined the essential features and concepts of decision analysis, formulated axioms and major stages. R. L. Keeney and D. Winterfeldt [8] suggested following the prudence principle in decision process, making decisions precisely and evaluating all possible alternatives, the aims of interested parties, subsequence of decision results and value changes, hereby minimizing the decision-making risk. T. L. Saati [9] in 1977 showed the global importance of solving problems with conflicting goals by using multi-criteria models and presented decision-making models with incomplete information for solving political and economical problems. In his latest works T. L. Saaty analysed measuring problems in assignments associated with uncertainty conditions and applied the AHP method to solve resource allocation problems [10]; he also analysed the peculiarities of decision-making based on the AHP method and the necessity to use the eigenvector for priority determination [11]; for financial crisis forecasting he proposed the ANP (Analytic Network Process) model based on a new measuring system [12].

Multiple criteria decision-making methods (MCDM) have different characteristics; therefore there are different ways to classify them. Multi-criteria methods can be classified by the type of initial information (deterministic, stochastic, fuzzy set theory methods) or by the number of decision-makers (one or group). Scientists classify deterministic MCDM methods differently. The classification of MCDM methods according to the type of information proposed by O. I. Larichev [13] is given here:

1) Methods based on quantitative measurements. The methods based on multi-criteria utility theory may be referred to this group (TOPSIS – Technique for Order preference by Similarity to Ideal Solution [14, 15], SAW – Simple Additive Weighting [16], LINMAP – Linear Programming Techniques for Multidimensional Analysis of Preference [17] and other new methods).

2) Methods based on qualitative initial measurements. These include two widely known groups of methods, i.e. analytic hierarchy methods [18] and fuzzy set theory methods [19].

3) Comparative preference methods based on pair-wise comparison of alternatives. This group comprises the modifications of the ELECTRE [20], PROMETHEE I and II [21], and other methods.

4) Methods based on qualitative measurements not converted to quantitative variables. This group includes methods of verbal decision-making analysis [22].

B. Urli and R. Nadeau [23] emphasized the importance of multi-criteria analysis. Their studies have shown that the area of application of decision-support systems could embrace the most important problems and their significance is underestimated. Researchers examined more than 800 European scientific publications in the period from 1985 to 1996. Since then the amount of articles dealing with multi-criteria analysis has considerably increased. Besides, the researches have noticed the dispersion of multi-criteria analysis to different areas.

K. Train [24] presents comprehensive general conclusion of existing methods and certify that at the eighty years of twenty century were delivered main models of qualitative selection analysis methods, defined statistic and economic properties of such methods. Methods were successfully applied in many fields, including transportation, energetic, civil engineering and market (enumerated a few only). He presents the development directions and ways of modern methods also. In this field are created a lot of procedures. Recent works: V. Kalinka and S. Frant [25] offers multi stage decision making procedure for evaluation of energy production in Israel. In this decision making process are participating agent and computer and are used Paretto, Topsis, Lexgraph methods. C. Parkan and M.L.Wu [26] investigates various variants of distance to the ideal point methods; M. Ben-Akiva, D. Bolduc and J. Walker [27] investigate logic methods.

The methods of multi-criteria analysis were tested in many fields and applied to different disciplines as well as to solving many specific problems. In spite of these facts, multi-criteria analysis is not sufficiently developed, the methods are not perfect, and scientists constantly raise the question, "Which is the best method for a given problem?" [28]. Most of the methods enable us to determine the priority rank for comparing the alternatives, not allowing, however, to establish the level at which one alternative can be better than another.

The evaluation according to many criteria computer programs are used at present time: DELFI, ELECTRE III, ELECTRE IV, PREFCALC, MAPPAC, CARTESIA, PROMCALC, and other. In these programs are used ELECTRE [29] (Valee and Zielniewicz, 1994), UTA (Jacquet-Lagreze, 1984; Jacquet-Lagreze, 1990) [1, 30], MAPPAC [31] (Matarazzo, 1986), CARTESIA [32] (Giarlotta, 1991), PROMETHEE [33, 34] (Brans *et al*., 1984; Brans *et al*., 1986) methods. When analysing the well-known programs it is possible to state that authors of programs mostly choose one problem's solution method and one way of decision-making matrix's transformation. Results obtained in such way are hardly comparable. Till present time there are no rules how to use multi-criteria evaluation methods and how to interpret results of solution. Therefore the solution of this problem must be found.

For multi-criteria selection of an alternative under uncertainty conditions E. K. Zavadskas *et al* [35] created the software LEVI–3.0 based on different methods for criteria normalization and optimal variant selection. The application of these methods increases the accuracy of determining an optimal decision. With new software it is possible to find solution of rational strategy problem using different methods under risk and uncertainty and to compare the results.

The game theory and its methods are instruments for developing the technological behaviour. Solution results enable to make more exact investigation and to choose more precise solution method.

2. Methodology of the simulation

Every problem to be solved is represented by a matrix, which contains variants (rows) and criteria (columns). The variants represent a set of situations for a problem that really exist. All considered variants are evaluated using the same criteria. The results of the evaluation are put in a matrix.

Usually the criteria have different dimensions. That is why their effectiveness cannot be compared directly. An exception is the application of evaluation numbers without any dimensions according to a points system. This, however, involves subjective influences to a great extent. Hence, it should only be used in exceptional cases.

In order to avoid the difficulties due to different dimensions of the criteria, the ratio to the optimal value is used. That way the discrepancy between the different dimensions of the optimal values is also eliminated. There are various theories about the ratio to the optimal value. Note that the decision for a theory may affect the solution. However, the values are mapped either on the interval [0; 1] or on the interval [0, infinity) by the Normalisation of decision-making matrix.

The linear normalization was used that is appropriate for both problems of maximisation and minimisation.

The linear normalisation uses a scale of the existing values. The calculated values are dependent on the size of the interval [a (io); a (iu)] and thus change if the interval is altered.

$$b_{ij} = \frac{a_{ij} - a_{iu}}{a_{io} - a_{iu}} \quad , \tag{1a}$$

if b_{ij} should be maximised, or

$$b_{ij} = \frac{a_{io} - a_{ij}}{a_{io} - a_{iu}} , \tag{1b}$$

if b_{ij} should be minimised, where a_{io} – maximum value, a_{iu} – minimum value.

Calculation of the relative deviation is a well performing linear normalisation. The application of this normalisation is limited to an interval (0..2 Min).

$$b_{ij} = 1 - \left| \frac{a_j^{\ *} - a_{ij}}{a_j^{\ *}} \right| , \tag{2}$$

where a (j*) – optimal value of the criterion.

Normalized decision-making matrix can be processed using different methods of multi-criteria analysis. Here we use methods of game theory.

A distinction is made between one-sided and two-sided problems for the methods of solution.

The one-sided problems are solved using various well-known methods of the selection of variants and the determination of an order of precedence. For one-sided problems only the method of solution "distance to the ideal point" is considered. Using this method an order of precedence according to the deviation from the ideal variant is determined.

Using the Game Theory, the two-sided question aims at finding the equilibrium as a result of the rational behaviour of two parties having opposite interests or at the equilibrium in a game against nature.

For two-sided problems a distinction is made between games with rational behaviour and games against nature.

The solutions for problems with rational behaviour are found in the ideal case as a saddle point solution (simple min-max principle) or as a combination of strategies (extended min-max principle).

Wald's rule (Wald, 1945) [36], **Savage criterion** (Savage, 1951) [37]**, Hurwicz's rule** (Hurwicz, 1951) [38]**, Laplace's rule, Bayes's rule** (Arrow, 1949) [39]**, Hodges-Lehmann rule** [40] are the methods represent the group of games against nature.

Wald's rule: This method searches for the best of the worse solutions (Wald, 1945) [36]. The decision-maker acts according to the worst situation occurring – pessimistic attitude.

$$S_1^* = \left\{ S_{1i} / S_{1i} \in S_1 \cap \max_i \min_j a_{ij} \right\}. \tag{3}$$

Savage criterion: The aim is the minimization of the loss of appropriateness, which is the difference between the greatest and the achieved benefit (Savage, 1951) [37].

$$S_1^* = \left\{ \begin{matrix} S_{1i} / S_{1i} \in S_1 \cap \min_i \max_j c_{ij} \cap c_{ij} = \\ = \left(\max_r a_{rs} \right) - a_{rs} \end{matrix} \right\} \tag{4}$$

There is r = $\overline{1,m}$; s = $\overline{1,n}$. Disadvantage of the method: the presence of non-optimal strategies affects the solution.

Hurwicz's rule: The optimal strategy is based on the best and the worst result (Hurwicz, 1951) [38]. These values, calculated from the row minimum and row maximum, are unified to a weighted average using optimism parameters.

$$S_1^* = \left\{ \begin{matrix} S_{1i} / S_{1i} \in S_1 \cap \max_i h_i \cap h_i = \\ = \min_i a_{ij} + (1-\lambda) \max_j a_{ij} \cap 0 \le \lambda \le 1 \end{matrix} \right\} \tag{5}$$

The value λ=1 gives the most pessimistic solution (Wald's rule). For the value λ=0 only the maximal values are considered, greatest risk.

Laplace's rule: The solution is calculated under the condition, that all probabilities for the strategies of the opponent are equal.

$$S_1^* = \left\{ S_{1i} / S_{1i} \in S_1 \cap \max_i \left(1/n \sum_{i=1}^{n} a_{ij} \right) \right\}. \tag{6}$$

Bayes's rule: If the probabilities for the strategies of the opponent are given, the maximum for the expected value can be used (Arrow, 1949) [39].

$$S_1^* = \left\{ S_{1i} / S_{1i} \cap \max_i \left(\sum_{j=1}^{n} q_j a_{ij} \right) \cap \sum_{j=1}^{n} q_j = 1 \right\}. \tag{7}$$

Hodges-Lehmann rule: With this rule confidence in the knowledge of the probabilities of the strategies of the opponent can be expressed by the parameter λ [40].

$$S_1^* = \left\{ \begin{matrix} S_{1i} / S_{1i} \in S_1 \cap \\ \cap \max_i \left[\lambda \sum_{j=1}^{n} q_j a_{ij} + (1-\lambda) \min_j a_{ij} \right] \cap \\ \cap 0 \le \lambda \le 1 \end{matrix} \right\}. \tag{8}$$

λ=0 (no confidence) gives the solution according to Wald's rule. λ=1 (great confidence) gives the solution according to Bayes's rule.

To illustrate application of the described methods, we shall consider the task of maintenance contractor selection applying the two methods from group of games against nature – **Wald's** and **Bayes's rules**.

3. Solution of the problem

The efficiency of maintenance depends on many micro- and macro-environmental factors. Therefore, planning and successful implementation of building maintenance requires the evaluation of the capabilities of the participants of this process and the influence of the environment on its efficiency. The participants of the maintenance process can perform their functions efficiently only taking into consideration the changing environment, pursuing the best coordination of actions, raising the quality of services and meeting the needs of apartment owners.

Efficiency is hereby perceived as the process of providing building maintenance services, which results in ultimate implementation of the goals of the interested groups participating in the process. The efficiency of any process is assessed in terms of criteria, which vary depending on the problem concerned and the particular goals of the interested groups. The utmost efficiency is often associated with the maximum gain from a specific activity. The more numerous and significant aims are achieved, the higher is the gain and the efficiency of the activity. The efficiency of a decision made will depend on the goals of all interested groups, participating in the maintenance process and with regard of the impact of the micro- and macro-environmental factors. Maintenance contractors cannot correct or change aforementioned factors, but they can realize their impact and evaluate it during the implementation of different projects, herewith successfully organizing their current and future activities.

The term efficiency can be interpreted differently; therefore one has to evaluate all the needs of the participants of the maintenance process. Modelling and multi-criteria analysis allow us to find a way to meet the goals of the participants of different process and to choose an optimal solution as well as the efficient ways to implement it.

As mentioned above, maintenance contractors were evaluated and compared from the viewpoints of building users represented by key maintenance persons. The initial data for comparing the contractors are written down in a decision-making matrix (Table 1). The alternatives n considered in the paper are arranged in columns, while quantitative and qualitative information describing them is given in rows.

A great amount of information characterizes the performance of maintenance suppliers. However, it is not always exactly defined; therefore we must deal with incomplete information. Alternative maintenance companies were evaluated and compared using mostly qualitative efficiency criteria: quality standard of management services, work organization, certification of company, range of services, reliability of company, staff qualification and past experience, communication skills, geographical market restrictions, etc. (Table 1). The character of distribution of initial data is shown in Fig. 1. Initial data for maintenance contractor's evaluation was put in the table for initial data storage in software Levi 3.0 (Fig. 2).

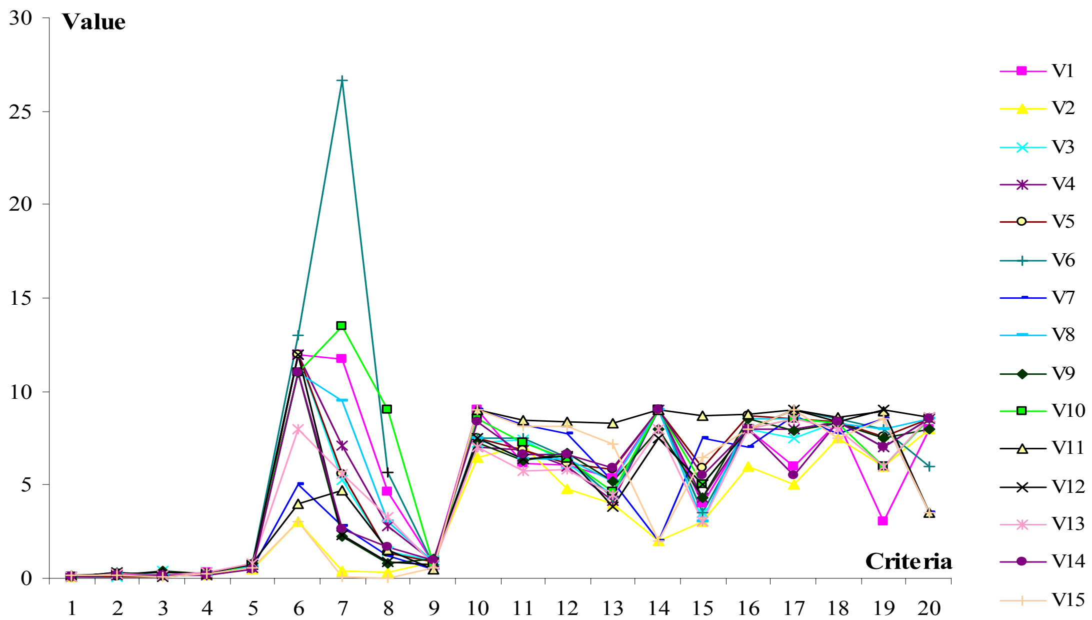


Figure 1. Decision-making initial data

TABLE 1. Initial data for multi-criteria evaluation (criteria values and initial weights)

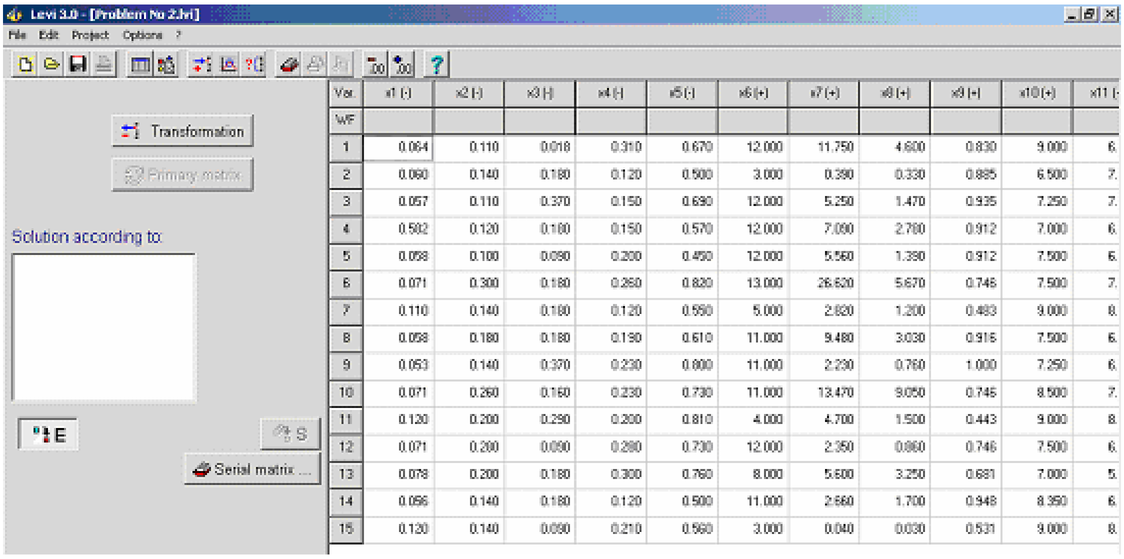
No.	Criteria	Units of measurements	Max/ min	Alternatives						
				V1	V2	V3	V4	V5	V6	V7
1.	Cost of building management	Lt*/m^2	min	0.064	0.060	0.057	0.058	0.058	0.071	0.110
2.	Cost of common assets management	Lt/m^2	min	0.110	0.140	0.110	0.120	0.100	0.300	0.140
3.	HVAC system maintenance cost (mean)	Lt/m^2	min	0.180	0.180	0.370	0.180	0.090	0.180	0.180
4.	Courtyard territory cleaning (in summer)	Lt/m^2	min	0.310	0.120	0.150	0.150	0.200	0.260	0.120
5.	Total service cost	Lt/m^2	min	0.670	0.500	0.690	0.570	0.450	0.820	0.550
6.	Length of time in maintenance business (experience)	years	max	12.000	3.000	12.000	12.000	12.000	13.000	5.000
7.	Market share for each contractor (in Vilnius)	%	max	11.750	0.390	5.250	7.090	5.560	26.620	2.820
8.	Number of projects per executive	units/per-son	max	4.600	0.330	1.470	2.780	1.390	5.670	1.200
9.	Evaluation of management cost (C_{min}/C_p)	-	max	0.830	0.885	0.935	0.912	0.912	0.746	0.483
10.	Quality standard of management services	points	max	9.000	6.500	7.250	7.000	7.500	7.500	9.000
11.	Quality of maintenance of common property	points	max	6.111	7.111	7.389	6.889	6.889	7.500	8.222
12.	Work organization	points	max	6.071	4.786	6.114	5.986	6.114	6.500	7.771
13.	The efficiency of information use	points	max	5.333	4.000	4.500	4.167	5.833	4.333	5.167
14.	Certification of company	points	max	9.000	2.000	9.000	9.000	9.000	9.000	2.000
15.	Range of services	points	max	4.000	3.000	3.500	4.300	5.900	3.500	7.500
16.	Reliability of company	points	max	8.000	6.000	8.000	8.000	8.700	8.000	7.000
17.	Company reputation	points	max	6.000	5.000	7.500	8.000	8.500	9.000	8.700
18.	Staff qualification and past experience	points	max	8.400	7.500	8.400	8.400	8.400	8.500	7.700
19.	Communication skills	points	max	3.000	6.000	7.000	7.000	7.600	8.000	8.500
20.	Geographical market restrictions	points	min	8.000	8.000	8.500	8.500	8.500	6.000	3.500

TABLE 1. Initial data for multi-criteria evaluation (criteria values and initial weights) *continuation*

No.	Criteria	Units of measurements	Max/ min	Alternatives								qj
				V8	V9	V10	V11	V12	V13	V14	V15	
1.	Cost of building management	Lt*/m^2	min	0.058	0.053	0.071	0.120	0.071	0.078	0.056	0.120	**0,038**
2.	Cost of common assets management	Lt/m^2	min	0.180	0.140	0.260	0.200	0.280	0.200	0.140	0.140	**0,088**
3.	HVAC system maintenance cost (mean)	Lt/m^2	min	0.180	0.370	0.160	0.290	0.090	0.180	0.180	0.090	**0,099**
4.	Courtyard territory cleaning (in summer)	Lt/m^2	min	0.190	0.230	0.230	0.200	0.280	0.300	0.120	0.210	**0,105**
5.	Total service cost	Lt/m^2	min	0.610	0.800	0.730	0.810	0.730	0.760	0.500	0.560	**0,335**
6.	Length of time in maintenance business (experience)	years	max	11.000	11.000	11.000	4.000	12.000	8.000	11.000	3.000	**0,016**
7.	Market share for each contractor (in Vilnius)	%	max	9.480	2.230	13.470	4.700	2.350	5.600	2.660	0.040	**0,019**
8.	Number of projects per executive	units/per-son	max	3.030	0.760	9.050	1.500	0.860	3.250	1.700	0.030	**0,011**

9.	Evaluation of management cost (C_{min}/C_p)	-	max	0.916	1.000	0.746	0.443	0.746	0.681	0.948	0.531	**0,029**
10.	Quality standard of management services	points	max	7.500	7.250	8.500	9.000	7.500	7.000	8.350	9.000	**0,029**
11.	Quality of maintenance of common property	points	max	6.389	6.333	7.222	8.444	6.422	5.778	6.611	8.111	**0,029**
12.	Work organization	points	max	6.357	6.700	6.400	8.343	6.571	5.829	6.643	8.100	**0,020**
13.	The efficiency of information use	points	max	5.167	5.167	4.667	8.333	3.833	4.500	5.900	7.167	**0,015**
14.	Certification of company	points	max	9.000	8.000	9.000	9.000	7.500	8.000	9.000	2.000	**0,016**
15.	Range of services	points	max	3.000	4.300	5.000	8.700	5.000	3.000	5.500	6.500	**0,024**
16.	Reliability of company	points	max	8.500	8.500	8.000	8.800	8.000	8.000	8.000	8.000	**0,029**
17.	Company reputation	points	max	8.500	7.900	8.500	9.000	9.000	8.500	5.500	9.000	**0,028**
18.	Staff qualification and past experience	points	max	8.300	8.300	8.300	8.600	8.400	8.000	8.400	7.500	**0,029**
19.	Communication skills	points	max	8.000	7.500	6.000	8.900	9.000	6.000	7.000	8.500	**0,025**
20.	Geographical market restrictions	points	min	8.500	8.000	8.500	3.500	8.600	8.600	8.500	3.500	**0,015**
												1,000

Note: a basic monetary unit of Lithuania, divided decimally into 100 cents, 1 Lt=3.4528 EUR (the exchange rate fixed by Lithuanian Central bank (2004-10-12))



Var.	x1 (-)	x2 (-)	x3 (-)	x4 (-)	x5 (-)	x6 (+)	x7 (+)	x8 (+)	x9 (+)	x10 (+)	x11 (-
WF											
1	0.064	0.110	0.018	0.310	0.670	12.000	11.750	4.600	0.830	9.000	6.
2	0.060	0.140	0.180	0.120	0.500	3.000	0.390	0.330	0.885	6.500	7.
3	0.057	0.110	0.370	0.150	0.690	12.000	5.250	1.470	0.935	7.250	7.
4	0.502	0.120	0.180	0.150	0.570	12.000	7.090	2.780	0.912	7.000	6.
5	0.058	0.100	0.090	0.200	0.450	12.000	5.560	1.390	0.912	7.500	6.
6	0.071	0.300	0.180	0.260	0.820	13.000	26.620	5.670	0.746	7.500	7.
7	0.110	0.140	0.180	0.120	0.550	5.000	2.820	1.200	0.483	9.000	8.
8	0.058	0.180	0.180	0.190	0.610	11.000	9.480	3.030	0.916	7.500	6.
9	0.053	0.140	0.370	0.230	0.800	11.000	2.230	0.760	1.000	7.250	6.
10	0.071	0.260	0.160	0.230	0.730	11.000	13.470	9.050	0.746	8.500	7.
11	0.120	0.200	0.290	0.200	0.810	4.000	4.700	1.500	0.443	9.000	8.
12	0.071	0.200	0.090	0.280	0.730	12.000	2.350	0.860	0.746	7.500	6.
13	0.078	0.200	0.180	0.300	0.760	8.000	5.600	3.250	0.681	7.000	5.
14	0.056	0.140	0.180	0.120	0.500	11.000	2.660	1.700	0.948	8.350	6.
15	0.120	0.140	0.090	0.210	0.560	3.000	0.040	0.030	0.531	9.000	8.

Figure 2. The fragment of initial data stored in software Levi 3.0

The formed decision-making matrix was normalized using the method for linear normalisation. Normalized decision-making matrix presented in Fig. 3.

Solving the task by Wald's rule the formula (3) was applied. In this case the weights of criteria are not evaluated. If a decision-maker takes different importance to each criterion, he/she has to use Bayes's rule applying formula (7).

Results of task being solved showed different priorities of alternatives. This difference is conditioned by the specific of methods being used. The main difference is that solving task by using the Bayes's rule the weights of criteria was evaluated. Therefore, if weights are important for decision maker, he/she has to use the results obtained applying Bayes's rule. And, on the contrary, if one doesn't consider the weights, the Wald's rule could be applied. As shown in Table 2 and 3, the expression $V_{10} \succ V_5 \succ V_{14} \succ (V_1 - V_4, V_6 - V_9, V_{11} - V_{13}, V_{15})$ was obtained based on applying Wald's rule method and expression $V_5 \succ V_{14} \succ V_7 \succ V_{15} \succ V_4 \succ V_2 \succ V_8 \succ V_1 \succ V_3 \succ V_{10} \succ V_{11} \succ V_{12} \succ V_9 \succ V_6 \succ V_{13}$ was obtained based on applying Bayes's rule method, were "$\succ$" means '"better than". This implies that, according to the priority order, the 10-th alternative is the best (Q_{10} = 0,19) in first case and the 5-th alternative is the best (Q_5 = 0,822) in another case (Fig. 4).

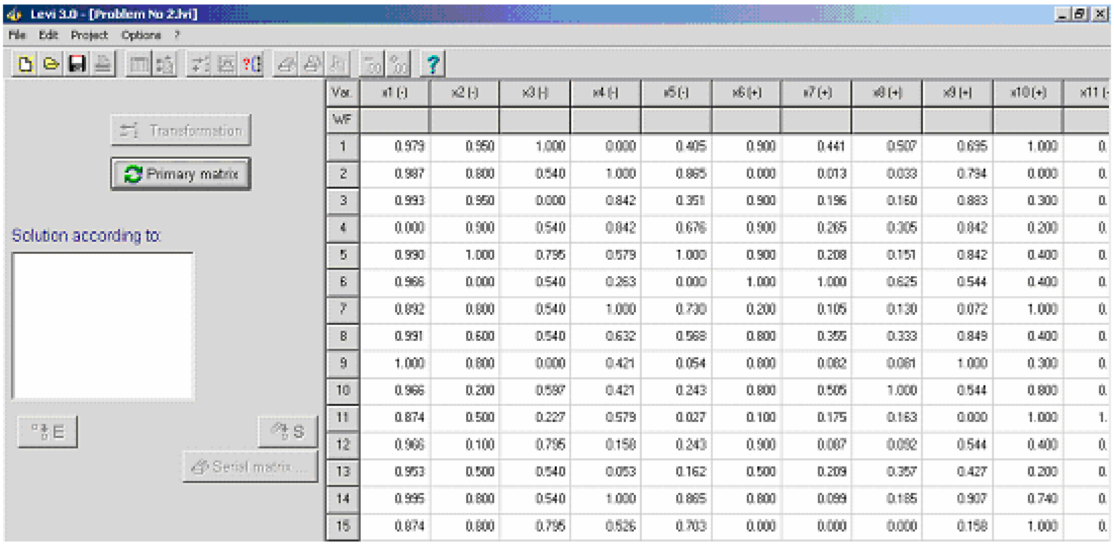


Figure 3. The fragment of normalized decision-making matrix

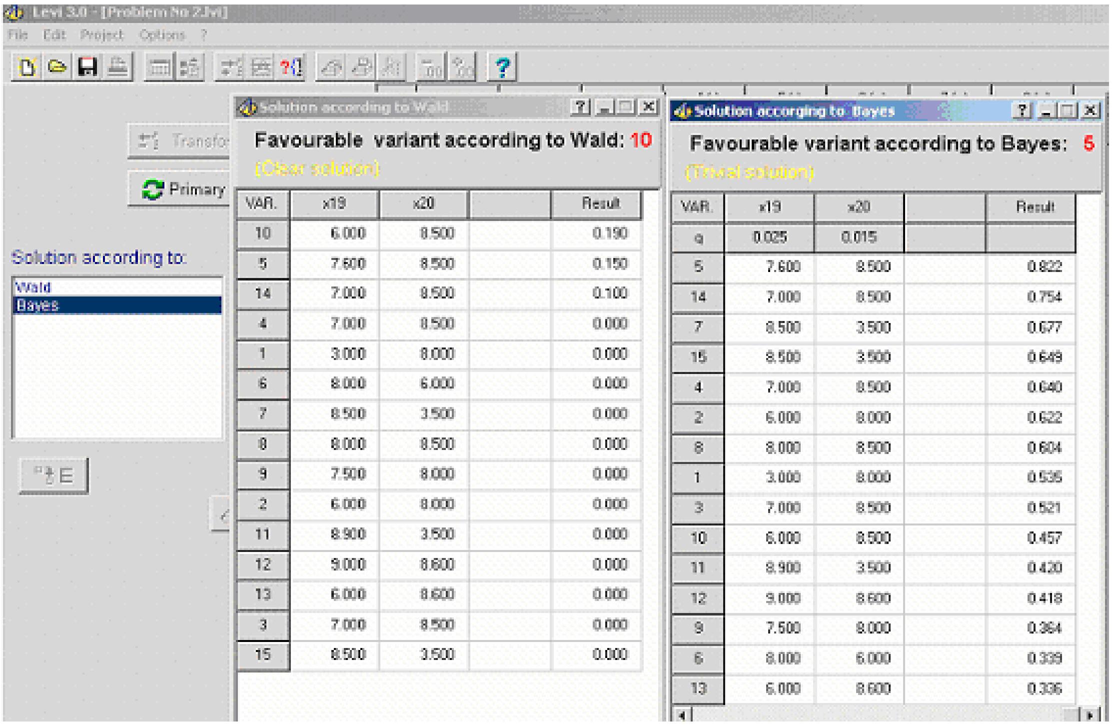


Figure 4. Favourable alternatives according to Wald's and Bayes's rules

TABLE 2. Comparison of results of calculation

Applied method	Alternatives														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Wald's	0	0	0	0	0,15	0	0	0	0	**0,19**	0	0	0	0.1	0
Bayes's	0,535	0,622	0,521	0,64	**0,822**	0,339	0,667	0,604	0,364	0,457	0,42	0,418	0,336	0,754	0,649

TABLE 3. Priority order of the alternatives applying different methods

Method of evaluation	Priority order of the alternatives
Wald's rule	V10 ≻ V5 ≻ V14 ≻ (V1, V2, V3, V4, V6, V7, V8, V9, V11, V12, V13, V15)
Bayes's rule	V5 ≻ V14 ≻ V7 ≻ V15 ≻ V4 ≻ V2 ≻ V8 ≻ V1 ≻ V3 ≻ V10 ≻ V11 ≻ V12 ≻ V9 ≻ V6 ≻ V13

Conclusions

The results obtained in solving the problem reveal that evaluating criteria weights the fifth alternative is more effective than other options not only in satisfying the needs and objectives of the client but from the viewpoint of maintenance manager as well. Multi-criteria analysis of maintenance contractors' performance allows for complex evaluation of the criteria characterizing this issue from the perspective of their agreement with the needs and technical and financial capabilities. The needs are described in terms of a set of criteria and values, with the importance of the criteria expressed in terms of their significances. Decisions criteria are chosen taking into account the interests and objectives of the client (building user) as well as the other factors affecting the efficiency of the maintenance process. Practical application of the suggested methods for maintenance contractor selection could help all the interested groups to harmonize their diverse interests and objectives and to enhance the procedure of decision-making. The application of multi-criteria analysis to the selection of maintenance contractor helps to take the appropriate decision based on various criteria that may reduce the risk in the process of contractor selection. This confirms an assumption that the above applied methods can be successfully used in maintenance contractor selection practice. The suggested methods may be successfully applied not only to planning the maintenance work but also to solve different problems in many other fields dealing with incomplete information. In transport field decision maker can analogically solve the tasks of means of locomotion type selection, selection of transport way, conveyers selection and others. New software enables to find solution of rational strategy problem using different methods under risk and uncertainty and to compare the results.

References

[1] Jacquet-Lagreze E. (1984) PREFCALT: evaluation et decision multicritere, *Revue de l'Utilisateur de l'IBM PC*, No 3, 38-55.

[2] Pareto V. (1971) *Manual of Political Economy*. A. M. Kelley, New York.

[3] Werzbicki AA. (1981) *Mathematical basis for satisfying decision-making*: Lecture Notes in Economics and Mathematical System. Berlin, Heidelberg, New York, 465-485.

[4] Seo F. (1981) *Organizational aspects of multi-criteria decision-making*: Lecture Notes in Economics and Mathematical System. Berlin, Heidelberg, New York, 363-379.

[5] Tanino T, Nakayama H, Swaragi Y. (1981) *Methodology for group decision support*: Lecture Notes in Economics and Mathematical System. Berlin, Heidelberg, New York, 409-423.

[6] Keeney RL, Raiffa H. (1976) *Decision with multiple objectives: preferences and value tradeoffs.* New York: John Wiley & Sons.

[7] Keeney RL.(1982) Decision analysis: an overview, *Operations Research*, **30**(5), 803-838.

[8] Keeney RL, von Winterfeldt D. (2001) Appraising the precautionary principle – a decision analysis perspective. *Journal of Risk Research* **4**(2), 191-202

[9] Saaty T.L. (1977) *Mathematical models of conflict situations.* Sov. Radio Moscow, 304 p. (in Russian).

[10] Saaty T.L, Vargas LG, Dellmann K. (2003) The allocation of intangible resources: The Analytic Hierarchy Process and linear programming, *Socio-Economic Planning Sciences,* **37**, 169-184.

[11] Saaty T.L. (2003) Decision-making with AHP: why is the principal eigenvector necessary, *European Journal of Operational Research*, **145**, 85-91.

[12] Niemira MP, Saaty T.L.(2003) An Analytic Network Process Model for financial-crisis forecasting, *International Journal of Forecasting* (in print).

[13] Larichev O. (2000) *Decision-making theory and methods*. Moscow: Logos, 295 p. (in Russian)

[14] Hwang C. L., Yoon K. S. (1981) *Multiple Attribute Decision Making. Methods and Applications.* Springer-Verlag. Berlin, Heidelberg, New York, 259 p.

[15] Arditi D., Gunaydin H.M. (1998) Perception of process quality in building projects, *Journal of Management in Engineering*, **15**(2), 43-53.

[16] MacCrimon K. R. (2000) *Decision Marking Among Multiple–Attribute Alternatives: A Survey and Consolidated Approach*, RAND Memorandum, RM-4823-ARPA.

[17] Srinivasan V., Shocker A. D. (19730 Linear Programming techniques for multidimensional analysis of privileged, *Psychometrika,* **38**, 337-369.

[18] Saaty T. L. (1994) Highlights and critical points in theory and application of the Analytic Hierarchy Process, *European Journal of Operational Research*, **74**, 426-447.
[19] Zimmermann H.-J. (2000) An application-oriented view of modelling uncertainty, *European Journal of Operational Research*, **122** (2), 190-198.
[20] Roy B. (1996) *Multi-criteria. Methodology for Decision Aiding.* Dortrecht: Kluwer Academic Publishers, 293 p.
[21] Brans J. P., Marschal B., Vincke Ph. (1984) Promethee: A new family of outranking methods in multi-criteria analysis. In: *Operational Research'84* / J. P. Brans (ed.). Elsevier Science Publishers B. V. (North Holland), 408-421.
[22] Larichev O., Moshkovich E. (1996) *Qualitative decision-making methods*: Moscow: Fizmalit, 43p. (in Russian)

[23] Urli B., Nadeau R. (1999) Evolution of multi-criteria analysis: a scientometric analysis, *Journal of Multi-criteria Decision Analysis,***8**, 31.
[24] Train K. (2002) *Discrete Methods with Simulation.* Cambridge University Press Publisher, 286 p.
[25] Kalinka V., Frant S. (1999) Environmental Aspects of Power Generation, *Energy Sources*, No.21, 687-704.
[26] Parkan C., Wu M. L. (1997) On the equivalence of operational performance measurement and multiple attribute decision-making, *International Journal of Production Research,* 3**5**, No 11, 2963-2988.
[27] Ben-Akiva M., Bolduc D., Walker J.(2001) Specification, estimation and identification of the logit kernel (or continuous mixed logit) model. Working Paper. Department of Civil Engineering, MIT, 228-238.
[28] Triantaphyllou E. (2000) Multi-criteria Decision-Making Methods: A Comparative Study, *Applied Optimization,* **4**4, 289.
[29] Valee D., Zielniewicz P. (1994) ELECTRE III and IV 3.x. Aspects methodologiques, *LAMSADE*, Paris, Document No.85, 156.
[30] Jacquet-Lagreze E. (1990) *Interactive assessment of preferences using holistic judgments: the PREFCALC system*: Multiple Criteria Decision Aid /Bana e Costa C (ed.). Springer-Verlag, Berlin, 335-350.
[31] Matarazzo B. (1986) Multicriterion analysis of preferences by means of pair wise actions and criterion comparisons (MAPPAC), *Applied Mathematics and Computation,***18**, No 2, 119-141.
[32] Giarlotta A. (1991) Multi-criteria Compensability Analysis Ranking Totally the Alternatives based on the Employment of a Non-symmetric Information Axiom (CARTESIA), *Annali dell Facolta di Economia e Commercio*, No 37,1-33.
[33] Brans J. P., Mareschal B., Vincke Ph. (1984) PROMETHEE - A new family outranking methods in multi-criteria analysis, *Operations Research*, North-Holland, 477-490.
[34] Brans J. P., Vincke Ph., Mareschal B. (1986) How to select and how to rank projects: The PROMETHEE method, *European Journal of Operational Research,* **24**, 228-238.
[35] Zavadskas EK, Ustinovičius L, Turskis Z, Peldschus F, Messing D. (2002) LEVI 3.0 – multiple criteria evaluation program for construction solutions, *Journal of Civil Engineering and Management,* **8**(3) 184-191. Technika, Vilnius.
[36] Wald A. (1945) Statistical decisions functions, which minimize the maximum risk, *Annals of Mathematics*, 265-280.
[37] Savage L. J. (1951) The Theory of Statistical Decision, *Journal of the American Statistical Association*, 55-57.
[38] Hurwicz L. (1951) Optimality Criteria for Decision-Making under Ignorance: Cowles Commission Paper, *Statistics*, No 370, 45-52.
[39] Arrow K. J. (1949) Bayes and Minimax Solutions of Sequential Decision Problems, *Econometrica*, 213-243.
[40] Hodges Jr. J. L., Lehmann E. L. (1952) The Use of Previous Experience in Reaching Statistical Decision, *Annals of Mathematics Studies,* 396-407.

Received on the 21st of June 2005

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 17-26
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

NEURAL NETWORKS MODELLING OF BUSINESS SITUATIONS AND DECISION-MAKING ANALYSIS

YU.N. SHUNIN, N. KNIGA

Information Systems Management Institute,
Department of Natural Sciences and Computer Technologies,
Lomonosov 1A, LV-1019, Riga, Latvia, e-mail: shunin@isma.lv, serenada@inbox.lv

An actuality of "neural networks modelling of business situations and decision making analysis" is connected with the increasing and intensity of business activity in modern society. Most enterprises aspires to that their activity was carried out maximally productively. Besides, the correctly accepted decision acts enormous part in any business. In the process of achieving the put purpose firms and companies permanently get risk situations, breaking the desired development of entrepreneurial activity. One of such problems is insufficient estimation of risk. The task is to decline risk at an acceptance of enterprise decisions by managers; namely, research the newest neural technologies and methodology development of risk sets in business situations. In particular, we consider: a) a prognostication at the fund market; b) an application of the intelligence system in marketing researches, namely, in the questionnaire; c) the task of classification of credit extension to physical persons.

Keywords: *forecasting, classification, the credit, neural network, genetic algorithm, questionnaire*

Introduction

Risk's science studies conformities to the law of actions of systems on determination of possible situations that can be met in their future activity. Risk science is a science about the future, because it is related to the prognoses estimations, possible by ends comings catastrophes and victories, thus, that will be attained, depends in a greater degree on a subject and it similar and far fewer from the mother of nature. An activity of businessmen is oriented to working out various problems in risks situations. The complex of decisions for the decision of any problems is offered: prognostication, tasks of classification. Filling up the traditional methods of estimation and management by the risk by the newest technologies, businessmen will purchase a powerful weapon in the fight against vagueness and other risk situations.

1. Application of artificial neural networks and genetic algorithms in control systems

1.1. INTELLECTUAL CONTROL SYSTEMS

Till the last decade of the last century a traditional approach in the construction of regulators has prevailed. However, much the regulators, built on the basis of the indicated approach, not always allowed the carrying out the robust control of difficult unstationary objects. This circumstance has served to a development of a new scientific direction - intellectual control systems (ICS).

ICS is capable to provide in respect to controlled object an «understanding» and teaching, taking into account external influences and work conditions. The basic feature of ICS is the presence of feedback mechanism. The main architectural feature, which distinguishes ICS from traditional control systems, is the mechanism of receipt, storage and treatment of knowledge for realization of its functions. Thus, the presence not only of databases with necessary information, but also the renewing knowledge databases is principal for ICS. There are some modern information technologies, allowing the creation of ICS, namely, consulting models, artificial neural networks, fuzzy logic, and genetic algorithms. For development of ICS these methods must be incorporated with achievements of the modern control theory.

Structurally ICS contains additional blocks executing system knowledge processing on the basis of the above-mentioned information technologies. These blocks can be executed either as buildings on ordinary regulators, influencing by necessary appearance his parameters or directly joined in the reserved contour of control [2].

1.2. NEURAL NETWORK STRUCTURE

Artificial neural networks (ANN) are calculable structures consisting of number of the same types elements, which execute relatively simple functions. Processes in ANS sometimes are associated with ones, which take place in the nervous system of living organisms.

Neuron network conception is widely applied for the solution of classification tasks, problems clusterization and images recognition. But there are some significant and principal development directions in neuron technologies, which are suitable for management tasks. Some developed and well-studied neuron network models are used in practical modeling (e.g., multi-layer perceptrons (MLP)).

The elementary converter in MLP networks is an artificial neuron (or a simple neuron, named so by similar to the biological prototype). ANN consists of a number of connected neuron, forming usually some layers (see, e.g., Figure 1).

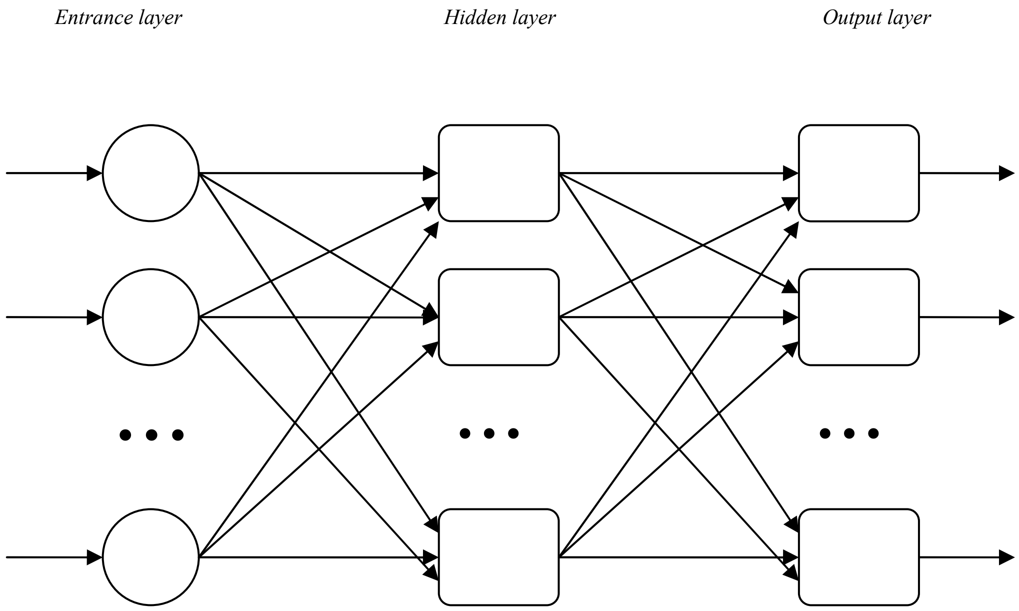


Figure 1. Two-layered neuron network

Let's note, that neurons of the first layer from the left in Figure 1 do not carry out mathematical operations, and serve only for duplication of signals and in the definition of layers number are not taken into account. To solve the proposed task ANN must be previously. The essence of training consists in tuning neurons weights on the basis of training sample examples. An efficiency of ANN use is established by a set of the so-called completeness theorems. The sense of these theorems is reduced to the fact, that any continuous function on the closed limited set can be regularly approximated by functions calculated by neural networks on the basement of some enough easy realized conditions. Thus, Artificial neural networks (ANN) are universal approximators [2].

1.3. NEURAL NETWORK APPLICATION

Neural networks entered in practice anywhere, where the tasks of prognostication, classification or management must be solved. Such an impressive success is determined by some reasons.

- *Rich possibilities.* Neural networks are the exceptionally powerful method of modelling, allowing to reproduce extremely difficult dependences. In particular, neural networks *are nonlinear* on the nature are able to construct any complicated many-factor models.
- *Using simplicity.* Neural networks are studied on examples. The neural network user picks up the representative information, and then starts *a teaching algorithm,* which automatically perceives the data structure. In this case the user, certainly, must have a set of heuristic knowledge about the way of information preparing, necessary network architecture choosing and interpretation results. However, a knowledge level, necessary for successful application of neural networks, is much more modest than, for example, in cases of using of traditional statistics methods.
- *Advantages.* Neural networks are attractive from the intuitional point of view, because they are based on the primitive biological model of the nervous systems. In the future, such neural and biological models can lead to a creation of indeed intellectual computers. But «simple» neural networks of *Statistica Networks Neural* are also a powerful technique of intellectual modelling.

2. Design of decisions of risk situations

2.1. GENETIC ALGORITHMS AND MANAGEMENT TASKS

A neural network is a mathematical model structure some of human brain work, demonstrating his possibilities for the informal teaching, generalization and clusterization of the unclassified information, ability for independent prognoses on the basis of the existed produced temporal rows.

Main their difference from other methods is neural networks an unnecessity of the beforehand known models. They build these on the basis of the produced information. For this reason neural networks and genetic algorithms have entered in practice everywhere, where it is needed to decide the tasks of prognostication, classifications, managements, in other words, in the field of human activity, where it is difficult to make a decision algorithm, and a participation of work of skilled experts group or adaptive systems of automation is needed. Practically, a neural network is used in two ways, namely, as software's products executable on ordinary computers, and as the specialized programmatic complexes. The basic task of neural computer is a treatment of appearances, based on teaching similar to biological neural systems [1].

2.2. INTELLIGENCE SYSTEMS AND MARKETING INVESTIGATIONS

Fuzzy logic systems are widely used in the commercial applications, management and planning, various fields of marketing.

Problem 1. Questioning of the clients by mail.

The goal of investigation is an analysis, structure and content optimization of questionnaire for clients, developed by telecommunications company experts. Following results of questioning a segmentation of company clients has been carried out. Neural network technologies allowed selecting from the great number of the questions set in questionnaires the most essential questions. It is also possible to delete unimportant, duplicated and strongly correlated between themselves questions, and, thus, to simplify a questionnaire and facilitate the process of filling of questionnaire by a client (this means the higher exactness).

On the first stage a basic attention is devoted to the optimization of structure and content of questionnaire from the point of view of every question *meaningfulness* and *information completeness* level, taking into account the duplication of obtained information. Using *Statistica Neural Networks software* the every question estimation of has been carried out from point of its contribution to the general information volume of the whole questionnaire. First of all the investigation interest was connected with the selected questions, which determines the successful work of a company.

Thus, taking into account the every question meaningfulness degree, it is possible to formulate recommendations on the optimal question in the proposed questionnaire.

Neural technologies applications in the development and perfection of questionnaires for the study companies clients opinions and preferences are effective for questioning results treatment and company clients clusterization, taking into account a company service level, which is principal for classical marketing. The obtained results allow companies more effectively to develop corporate marketing's strategies on a work with clients [5].

The Kohonen neural network in the framework of *Statistica Neural Networks* software strongly differs from all other networks types. While all the other networks are intended for tasks with the guided process of teaching, the Kohonen neural network is mainly considered as a non-guided teaching technique.

The Kohonen network can recognize information clusters and also establish the classes' closeness. Thus, a user can improve an understanding of a data structure and then make better qualities of a neural network model. The Kohonen neural network can be used in those tasks of classification, where classes are already given. In this case an advantage is in a neural network ability to find out a similarity between different classes. The Kohonen neural network has only two layers: an input and output made from radial elements (an output layer is named also the of topology map layer). The elements of topology map are disposed in some space, as a rule, in 2D (in *Statistica Neural Networks software* 1D Kohonen network can be also realized) [3].

A research hypothesis is directed on the creation of questionnaire by means of determination of collected information qualities. Consequently, a research hypothesis determines the questions types and answers forms, which are used for the data collection [3]. The developed questionnaire has nine questions with four possible variants of answers. Every answer has it's own weight, which we define from 1 to 4.

TABLE 1. Example of questionnaire about operations efficiency of Telecommunication Company

1	**How do You get information about a company?**
	by phone *(4)* from newspapers *(3)* from radio *(2)* from TV *(1)*
2	**How often do You use company's service?**
	A few times a week *(4)* once a week *(3)* once a month *(2)* once in a half-year *(1)*
3	**What consumer qualities do You prefer?**
	service cost *(4)* transfer rates *(3)* transfer reliability *(2)* image quality *(1)*
4	**What is the main lack of company's operations?**
	fax's delays *(4)* time of fax's transfer *(3)* non-reliability of transfer *(2)* no lacks *(1)*
5	**What companies' service did You use earlier?**
	Lattelekom *(4)* Alerlain *(3)* No experience *(2)* Tele2 *(1)*
6	**Who are You?**
	Action Society *(4)* Joint-Stock Company *(3)* manager *(2)* private person *(1)*
7	**Where do You live?**
	Latvia *(4)* Baltic state *(3)* other European state *(2)* others *(1)*
8	**What states do You send faxes to?**
	Non-European state *(4)* European state *(3)* Baltic state *(2)* Latvia *(1)*
9	**What business do You work in?**
	service *(4)* production *(3)* education *(2)* others *(1)*

The more question information quality the more is it's weight. 30 respondents are questioned. We use *Kohonen Network*.

Step 1. Create a data file. Information contains the values of two variables: an answer's number and answer's weight. After creation of new data file a window of denotations of neural network inputs and outputs appears.

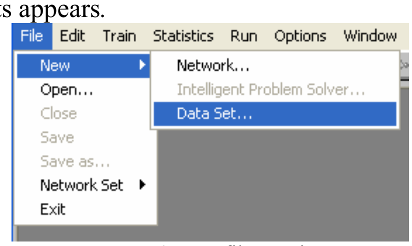


Figure 2. Data file creation

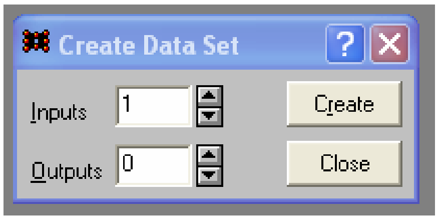


Figure 3. Neural networks inputs and outputs

Step 2. Create a neural network. [Options: ***Network***, File*: New*, ***Type****: Network of Kohonen*, *No Layers=2* (Number of layers), *Temporal window (Steps)* = 1, Advice, *Create*]. A network with 30 inputs and 4 outputs appears on the screen.

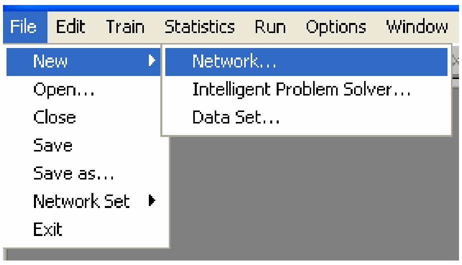


Figure 4. Neural network creation

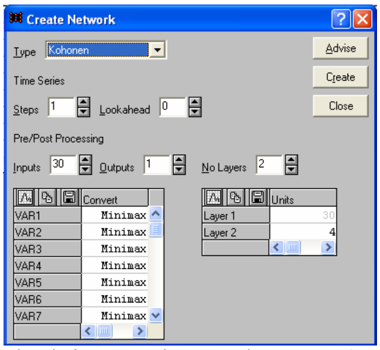


Figure 5. The choice network type and perceptron's parameters definition

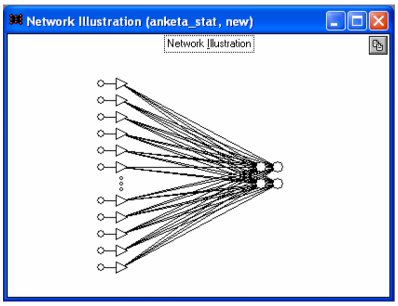


Figure 6. Kohonen network

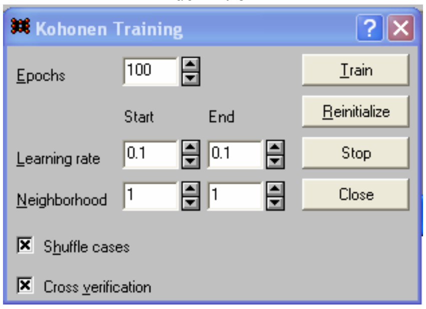


Figure 7. Kohonen network's training

Step 3. *Teaching of network.* [Options: A dialog box: *Training Kohonen*, *Kohonen to Teach, Train*: *teaching Speed,* parameters: *Learning rate* and *Neighborhood*. Usually a teaching of Kohonen network is divided into two phases: the rough approaching and clarification. We use the epoch's number equal 100. Since a network is trained, it is possible to consider formed clusters and their interpretation. Clusters distribution is fixed in the option *Topological Map*.

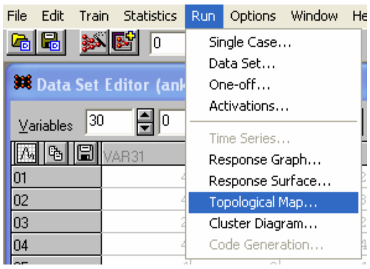


Figure 8. Topological map's choice

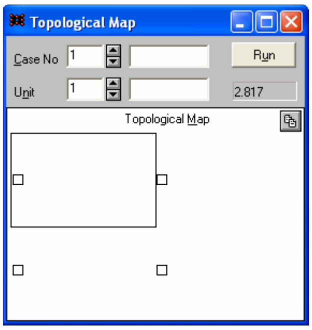


Figure 9. The 1st question's topological map

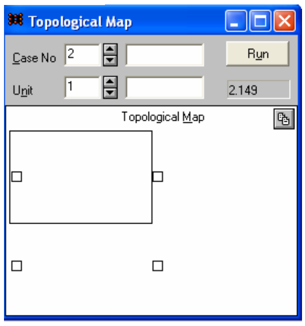


Figure 10. The 2nd question's topological map

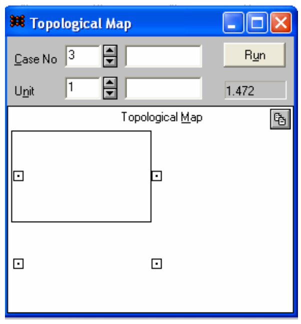


Figure 11. The 3rd question's topological map

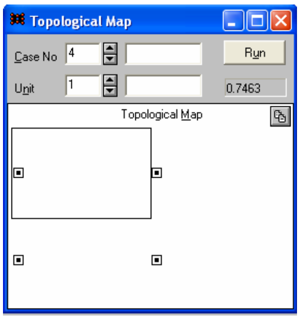


Figure 12. The 4th question's topological map

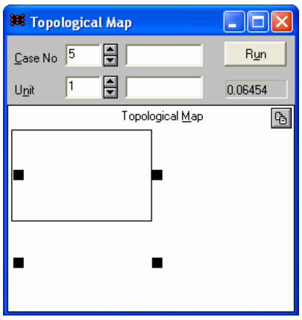


Figure 13. The 5th question's topological map

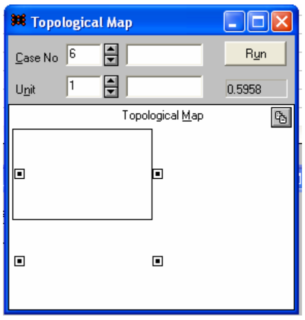


Figure 14. The 6th question's topological map

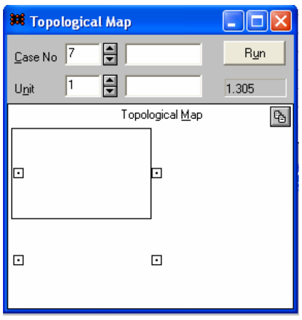


Figure 15. The 7th question's topological map

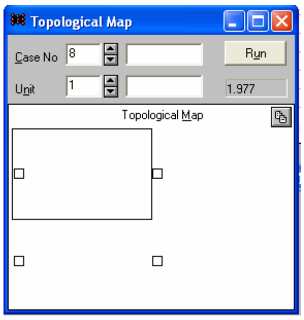


Figure 16. The 8th question's topological map

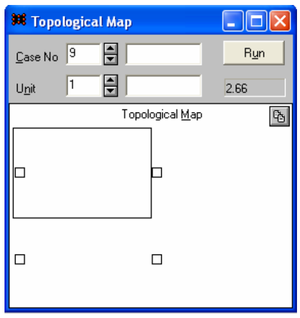


Figure 17. The 9th question's topological map

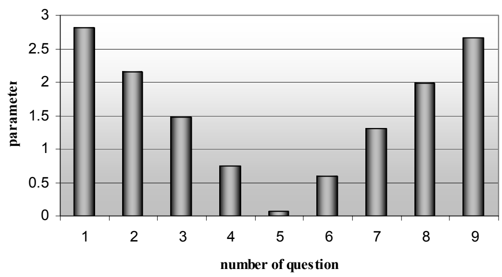


Figure 18. Parameters of the *Topological Map* for every question

During a current measurement processing each degree of the closeness of cluster elements is analyzed. The lesser the question parameter (*Run* parameter) the more meaningful is question (see Figure 3: the 1st and 9th questions have the least meaningfulness.

2.3. CREDITING OF A PHYSICAL PERSON

Business situations of physical person crediting are standard for nowadays. But the problem for credit establishment manager is to collect all possible (official and unofficial) information about a client. The manager of credit establishment often uses special questionnaire. An evaluation scale for any client answer gives some system information on a business situation. Collecting enough points' sum a physical person can hope on a credit. An evaluation scale is based on expert estimations and crediting experience.

Problem 2. Evaluation of crediting risks

In the framework of *Statistica Neural Networks software* the classification problem of client abilities can be solved on the basement of multi-layered perceptron model, radial base function model, Kohonen model, probabilistic neural network model and linear neural network model [3].

The crediting problem is the classification task. All clients are subdivided into three classes, namely, reliable clients, non-reliable clients and probable clients.

Step 1. Create a data file. The number of inputs is 37, outputs - 1. Pay attention to nominal variables in a Table 1. The more variants of variables, the more additional columns (inputs) are necessary.

TABLE 2. Example of presentation of nominal variable

Working status	**v**	**u**	**k**	**n**	**s**	**pi**
	0	**0**	**1**	**0**	**0**	**0**
	1	**0**	**0**	**0**	**0**	**0**
	0	**0**	**1**	**0**	**0**	**0**

Step 2. Networking. Use the button *Advise.*

Step 3. Network training. *Train-Propagation Back*. Amount of epochs is 100. Right after training of network the chart of perceptron is built.

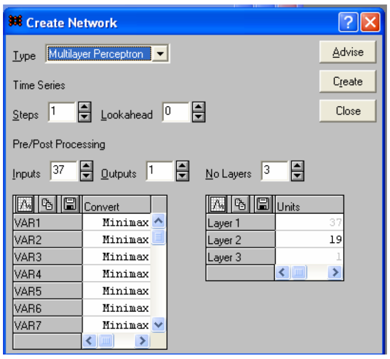


Figure 19. Network type's choice

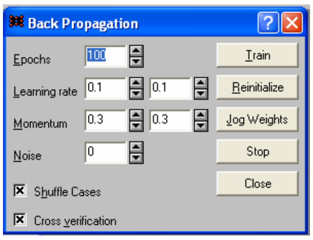


Figure 20. Network training

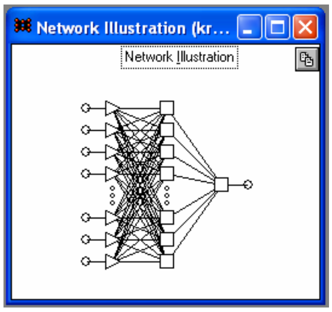


Figure 21. 3-layered perceptron

Step 4. Classification of client. *Run-off Case One*. In the opened window it is necessary to enter all entrances of supervision and find an unknown output in the cell *of Output*.

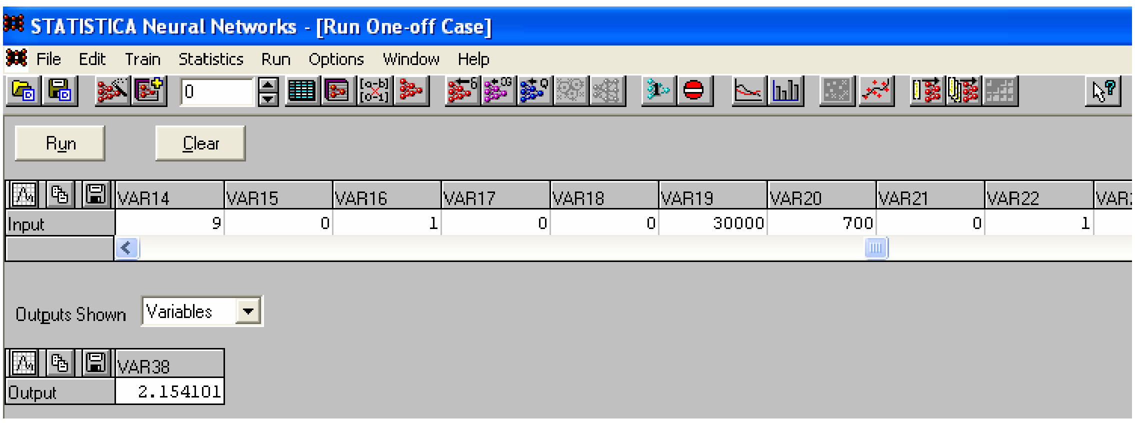


Figure 22. Classification

2.4. FUND MARKET PROGNOSTICATION

Regression tasks in the framework of *Statistica Neural Networks software* can be solved in some ways, namely, using a multi-layered perceptron, radial base function, generalized-regressive network and linear network.

Problem 3. Prognostication of currency exchange course

Use a multi-layered perceptron's model. The basic initial information is placed in Table 3.

TABLE 3. Ls-$ currency exchange course

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Month											
I	0.546	0.544	0.563	0.595	0.569	0.583	0.614	0.638	0.587	0.537	0.533
II	0.541	0.546	0.578	0.592	0.579	0.594	0.618	0.642	0.583	0.535	0.540
III	0.522	0.547	0.580	0.594	0.586	0.596	0.624	0.64	0.584	0.543	**0.531***
IV	0.508	0.551	0.583	0.596	0.59	0.597	0.63	0.637	0.584	0.547	
V	0.514	0.553	0.578	0.595	0.593	0.61	0.632	0.627	0.570	0.551	
VI	0.512	0.554	0.575	0.600	0.597	0.601	0.639	0.616	0.565	0.546	
VII	0.513	0.552	0.580	0.601	0.598	0.604	0.639	0.601	0.572	0.543	
VIII	0.529	0.548	0.590	0.603	0.586	0.611	0.628	0.605	0.577	0.546	
IX	0.54	0.552	0.588	0.587	0.582	0.618	0.622	0.605	0.574	0.546	
X	0.534	0.556	0.584	0.570	0.576	0.621	0.625	0.607	0.558	0.541	
XI	0.535	0.550	0.581	0.574	0.581	0.624	0.63	0.601	0.558	0.529	
XII	0.538	0.556	0.590	0.571	0.583	0.619	0.632	0.598	0.546	0.52	

*) "the real value" – the goal of prognostication

Step 1. Create a data file (Figure 21).

Step 2. Open data file (Figure 22).

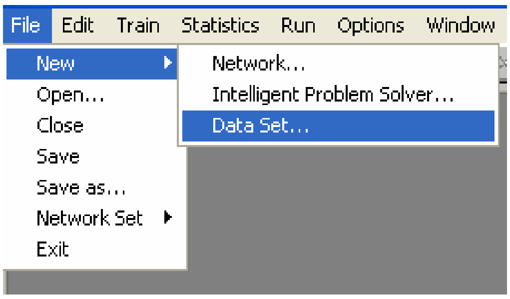


Figure 23. Data file creation

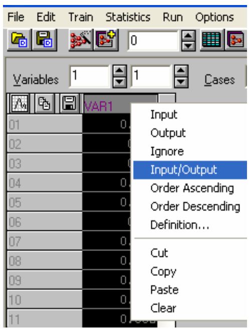


Figure 24. Variable type's choice

Step 3. Create a neural network

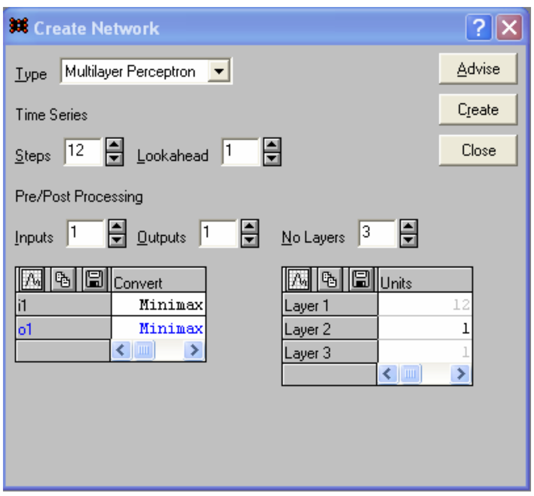


Figure 25. Perceptron's parameters definition

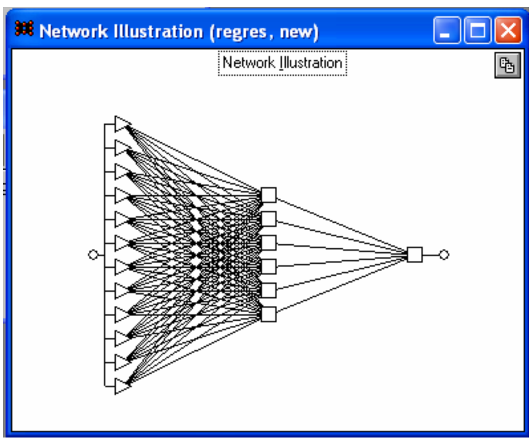


Figure 26. Three-layered perceptron

Step 4. Network training. Let us use 55 *teaching (Training)* and 55 verificating (Verification) observations.

Figure 27. The choice of teaching and verificating observations

Use the *Shuffle* option.

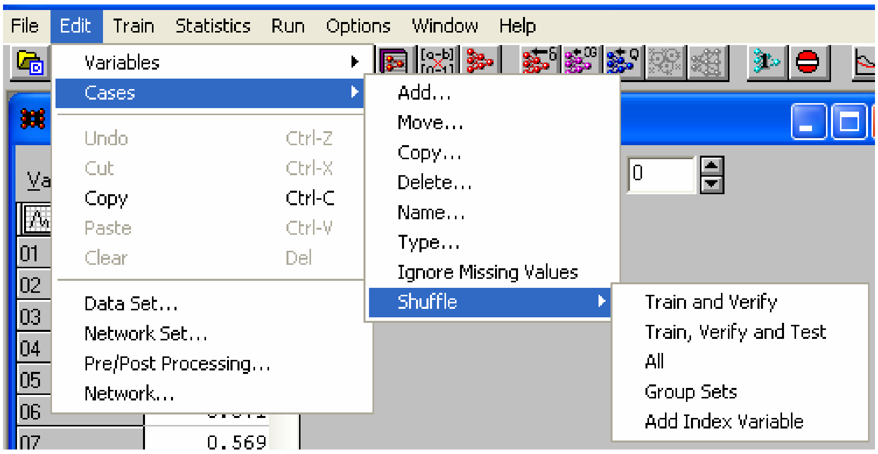


Figure 28. The choice of *Shuffle* option: the *Shuffle* option allows mixing observations of teaching process in a random way

The option of interfusion allows mixing the teaching and verificating observations in a data file. For a network teaching a method of the conjugated gradients is used.

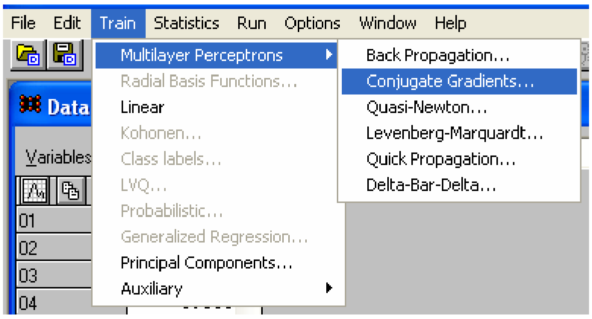


Figure 29. The choice of conjugated gradients for network teaching

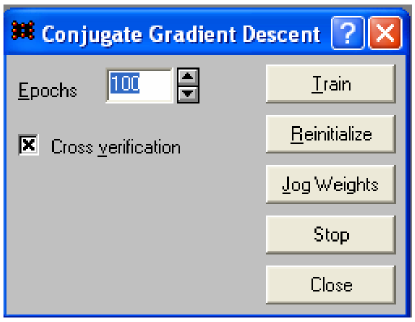


Figure 30. Minimization by conjugated gradients method

The option *Epochs* sets the number of teaching epochs during one teaching cycle. A default value 100 is accepted.

Step 5. Estimation of quality of prognosis. To estimate a quality the network operation we should open the window *Regression Statistics (*the button *Run).*

Step 6. Build the *1-step forward* prognosis (the window *Run Single Case).*

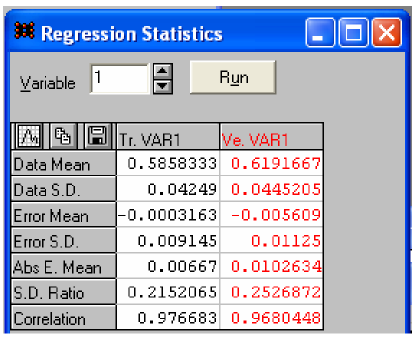


Figure 31. Estimation of prognosis quality

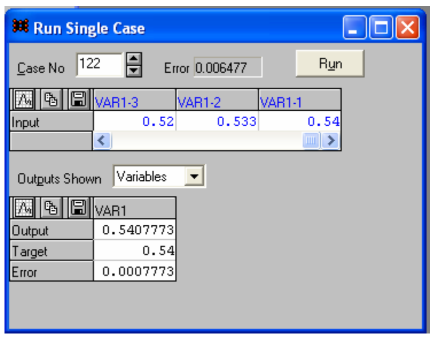
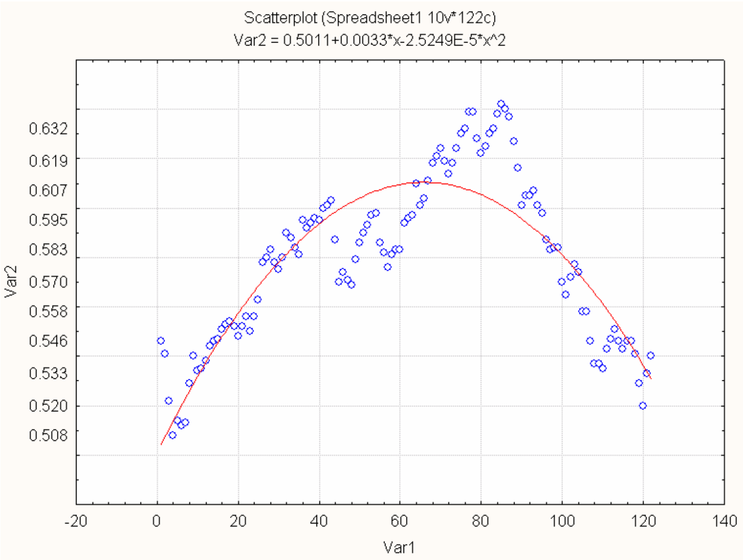


Figure 31. *1-step forward* prognosis on the basement of the developed trained neural network

In the field *Case No* we enter the number of observation (e.g. 122) and obtain the result of prognosis (*Output=0.5407773).*

2.4.1. A comparison of polynomial trend and multi-layered perceptron approaches



The usual polynomial trend is presented on the Figure 32 (see also Table 3).

Figure 32. Polynomial trend of dollar exchange course dynamics: **Var1** is the month number; **Var2** is the exchange course

The polynomial approach gives on March 2005 the value 0,520. Compare the results of prognostication (see Table 4).

TABLE 4. Comparison of prognostication results

	Multi-layered perceptron	Polynomial trend
Prognosis	0,540	0,520
Real value	0,531	0,531
Absolute error	+ 0,009	- 0,011

4. Conclusion

Neural network and genetic algorithms applications are very convenient for business situation analysis. The main problem is the correct choice of neural network type, taking into account the necessary number of inputs and outputs. The presented three business tasks' solutions demonstrate useful algorithms. Thus, the first problem solution gives a possibility to optimize questionnaires on the basement of questions quality analysis (*Kohonen network*) and exclude the "worst" ones. The second problem of physical person crediting (*3-layered perceptron*) as a solution gives an effective way for clients' classification and thus the primary information for decision-making. The third problem solution (*3-layered perceptron*) demonstrates the effectiveness of neural network approaches (in comparison with the "traditional" regression) in a currency exchange prognostication on the basement all pre-history details of currency behavior.

The main advantages of neural network technologies are possibilities of training, taking into account all available information about investigated phenomena. This fact essentially differs neural technologies approaches from "formal" and "traditional" regression ones.

Acknowledgment

This investigation is supported by **Grant 04.1039** of Latvian Council of Science

References

[1] Комарцова Л.Г., Максимов А.В. (2002) *Нейрокомпьютеры*. Москва: Издательство МГТУ имени Н.Э. Баумана. 320 с.

[2] Усков А.А., Кузьмин АВ. (2004) *Интеллектуальные технологии управления. Искусственные нейронные сети и нечеткая логика.* Москва: Горячая линия – Телеком. 143 с.

[3] *Нейронные сети STATISTICA Neural Networks*. (2001) Москва: Горячая линия – Телеком. 182 с.

[4] Буянов В.П., Кирсанов К.А., Михайлов Л.М. (2003) *Рискология (управление рисками)*. Москва: Экзамен. 384 с.

[5] http://www.dis.ru/market/arhiv/2000/5/12.html

[6] Leitch D. (1995) *A New Genetic Algorithm for the Evolution of Fuzzy System.* Ph.D. University of Oxford Trinity Term. Robotics Research Group. Department of Engineering Science.

Received on the 21st of June 2005

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 27-32
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

ОЦЕНКА УРОВНЯ СТОХАСТИЧНОСТИ ВРЕМЕННЫХ РЯДОВ ПРОИЗВОЛЬНОГО ПРОИСХОЖДЕНИЯ ПРИ ПОМОЩИ ПОКАЗАТЕЛЯ ХЁРСТА

В. БУТАКОВ, А. ГРАКОВСКИЙ

Институт транспорта и связи
Ломоносова 1, Рига, LV-1019, Латвия
Тел.: (+371)-7100665, Факс: (+371)-7100535, E-mail: avg@tsi.lv

Предлагается алгоритм, выполняющий оценку показателя Хёрста с помощью кусочно-линейной аппроксимации статистики. Предусматривается вариант быстрого метода и метода с усреднением по обрабатываемому периоду. Определение различных значений показателя для разных участков характеристики дает возможность попутно оценить потенциально возможную глубину прогноза, если исследуемый временной ряд обладает должной степенью самоподобия.

Ключевые слова: *показатель Хёрста, прогноз, кусочно-линейная аппроксимация*

Данная работа посвящена проблеме классификации процессов и связанных с ними временных рядов или сигналов. Все стационарные процессы можно разделить на 3 группы: *детерминированные*, *случайные* и *хаотические детерминированные*, занимающие промежуточное положение между первыми двумя. На верхнем графике рисунка 1 мы видим пример такого процесса. Это так называемый «логистический» процесс. Внешне он похож на случайный, расположенный на нижнем графике рисунка 1, но, в отличие от случайного, подчиняется известному закону управления [**2**]. Использование стандартных статистических методов, таких как автокорреляционный анализ [**1**], не позволяет разделить эти процессы. Всё выше перечисленное заставило обратиться к не столь широко распространенному методу анализа как статистика Хёрста.

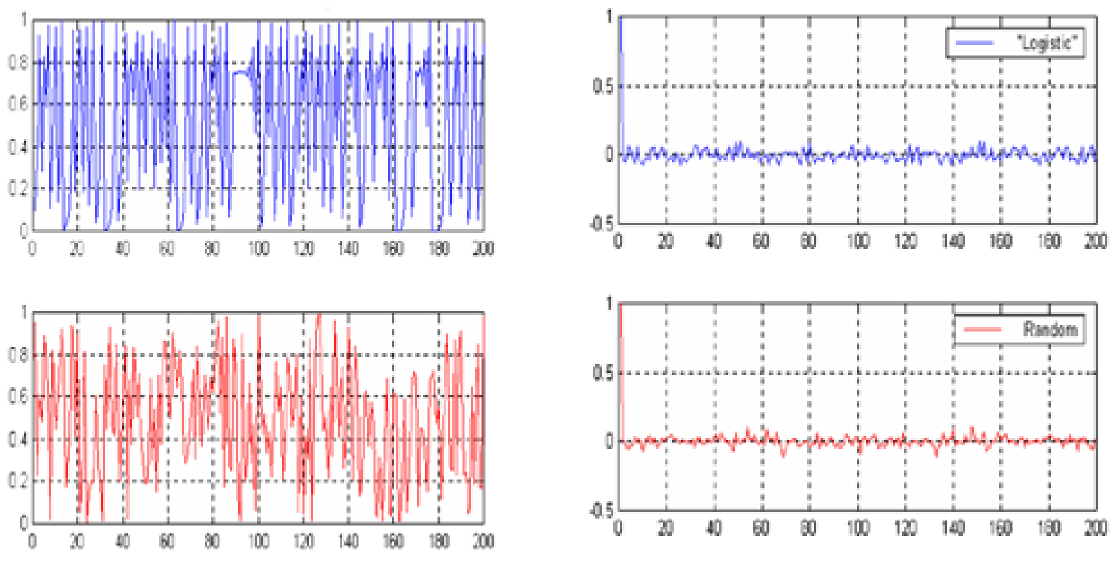


Рис. 1. Логистический и случайный сигналы: автокорреляционная функция

Хёрст был гидрологом, который начал работать над проектом нильской плотины около 1907 г., и прожил в регионе Нила почти сорок лет. Все это время он занимался проблемой контроля за уровнем воды в резервуаре. Проблема заключалась в том, какой ежегодный сброс воды выбрать, чтобы резервуар никогда не переполнялся и не оставался пустым. При создании модели было выдвинуто общее предположение о том, что неуправляемая часть системы — в данном случае приток воды от дождей — следует случайным блужданиям.

Хёрст измерял колебания уровня воды в резервуаре относительно среднего с течением времени [**2**]. Можно было ожидать, что диапазон этих флуктуаций будет меняться в зависимости от величины временного промежутка измерений. Если ряд случайный, размах будет увеличиваться пропорционально корню квадратному из времени. Для калибровки этих временных измерений Хёрст ввел безразмерное отношение посредством деления размаха на стандартное отклонение наблюдений. Этот способ анализа стал называться методом нормированного размаха (***R/S***-анализ). Хёрст показал, что большинство естественных явлений, включая речные стоки, температуру, осадки, солнечные пятна, следуют «смещенному случайному блужданию» — тренду с шумом. Величина коэффициента ***H*** (это и есть показатель Хёрста) характеризует отношение силы тренда (детерминированный фактор) к уровню шума (случайный фактор).

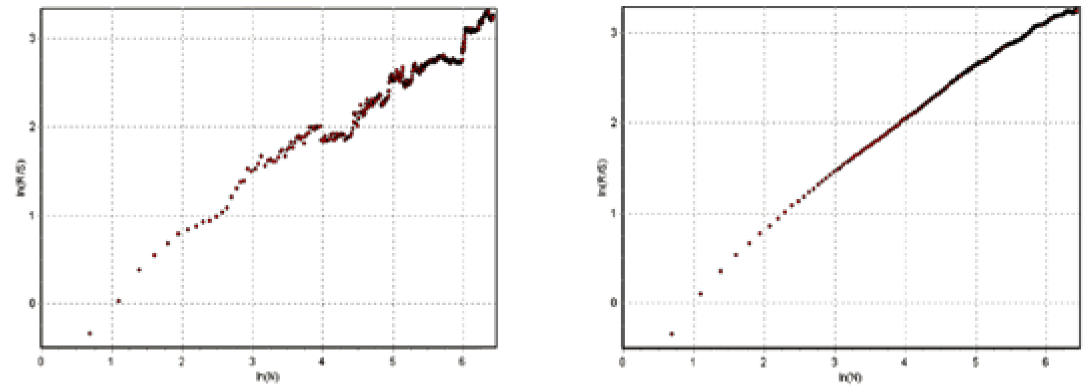


Рис. 2. Алгоритмы: быстрый (слева) и «с усреднением» (справа)

Если алгоритм даёт слишком изломанный график (рис. 2) зависимости, можно прибегнуть к также реализованному в программе более медленному алгоритму усреднения движущимся окном. Вычисление показателя Хёрста производится по следующей схеме:

1. Сначала вычисляются отклонения от среднего значения:

$$X_{t,N} = \sum_{u=1}^{t}(e_u - M_N)\,, \tag{1}$$

где N – длина периода, меняющаяся от 2 до <длины временного ряда>; t – переменная, меняющая своё значение от 1 до $N-1$; M_N – среднее N элементов; e – конкретный элемент временного ряда.

2. На каждой итерации мы получаем $N-1$ значений $X_{t,n}$, которые мы используем в следующей формуле:

$$R := Max(X_{t,N}) - Min(X_{t,N})\,, \tag{2}$$

где R – размах отклонения X.

3. Далее мы нормируем размах делением на стандартное отклонение S, которое вычисляется по N значениям.
4. Логарифмируем R/S и N и строим на основании полученных данных график.
5. По графику функции ***log(R/S)*** от ***log(N)*** находим наклон путём линейной аппроксимации. Тангенс угла этого наклона и является показателем Хёрста.

Другой способ вычисления показателя Хёрста практически аналогичен рассмотренному выше, за исключением того, что существует ещё один цикл, обрамляющий выше описанную процедуру. С помощью этого цикла осуществляется передвижение периода N по всему временному ряду. Соответственно t меняется уже не от единицы, а от начало периода N, который не совпадает с началом временного ряда. В результате мы получаем несколько показателей ***R/S***. На графике отображается логарифм среднего значения ***R/S***.

Чаще всего результатом ***R/S*** анализа является искривленная линия. Поэтому инструментом исследования была выбрана кусочно-линейная аппроксимация, что позволяет определять показатель Хёрста на нескольких интервалах длины периода, где основную оценку даёт центральный интервал.

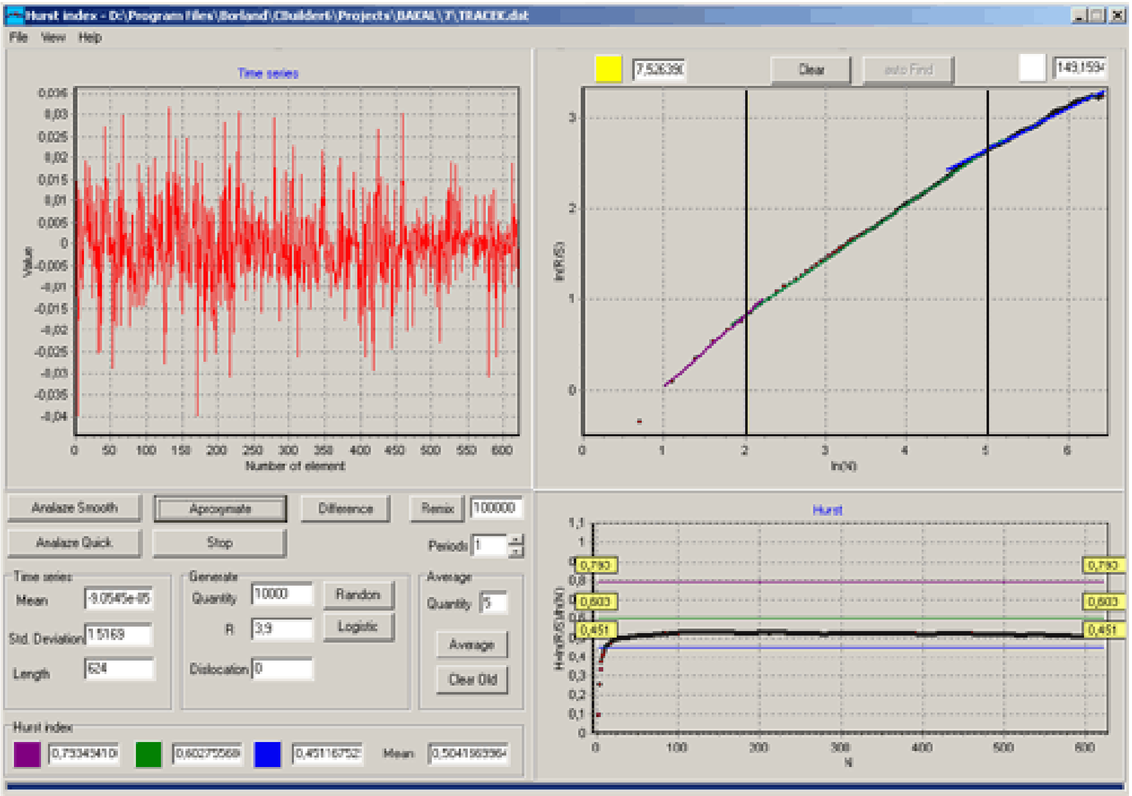


Рис. 3. Интерфейс программы вычисления показателя Хёрста

На рис. 3 представлен интерфейс программы. Программа представляет собой инструмент для оценки показателя Хёрста двумя различными методами, дающими близкий друг к другу результат, но существенно отличающимися по скорости. Предусмотрено автоматическое вычисление основных статистических характеристик (среднего и стандартного отклонения). Также имеется блок генерации модельных сигналов и блок, осуществляющий сглаживание сигнала по заданному количеству точек.

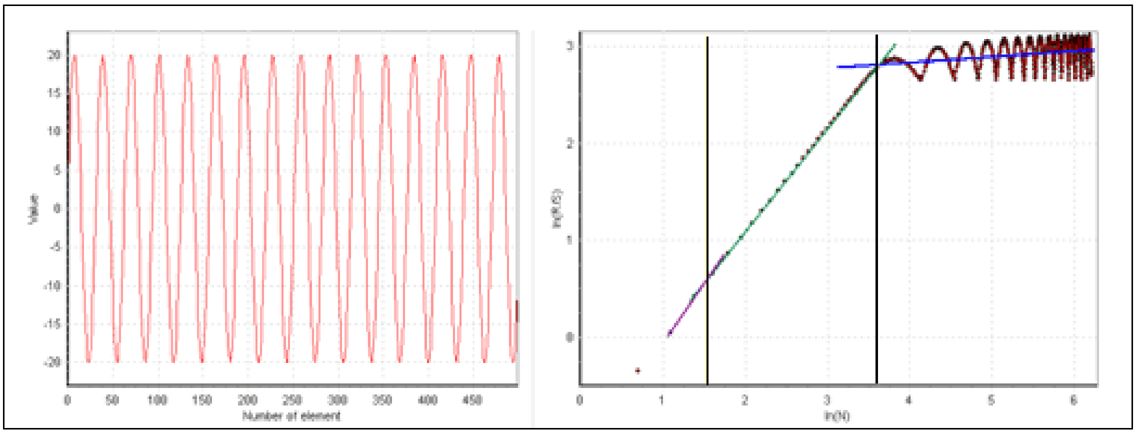


Рис. 4. Синусоидальный сигнал. Исходный график (слева) и график зависимости Хёрста

Проверка работоспособности алгоритма проводилась на различных модельных сигналах. Например, для синусоидального сигнала (рис. 4), т.е. детерминированного, показатель Хёрста равен 1,026, что подчеркивает наличие жесткого закона управления. Псевдослучайный сигнал, полученный с помощью стандартного генератора случайных чисел (рис. 5), демонстрирует некоторое превышение уровня 0,5 – уровня идеального случайного сигнала. Показатель Хёрста равен 0,56, что объясняется существованием алгоритма генерации этого сигнала.

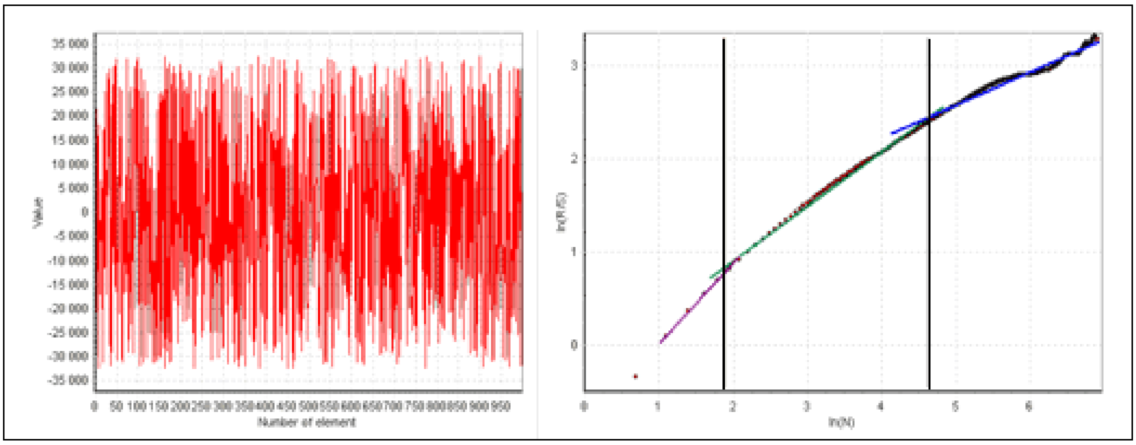


Рис. 5. Случайный сигнал. Исходный график (слева) и график зависимости Хёрста

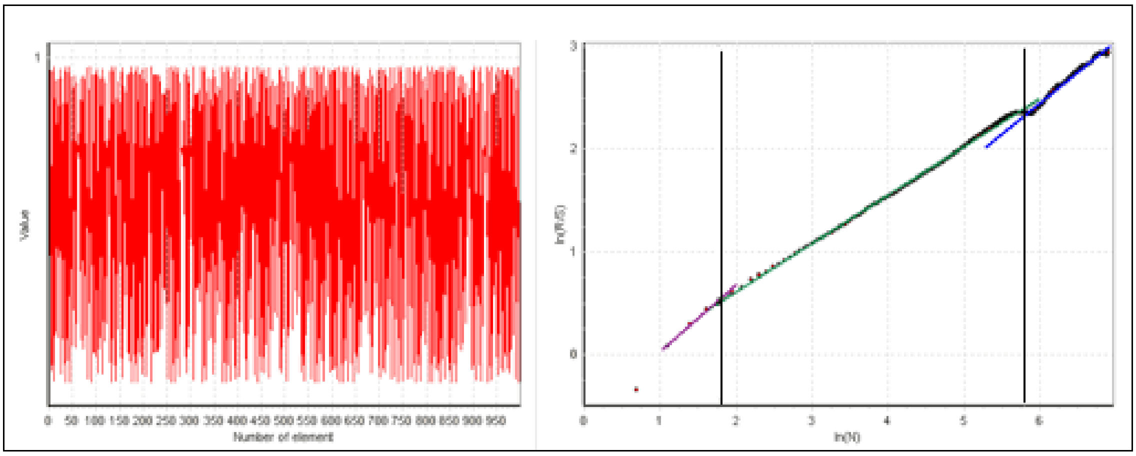


Рис. 6. Логистический сигнал. Исходный график (слева) и график зависимости Хёрста

В то же самое время логистический хаотический сигнал (рис. 6) даёт значение меньшее, чем уровень 0,5, а именно – 0,46. Как видно, величина показателя Хёрста в целом позволяет классифицировать эти сигналы.

Было рассмотрено также влияние сглаживания исходного сигнала. Блок Average, интегрированный в программу, позволяет осуществить сглаживание сигнала по заданному количеству точек. Показатель Хёрста для логистического сигнала (рис. 6) с параметром R=3,9 равен 0,46, что характеризует его как быстро меняющий своё направление сигнал, очень близкий к стохастичному. После выполнения сглаживания (рис. 7) показатель становиться равным 0,737. Такое изменение обусловлено тем, что при сглаживании сигнал становится менее «дёрганым», и в нем начинает проявляться определенная закономерность.

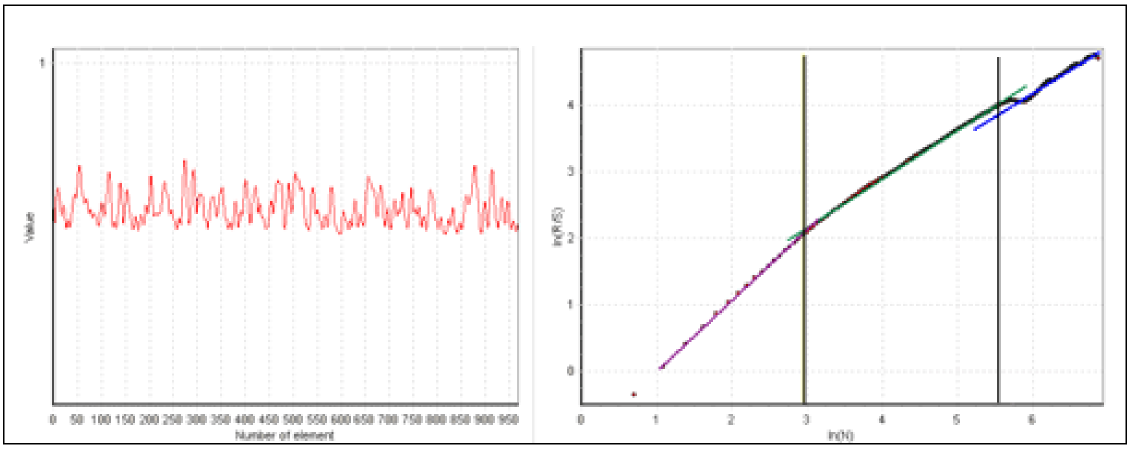


Рис. 7. Логистический сигнал после 10-кратного сглаживания 3-мя точками

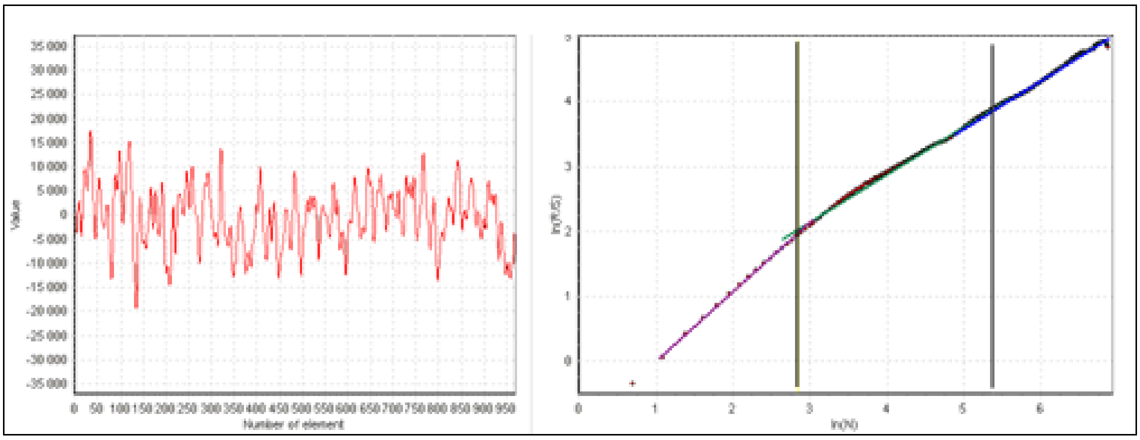


Рис. 8. Случайный сигнал после 10-кратного сглаживания 3-мя точками

Точно такое же исследование проведено со случайным сигналом. Показатель Хёрста при этом изменился с 0,56 до 0,733. То есть, после сглаживания эти процессы опять стали не различимыми.

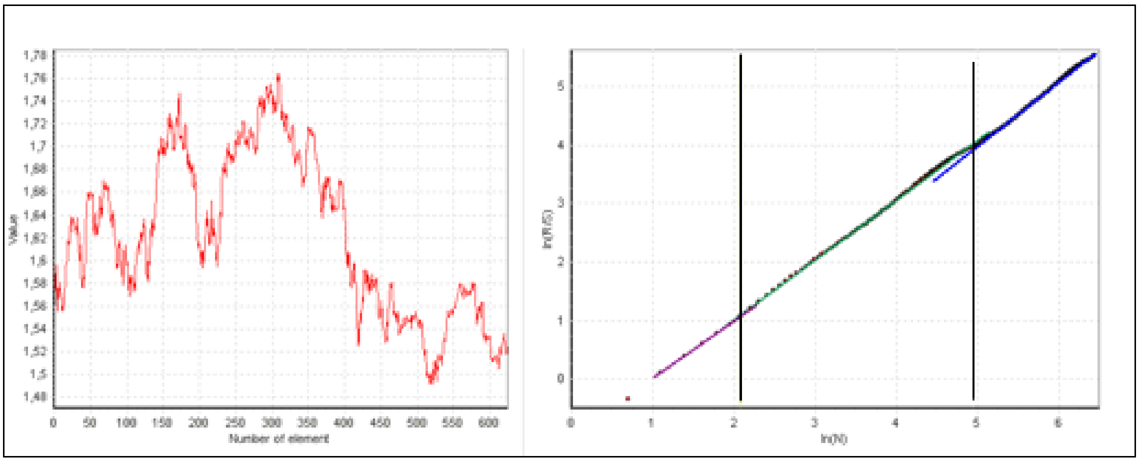


Рис. 9. Курс валют USD/DM за 1994-1996 гг.

При анализе персистентных сигналов, например временного ряда, построенного на основании ежедневного курса валют USD/DM за период с 1994 по 1996 годы, мы получаем показатель Хёрста, очень близкий или равный единице (рис. 9).

Для анализа таких сигналов надо использовать разность элементов временного ряда (рис. 10). В этом случае результат получается равным 0,58, что близко к показателю Хёрста псевдослучайного сигнала (0,56). Это говорит о том, что данный процесс имеет скрытый закон, сходный со стандартным генератором случайных чисел.

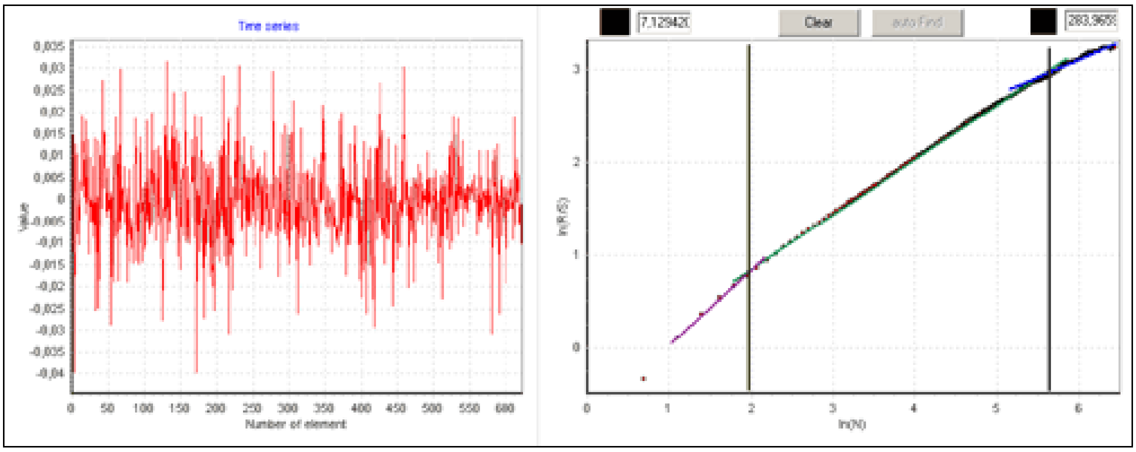


Рис. 10. Разность (динамика) временного ряда курса валют USD/DM за 1994-1996 гг.

Кроме того, из результатов анализа можно получить некоторую оценку интервалов предсказуемости поведения данного ряда [**3**]. Эти границы характеризуются точками излома статистики Хёрста, на которых оценка показателя Хёрста существенно меняется [**2**]. Например, для данного временного ряда очевидные изломы характеристики соответствуют временным интервалам 10 и 287. Значения показателя Хёрста на интервале от 0 до 10 – 0,81, от 10 до 287 – 0,58 и от 287 до конца временного ряда – 0,38.

Это можно интерпретировать следующим обоазом. На интервале до 10 дней процесс ведёт себя достаточно предсказуемо и может быть спрогнозирован. На интервале от 10 до 287 дней закон управления процессом аналогичен генератору псевдослучайных чисел. И, наконец, на интервале свыше 287 дней процесс меняет характер (закон управления). Он ведёт себя антиперсистентно, т.е. если процесс демонстрирует рост в предыдущем локальном периоде колебаний, то, скорее всего, в следующем периоде начнётся спад. Этот момент хорошо виден на рис. 9. Стоит отметить, что кривая курса валют в момент, соответствующий 287 дням, прекращает свой рост и начинает плавное падение.

Как видно из всего выше сказанного показатель Хёрста можно использовать для классификации и оценки стохастичности и/или детерминированности реальных процессов, а также для оценки временных интервалов предсказуемости.

Литература

[1] Bendat J., Piersol A. (1986) *Random data. Analysis and Measurement Procedures*. New York: John Wiley & Sons, Inc.

[2] Peters E. (1996) *Chaos and Order in the Capital Markets. A New View of Cycles, Prices, and Market Volatility*. New York: John Wiley & Sons, Inc.

[3] Williams B. (1998) *Trading Chaos. Applying Expert Techniques to Maximize Your Profit*. New York: John Wiley & Sons, Inc.

Received on the 21st of June 2005

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 33-40
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

СИСТЕМА MAP/M/C С АДРЕСНОЙ СТРАТЕГИЕЙ ПОВТОРНЫХ ВЫЗОВОВ И ИДЕНТИЧНЫМИ ПРИБОРАМИ

В.В. МУШКО

Факультет прикладной математики и информатики
Белорусский государственный университет
пр-т Ф. Скорины, 4, 220050, г. Минск, Беларусь
E-mail: vmushko@tut.by

Рассматривается многоканальная система, имеющая *c* идентичных приборов. Поток, входящий в систему, является марковским. Время обслуживания на каждом приборе имеет экспоненциальное распределение. Интенсивность повторных вызовов линейно зависит от числа вызовов на орбите. Поведение данной системы описывается многомерной цепью Маркова с непрерывным временем, которая принадлежит к классу асимптотически квазитеплицевых цепей Маркова. Получено достаточное условие существования стационарного распределения, разработан и реализован численно алгоритм нахождения стационарного распределения вероятностей и основных характеристик функционирования системы. Представлены численные результаты.

Ключевые слова: *многоканальная система, марковский входящий поток, адресная стратегия повторных вызовов, асимптотически квазитеплицевы цепи Маркова, стационарное распределение*

1. Введение

Важным разделом теории массового обслуживания является теория систем с повторными вызовами ("retrials" или "repeated customers"). Такие системы характеризуются следующим поведением. Если вызов поступил в систему, в которой все приборы и места для ожидания (если имеется буфер) заняты, то он покидает систему на некоторое случайное время, иначе говоря, уходит на орбиту ("orbit" или "retrial group"), а затем повторяет попытки попасть на обслуживание.

Важность этого раздела теории обусловлена его широкими практическими приложениями. Область приложений лежит в оценивании производительности и проектировании телефонных сетей, локальных вычислительных сетей с протоколами случайного множественного доступа, широковещательных радиосетей, мобильных сотовых радиосетей. Наличие повторных попыток получить обслуживание является неотъемлемой чертой этих систем, игнорирование данного эффекта может привести к значительным погрешностям при принятии инженерных решений.

Первые математические результаты, касающиеся систем с повторными вызовами, были опубликованы в 40-х гг. [1]. Обзоры работ, посвященные данным системам, содержатся в статьях [2–6], а также монографиях известных специалистов в области теории систем с повторными вызовами Г.И. Фалина, Дж. Темплтона [7] и С.Н. Степанова [8].

Системы с повторными вызовами отличаются числом приборов, видом интенсивности повторных вызовов, размерами орбиты, наличием очереди, наличием нескольких типов вызовов, стратегией повторов, стратегией первичного доступа.

Более интенсивно исследуются однолинейные системы, в то время как многолинейные системы исследованы в меньшей степени. Это можно объяснить тем, что стохастические процессы, описывающие поведение последних, имеют более сложную структуру. Аналитические результаты получены только в частных случаях, включая случай $c \le 2$, где c – число приборов (см., например, [9]). Для случая $c > 2$ применяют аппроксимационные и численные методы.

Иногда рассматривают системы, в которых повторные вызовы образуют стационарный пуассоновский поток с постоянной интенсивностью ("constant retrial rate") $\alpha_i = \gamma, i \ge 1, \gamma > 0$, не зависящей от числа требований на орбите (см., например, [9]). Этот факт можно интерпретировать двояко. Первый вариант: при наличии i вызовов на орбите каждый вызов получает право совершать повторные попытки независимо от других вызовов через экспоненциально распределенное (с параметром γ / i) время. Второй вариант: только одному из вызовов разрешается совершать повторные попытки через экспоненциально распределенные (с параметром γ) интервалы времени.

Чаще рассматривают системы, в которых суммарная интенсивность повторных вызовов определяется по формуле $\alpha_i = i\alpha, i \geq 0, \alpha > 0$, где i – число вызовов на орбите, α – интенсивность потока повторных попыток одного вызова. Такой механизм повторных вызовов называется классическим ("classical retrial rate"), см., например, [10].

В работе [11] исследуется система с линейной зависимостью ("linear retrial rate") интенсивности потока повторных вызовов с орбиты от текущей величины орбиты:

$$\alpha_i = \begin{cases} 0, & i = 0, \\ i\alpha + \gamma, \alpha > 0, \gamma > 0, & i > 0. \end{cases}$$

В [12] рассмотрена квадратичная зависимость интенсивности повторных вызовов от количества вызовов на орбите $\alpha_i = i^2\beta + i\alpha + \gamma, \beta > 0, \alpha > 0, \gamma > 0$ ("quadratic retrial rate").

Исследование управляемых систем подтолкнуло к созданию моделей, где интенсивность повторных вызовов имеет линейную зависимость от текущей величины орбиты и, кроме того, зависит от состояния марковского управляющего процесса ξ_t

$$\alpha_i = i\alpha^{(\xi)} + \gamma^{(\xi)}, i \geq 1,$$

где ξ – состояние управляющего процесса $\xi(t)$, $\xi \in \{0, \dots, K\}$, i – число вызовов на орбите, $\alpha_0 = 0$ ("modulated retrial rate"). Такие системы рассмотрены, например, в работе [13].

Что касается орбиты, то она может быть конечной (см., например, [14]) или бесконечной (см., например, [15]).

В работах [15] и [14] рассмотрены системы с конечным и бесконечным буферами соответственно.

Вызовы, входящие в систему, могут быть настойчивыми (см., например, [11]) или нетерпеливыми (см., например, [16]).

Для многолинейных систем могут быть рассмотрены различные стратегии доступа к приборам. Так классическая стратегия предполагает, что если в момент повтора имеются один или несколько свободных приборов, то вызов занимает любой из них (см., например, [11]). Стратегия полного доступа заключается в том, что если в момент повтора имеются i свободных приборов, в то время как на орбите находится k повторных вызовов, то $\min\{i, k\}$ вызовов занимают свободные приборы (см., например, [17]). Кроме перечисленных выше, также можно упомянуть о существовании различных схем распределения каналов, которые в основном подразумевают использование зарезервированных каналов ("guard channels") или приоритетных очередей (см., например, [15]).

2. Математическая модель

Рассматривается многоканальная система, имеющая c идентичных приборов. Время обслуживания на каждом приборе имеет экспоненциальное распределение с параметром μ, $\mu > 0$.

Поток, входящий в систему, является марковским (*MAP – Markovian Arrival Process*, введен в [18]). Поведением *MAP* управляет цепь Маркова $\eta_t, t \geq 0$, $\eta_t = \overline{0,W}$, с непрерывным временем. Время пребывания процесса $\eta_t, t \geq 0$, в состоянии η имеет показательное распределение с параметром λ_η, $\eta = \overline{0,W}$. После того, как пребывание в состоянии η заканчивается, процесс $\eta_t, t \geq 0$, перескакивает в состояние η', $\eta' = \overline{0,W}$ с вероятностью $p_k(\eta, \eta')$, при этом сгенерируется k вызовов *MAP*-потока, $k = 0,1$. Предполагается, что скачок из состояния η в это же состояние без генерации вызовов невозможен, т. е. $p_0(\eta, \eta) = 0$. Естественно, предполагается, что вероятности $p_k(\eta, \eta')$ удовлетворяют условию нормировки:

$$\sum_{k=0}^{1} \sum_{\nu'=0}^{W} p_k(\eta, \eta') = 1 \text{ для } \eta = \overline{0,W}.$$

Таким образом, *MAP*-поток полностью характеризуется размерностью $W+1$ управляющего процесса, интенсивностями λ_η времен пребывания этого процесса в своих состояниях, $\eta=\overline{0,W}$, и набором вероятностей $p_k(\eta,\eta')$, $\eta,\eta'=\overline{0,W}$, $k=0,1$.

Информацию о *MAP*-потоке принято хранить в виде матриц D_k, $k=0,1$, размера $(W+1)\times(W+1)$, определяемых следующим образом.

$(D_k)_{\eta,\eta'}$ – (η,η')-й элемент матрицы D_k, $k=0,1$ – имеет вид:

$(D_1)_{\eta,\eta'}=\lambda_\eta p_1(\eta,\eta')$, $\eta,\eta'=\overline{0,W}$,

$$(D_0)_{\eta,\eta'}=\begin{cases}\lambda_\eta p_0(\eta,\eta'), \eta\neq\eta', \eta,\eta'=\overline{0,W},\\ -\lambda_\eta, \eta=\eta', \eta=\overline{0,W}.\end{cases}$$

Нетрудно видеть, что элементами матрицы D_1 являются интенсивности перехода процесса $\eta_t, t\geq 0$, сопровождающегося генерацией вызова. Аналогичный смысл имеют недиагональные элементы матрицы D_0, диагональными элементами матрицы D_0 являются взятые с противоположным знаком интенсивности выхода процесса $\eta_t, t\geq 0$, из своих состояний.

Обозначим через θ вектор-строку стационарных вероятностей цепи $\eta_t, t\geq 0$. Он удовлетворяет уравнениям $\theta(D_0+D_1)=\vec{0}$, $\theta\boldsymbol{e}=1$, где $\vec{0}$ – вектор-строка, состоящий из нулей, $\boldsymbol{e}$ – вектор-столбец, состоящий из единиц. Размерности векторов $\vec{0}$ и $\boldsymbol{e}$ определяются из контекста.

Средняя интенсивность *MAP*-потока (фундаментальное среднее) λ задается формулой $\lambda=\theta D_1\boldsymbol{e}$.

В момент прибытия вызов выбирает для обслуживания r-й прибор с вероятностью $1/c$, $r=\overline{1,c}$. Если выбранный прибор свободен, то вызов занимает его и после обслуживания покидает систему. Если выбранный прибор занят, то вызов направляется в некоторую виртуальную динамическую область, называемую орбитой, и пытается получить обслуживание позже. Каждый вызов, находящийся на орбите, делает повторные попытки через интервалы времени, имеющие экспоненциально распределенную длину с параметром $\alpha, \alpha>0$, независимо от других вызовов. В момент повтора вызов выбирает r-й прибор с вероятностью $1/c$, $r=\overline{1,c}$. Если прибор свободен, то вызов занимает его и покидает систему после обслуживания. Если прибор занят, то вызов возвращается на орбиту, даже если один или несколько других приборов свободны в этот момент. Вызовы с орбиты пытаются получить обслуживание до тех пор, пока им не удастся занять прибор, выбранный при соответствующей попытке.

3. Описание поведения системы в терминах цепи Маркова с непрерывным временем

Рассмотрим процесс $\zeta_t=\{i_t, m_t, \eta_t\}, t\geq 0$, где

- $i_t, t\geq 0$ – число вызовов на орбите в момент времени *t*, $i_t\geq 0$;
- $m_t, t\geq 0$ – число занятых приборов в момент времени *t*, $m_t=\overline{0,c}$;
- $\eta_t, t\geq 0$ – состояние управляющего процесса *MAP*-потока в момент времени *t*, $\eta_t=\overline{0,W}$.

Очевидно, что процесс $\zeta_t, t\geq 0$, является цепью Маркова с непрерывным временем. Обозначим стационарное распределение этой цепи через

$$p(i,m,\eta)=\lim_{t\to\infty}P\{i_t=i, m_t=m, \eta_t=\eta\},\ i\geq 0,\ m=\overline{0,c}, \eta=\overline{0,W}. \quad (1)$$

Условие существования предела в (1) приведено ниже и предполагается далее выполненным.

Занумеруем состояния цепи Маркова $\zeta_t, t \ge 0$, в лексикографическом порядке и сформируем векторы-строки вероятностей $\vec{p}_i$, соответствующие состоянию i числа вызовов на орбите. Размерности этих векторов равны $M = (c+1)\overline{W}$, $\overline{W} = W + 1$.

Сформируем также макровектор $\vec{p} = (\vec{p}_0, \vec{p}_1, \ldots, \vec{p}_i, \ldots)$.

Лемма. Вектор $\vec{p}$ является единственным решением системы:

$$\begin{aligned} &\vec{p}Q = \vec{0}, \\ &\vec{p}\boldsymbol{e} = 1, \end{aligned} \qquad (2)$$

где инфинитезимальный генератор Q цепи Маркова $\zeta_t, t \ge 0$, имеет форму

$$Q = \begin{pmatrix} Q_{0,0} & Q_{0,1} & 0 & 0 & \cdots \\ Q_{1,0} & Q_{1,1} & Q_{1,2} & 0 & \cdots \\ 0 & Q_{2,1} & Q_{2,2} & Q_{2,3} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix},$$

где блоки $Q_{i,j}$ вычисляются следующим образом:

$Q_{i,i-1} = i\alpha L, i \ge 1$,

$Q_{i,i} = A - i\alpha B,\ i \ge 0$,

$Q_{i,i+1} = S, i \ge 0$,

квадратные матрицы A, B, L, S размерности M имеют вид

$$A = \begin{pmatrix} D_0 & D_1 & O & O & \cdots & O & O \\ \mu I & D_0 - \mu I & D_1 \cdot (c-1)/c & O & \cdots & O & O \\ O & 2\mu I & D_0 - 2\mu I & D_1 \cdot (c-2)/c & \cdots & O & O \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ O & O & O & O & \cdots & D_1 \cdot 2/c & O \\ O & O & O & O & \cdots & D_0 - (c-1)\mu I & D_1 \cdot 1/c \\ O & O & O & O & \cdots & c\mu I & D_0 - c\mu I \end{pmatrix},$$

$$B = diag(I,\quad I\cdot(c-1)/c,\quad I\cdot(c-2)/c,\quad \ldots,\quad I\cdot 2/c,\quad I\cdot 1/c,\quad O),$$

$$L = \begin{pmatrix} O & I & O & \cdots & O & O & O \\ O & O & I\cdot(c-1)/c & \cdots & O & O & O \\ O & O & O & \cdots & O & O & O \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ O & O & O & \cdots & O & I\cdot 2/c & O \\ O & O & O & \cdots & O & O & I\cdot 1/c \\ O & O & O & \cdots & O & O & O \end{pmatrix},$$

$$S = diag(O,\quad D_1\cdot 1/c,\quad D_1\cdot 2/c,\quad \ldots,\quad D_1\cdot(c-2)/c,\quad D_1\cdot(c-1)/c,\quad D_1).$$

Здесь I – тождественная матрица размерности $\overline{W}$, O – нулевая матрица размерности $\overline{W}$, $diag\,(E_1, E_2, \ldots, E_{c+1})$ – диагональная матрица с диагональными блоками $E_1, E_2, \ldots, E_{c+1}$.

Доказательство. Составив систему уравнений равновесия для компонент вектора $\vec{p}$ и перейдя к матричному виду, получим (2).

4. Стационарное распределение цепи Маркова. Условие эргодичности

Очевидно, что цепь Маркова $\zeta_t, t \geq 0$, принадлежит к классу асимптотически квази-теплицевых цепей Маркова с непрерывным временем (asymptotically quasi-Toeplitz Markov chains – AQTMC, [19]). Поэтому аппарат асимптотически квазитеплицевых цепей Маркова с непрерывным временем может быть применен для установления условий существования стационарного распределения и вычисления вектора $\vec{p}$ стационарных вероятностей.

Обозначим

$$\widetilde{Y}(z) = \widetilde{Y}_0 + \widetilde{Y}_1 z + \widetilde{Y}_2 z^2, \ |z| \leq 1, \qquad (3)$$

где

$$\widetilde{Y}_k = \lim_{i \to \infty} P_{i,i+k-1}, \ \ k = 0,1,2,$$

$$P_{i,i-1} = i\alpha\,(F + i\alpha\,\hat{I}_M)^{-1} L, \ i \geq 1,$$

$$P_{i,i} = I_M + (F + i\alpha\hat{I}_M)^{-1}(A - i\alpha B), \ i \geq 0,$$

$$P_{i,i+1} = (F + i\alpha\hat{I}_M)^{-1} S, \ i \geq 0,$$

$$F = I_{c+1} \otimes diag\{\lambda_0, \ldots, \lambda_W\} + c\mu I_M,$$

I_M – тождественная матрица размерности M, матрица $\hat{I}_M$ получена из матрицы I_M заменой последнего диагонального блока размерности $\overline{W}$ на нулевой.

Как следует из [19], достаточное условие существования стационарного распределения цепи Маркова $\zeta_t, t \geq 0$, имеет следующую форму:

$$\vec{X}\,\widetilde{Y}'(1)\boldsymbol{e} < 1, \qquad (4)$$

где вектор $\vec{X}$ удовлетворяет уравнениям:

$$\vec{X}\,\widetilde{Y}(1) = \vec{X}, \qquad (5)$$

$$\vec{X}\boldsymbol{e} = 1.$$

Используя это утверждение, докажем следующую теорему.

Теорема 1. Стационарное распределение цепи Маркова $\zeta_t, t \geq 0$, существует, если выполнено следующее условие:

$$\rho = \frac{\lambda}{c\mu} < 1. \qquad (6)$$

Доказательство. Подставляя (3) в (4), (5), получим:

$$\vec{X}[I_M - B + \bar{I}_M F^{-1}(A + 2S)]\boldsymbol{e} < 1, \qquad (7)$$

где вектор $\vec{X}$ удовлетворяет уравнениям:

$$\vec{X}\begin{pmatrix} -I & I & O & \cdots & O & O & O \\ O & -I\cdot(c-1)/c & I\cdot(c-1)/c & \cdots & O & O & O \\ O & O & -I\cdot(c-2)/c & \cdots & O & O & O \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ O & O & O & \cdots & -I\cdot 2/c & I\cdot 2/c & O \\ O & O & O & \cdots & O & -I\cdot 1/c & I\cdot 1/c \\ O & O & O & \cdots & O & F_{c+1}^{-1}c\mu & F_{c+1}^{-1}(D_0 + D_1 - c\mu I) \end{pmatrix} = \vec{0}, \qquad (8)$$

$\vec{X}\boldsymbol{e} = 1$,

F_{c+1} – последний диагональный блок матрицы F, имеющий размерность $\overline{W}$, $\bar{I}_M = I_M - \hat{I}_M$.

Представим вектор $\vec{X}$ в виде $\vec{X} = (X_1, X_2, \ldots, X_{c+1})$, где блок X_l, $l = \overline{1, c+1}$, имеет размерность $\overline{W}$. Очевидно, что вектор $\vec{X}$ имеет только два ненулевых блока X_c и X_{c+1}. Тогда (7), (8) перепишем в виде

$$(c-1)/c \cdot X_c\boldsymbol{e} + X_{c+1}(I + F_{c+1}^{-1}(D_0 + 2D_1))\boldsymbol{e} < X_c\boldsymbol{e} + X_{c+1}\boldsymbol{e}, \tag{9}$$

$$\begin{cases} -1/c \cdot X_c + c\mu X_{c+1}F_{c+1}^{-1} = \vec{0}, \\ 1/c \cdot X_c + X_{c+1}F_{c+1}^{-1}(D_0 + D_1 - c\mu I) = \vec{0}, \end{cases} \tag{10}$$

где $(X_c + X_{c+1})\boldsymbol{e} = 1$.

Выразим из первого уравнения системы (10) X_c и подставим полученное выражение в (9). Приведя подобные слагаемые, запишем (9) в виде

$$X_{c+1}F_{c+1}^{-1}(D_1 - c\mu I)\boldsymbol{e} < 0. \tag{11}$$

Выразив из каждого уравнения системы (10) X_c и приравняв полученные выражения, имеем $X_{c+1}F_{c+1}^{-1}(D_0 + D_1) = \vec{0}$. Очевидно, что $X_{c+1}F_{c+1}^{-1} = a\theta$, где a – константа. Тогда неравенство (11) эквивалентно следующему неравенству:

$\theta(D_1 - c\mu I)\boldsymbol{e} < 0$.

Что и следовало доказать.

5. Стационарное распределение цепи Маркова. Алгоритм вычисления

Предположим, что условие (6) выполнено. Так как цепь Маркова $\zeta_t, t \ge 0$, принадлежит к классу AQTMC, то следующее утверждение следует прямо из [19].

Теорема 2. Векторы $\vec{p}_i, i \ge 0$, стационарных вероятностей имеют следующую форму

$\vec{p}_i = \vec{p}_0 F_l, l \ge 1$, где матрицы $F_i, i \ge 1$, определяются из формул:

$$F_0 = I,\ F_l = \sum_{i=0}^{l-1} F_i \overline{Q}_{i,l}(-\overline{Q}_{l,l})^{-1},\ l \ge 1,$$

матрицы $\overline{Q}_{i,l}$ определяются из формул:

$\overline{Q}_{i,l} = O, i < l-1, i > l+1$,

$\overline{Q}_{l-1,l} = Q_{l-1,l}$,

$\overline{Q}_{l,l} = Q_{l,l} + Q_{l,l+1}G_l$,

$\overline{Q}_{l+1,l} = Q_{l+1,l} + Q_{l+1,l+1}G_l + Q_{l+1,l+2}G_{l+1}G_l$,

где матрицы G_i удовлетворяют следующей обратной рекурсии:

$G_i = (-Q_{i+1,i+2}G_{i+1})^{-1}Q_{i+1,i}, i \ge 0$.

$\vec{p}_0$ есть единственное решение следующей системы алгебраических уравнений:

$\vec{p}_0(-\overline{Q}_{0,0}) = \vec{0}$,

$\vec{p}_0 \sum_{l=0}^{\infty} F_l e = 1$.

Ниже приведены некоторые характеристики функционирования системы:

- среднее число вызовов на орбите $L_0 = \sum_{i=0}^{\infty} i\vec{p}_i e$;
- среднее число занятых приборов $L_s = \sum_{i=0}^{\infty}\sum_{m=0}^{c}\sum_{\eta=0}^{W} mp(i,m,\eta)$;
- среднее число вызовов в системе $L = L_0 + L_s$;
- вероятность того, что все приборы свободны $P_{idle} = \sum_{i=0}^{\infty}\sum_{\eta=0}^{W} p(i,0,\eta)$;
- вероятность того, что все приборы заняты $P_{busy} = \sum_{i=0}^{\infty}\sum_{\eta=0}^{W} p(i,c,\eta)$;
- вероятность того, что k приборов свободно $P_k = \sum_{i=0}^{\infty}\sum_{\eta=0}^{W} p(i,c-k,\eta),\ k=\overline{0,c}$;
- вероятность того, что любой вызов получит обслуживание немедленно после прибытия $P_{hit} = \frac{1}{\lambda}\sum_{i=0}^{\infty}\sum_{m=0}^{c-1}\frac{c-m}{c}\vec{p}(i,m)D_1\boldsymbol{e}$.

6. Численный пример

С использованием инфраструктуры пакета прикладных программ “SIRIUS++” [20] был разработан алгоритм вычисления стационарного распределения вероятностей и характеристик функционирования системы. Для иллюстрации работы программы рассмотрим следующий пример.

Пусть число приборов c равно 4. Интенсивность повторных вызовов α принимает значения из множества $\{1,2,3,4,5,6,7,8,9,10,15,20,25,30,35,40,45,50\}$. Интенсивность обслуживания μ принимает значения из множества $\{0.9861,\ 0.4931,\ 0.3287,\ 0.2465,\ 0.1972,\ 0.1643,\ 0.1408,\ 0.1233,\ 0.1096\}$, при этом загрузка системы ρ варьируется от 0.1 до 0.9.

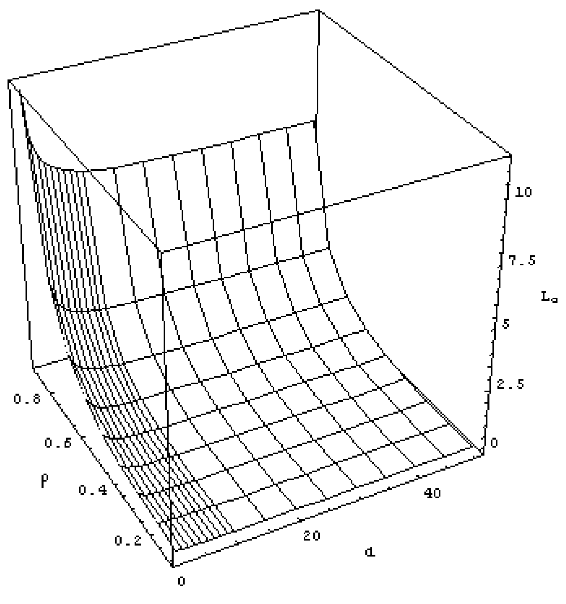


Рисунок 1. Зависимость числа L_0 вызовов на орбите от загрузки системы ρ и интенсивности повторных вызовов α

MAP-поток задается матрицами:

$$D_0 = \begin{pmatrix} -0.4 & 0 & 0 \\ 0 & -0.3 & 0 \\ 0 & 0 & -0.6 \end{pmatrix},$$

$$D_1 = \begin{pmatrix} 0.2 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.1 \\ 0.3 & 0.2 & 0.1 \end{pmatrix}$$

и имеет среднюю интенсивность $\lambda = 0.3944$.

На рис. 1 представлена зависимость числа вызовов на орбите от загрузки системы и интенсивности повторных вызовов. Очевидно, что при увеличении загрузки системы и уменьшении интенсивности повторных вызовов наблюдается увеличение числа вызовов на орбите.

7. Заключение

В данной работе была исследована многоканальная система, имеющая *c* идентичных приборов. Поток, входящий в систему, является марковским. Время обслуживания на каждом приборе имеет экспоненциальное распределение. Интенсивность повторных вызовов линейно зависит от числа вызовов на орбите. Поведение данной системы описывается многомерной цепью Маркова с непрерывным временем, которая принадлежит к классу асимптотически квазитеплицевых цепей Маркова. Получено достаточное условие существования стационарного распределения, разработан и реализован численно алгоритм нахождения стационарного распределения вероятностей и основных характеристик функционирования системы. Представлены численные результаты.

Литература

[1] Kosten L. (1947) On the influence of repeated calls in the theory of probabilities of blocking, *De Ingenier,* **59**, 1-25.

[2] Artalejo J.R. (1999) A classified bibliography of research on retrial queues: Progress in 1990–1999, *Top* **7**, No 2, 187-211.

[3] Artalejo J.R. (1999) Accessible bibliography on retrial queues, *Mathematical and Computer Modelling,* **30**, 223-233.

[4] Falin G.I. (1990) A survey of retrial queues, *Queuing Systems,* **7**, 127-167.

[5] Yang T., Templeton J.G.C. (1987) A survey of retrial queues, *Queuing Systems,* **2**, 201-233.

[6] Kulkarni V.G., Liang H.M. (1997) Retrial queues revisited. Frontiers in Queuing. In: *Models and Applications in Science and Engineering /J.H. Dshalalow (eds.).* CRC Press, Inc., Boca Raton, pp. 19-34.

[7] Falin G.I., Templeton J.G.C. (1997) *Retrial Queues*. London: Chapman&Hall.

[8] Степанов С.Н. (1983) *Численные методы расчета систем с повторными вызовами*. Москва: Наука.

[9] Artalejo J.R. (1996) Stationary analysis of the characteristics of the M/M/2 queue with constant repeated attempts, *Opsearch,* **33**, No 2, 83-95.

[10] Diamond J.E., Alfa A.S. (1998) The MAP/PH/1 retrial queue, *Stochastic Models,* **14,** 1151- 1177.

[11] Dudin A.N., Klimenok V.I. (2000) A retrial BMAP/SM/1 system with linear repeated requests, *Queueing Systems,* **34**, No 1–4, 47-66.

[12] Artalejo J.R., Lopez-Herrero M.J. (2001) On the M/G/1 queues with quadratic repeated attempts, *Statist. Methods,* **3**, No 2, 60-78.

[13] Dudin A.N., Klimenok V.I. (1999) BMAP/SM/1 model with Markov modulated retrials, *Top* **7**, No 2, 267-278.

[14] Choi B.D., Chang Y. (1999) $MAP_1, MAP_2/M/c$ retrial queues with the retrial group of finite capacity and geometric loss, *Mathematical and Computer Modelling,* **30**, 99-113.

[15] Choi B.D., Chang Y. (1999) $MAP_1, MAP_2/M/c$ retrial queues with guard channel and its application to cellular networks, *Top* **7**, No 2, 231-248.

[16] Klimenok V.I., Orlovsky D.S., Dudin A.N. (2004) A retrial BMAP/PH/N system with impatient calls. In: *Proceedings of Fifth International Workshop on Retrial Queues, Seoul, Korea, September 2004,* 89-102.

[17] Artalejo J.R., Gomez-Corral A., Neuts M.F. (2000) Numerical analysis of multiserver retrial queues operating under a full access policy. Advances in Matrix Algorithmic Methods for Stochastic Models. In: *Proc. of the 3rd Int. Conf. on Matrix Analytic Methods /G. Latouche and P. Taylor (eds.).* New Jersey: Notable Publications, Inc., pp. 1-19.

[18] Lucantoni D.M., Meier-Hellstern K.S., Neuts M.F. (1990) A single-server queue with server vacations and a class of non-renewal arrival processes, *Adv. Appl. Prob*., **22**, 676-705.

[19] Klimenok V.I., Dudin A.N. (2005) Continuous-time asymptotically quasi-Toeplitz Markov chains. Queues: flows, systems, networks. In: *Proceedings of the International conference "Mathematical methods of optimisation of telecommunication networks", 22-24 February 2005.* Minsk, 76-84.

[20] Dudin A.N, Tsarenkov G.V., Klimenok V.I. (2002) Software "SIRIUS++" for performance evaluation of modern communication networks. In: *"Modelling and Simulation 2002", 16th European Simulation Multi-conference.* Darmstadt, 489-493.

Received on the 21st of June 2005

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 41-48
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

TRANSITION PERIOD IN LATVIA AS A SOCIAL-ECONOMIC "SIMPLE CATASTROPHE"

YU. KOCHETKOV

Riga Technical University
1 Kalku Str., LV-1658, Riga, Latvia

The paper describes the transition period of the social-economic system in Latvia in the 1990s. For analysis of the period the macroeconomic quality-quantity model of "simple catastrophe" of gather is offered. The flags of the catastrophe are analysed. The offered model permits to better understand the point of the course of events and show the most rational way out of the chaos and crisis state, which is an inevitable attribute of the existing complex systems in transition periods.

Keywords: *flag of the catastrophe, simple catastrophe of gather, bifurcational multitude, living standard of population*

For Latvia the period of the 1990s was a period of regaining independence of a sovereign state on the one hand, but on the other hand it was a transition period from a commanding-administrative system in economics and public life to market based relations in the conditions of democracy. During this period noticeable social-economic processes of restructuring took place in society of Latvia as well as formation of market economy. The transition period in Latvia (as in many other countries of Eastern Europe) adversely affected the welfare and living standards of a considerable part of the country's population: marked stratification of the society occurred due to the amount of their income, unemployment increased considerably, a great number of poor people and people on the brink of poverty [1; 2] appeared. Latvia faced also a deep demographic crisis, the death rate greatly exceeded the birth rate and tremendous decrease of the number of population of the country was observed. Demographic crisis was a direct consequence of the social-economic crisis in the country.

The social-economic situation of a country might be treated as a "soft" dynamic structure, the people themselves determine functioning and development of which to a great extent. Commanding-administrative system that existed in Latvia before the 1990s was relatively developed and stable: the dynamics of the growth of the gross domestic product in Latvia (see below) is indicative of that. Therefore restructuring of the system and transition to market economy using the methods of gradual continuous improvement of its functioning were not possible [3]. The complexity of the mathematical theory of restructuring social-economic systems is connected with their non-linear character: the results of their influence on the elements of the system are quite often disproportionate to the exerted effort. The following can serve as an example to this type of a conclusion – considerable amount of financial means invested into the national economy in the 1980s did not bring about great efficiency, did not improve the people's welfare. The aim of the present paper is to give analysis of the development of the social-economic situation in Latvia and its impact on people's welfare during the 1990s using modern mathematical theories, in particular topological dynamics.

In the period between 1980 and 1990 there was observed a steady growth of the gross domestic product (GDP) – an average of 5% per year: in 1990 GDP had increased 1.5 times as compared to 1980. In this case and further on the data from annual materials of the Central Statistics Bureau of Latvia (CSB) are used as well as materials from CSB reports on investigation of the budgets of family households in Latvia for the period 1990–2000. However, at the beginning of the transition period a substantial decrease of the volume of GDP is observed: in 1993 the volume of GDP of Latvia constituted about a half of that of 1990. Only beginning with 1996 GDP started increasing in Latvia again. With the purpose of analysing the dynamics of the basic social-economic data of the development of the country in the transition period basing on the statistical data of CSB of Latvia the author has made calculations of the basic indices with a constant basis for comparison. The values of the indices in the year 1990 – corresponding to 1.00 were taken as basis for comparison (see Table 1).

TABLE 1. Systems of the basic indices of the main social-economic data

No.	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	Gross domestic product (GDP)	**1.00**	**0.896**	**0.584**	**0.497**	**0.500**	**0.496**	**0.513**	**0.557**	**0.578**	**0.585**	**0.623**
2	**A** - quantity reverse of the percentage of people looking for a job to the number of economically active population of the country	**1.00**	**0.833**	**0.128**	**0.057**	**0.030**	**0.028**	**0.026**	**0.034**	**0.036**	**0.037**	**0.038**
3	**B** - the real wages of people working in national economy	**1.00**	**0.684**	**0.467**	**0.490**	**0.529**	**0.513**	**0.467**	**0.486**	**0.510**	**0.525**	**0.541**
4	**C** - proportion of the average income per one household member to subsistence minimum	**1.00**	**0.768**	**0.484**	**0.471**	**0.503**	**0.497**	**0.452**	**0.452**	**0.490**	**0.503**	**0.529**
5	Statical curtailment **S** of the data **A**, **B**, **C**	**1.00**	**0.757**	**0.249**	**0.138**	**0.081**	**0.075**	**0.069**	**0.090**	**0.093**	**0.096**	**0.100**

All data given in Table 1 are non-dimensional quantities. It is known that the notions “living standard” and “quality of life” are artificially created. It is a common opinion that if a person’s living standard basically depends on the proportion of expenses on purchasing foodstuffs then the quality of life depends on lots of factors. The author of the present paper uses statistical curtailment of the three basic values A, B, C as a generalised index of the quality of life of the population determining social-economic conditions of people in the country (Table 1). Summing the reverse of the value in this case performs calculation of the curtailment:

$$\mathbf{1/S = 1/A+1/B+1/C;\ S = ABC/(BC+AC+AB)}.$$

Here we can see a non-linear dependence, which characterises the saturation of the result of curtailment **S** in case separate values (**A**, **B**, **C**) being increased.

Taken as a whole Table 1 testifies that until 1996 the decrease of the value of GDP was observed, later it started to grow slowly. The values characterising the quality of life of the population of Latvia were decreasing until 1997: the year 1996 is the last year having decrease in the indices, there appeared “a delay” in changes of these values by one year compared with the changes in GDP. In the period up to 2001 the index of the quality of life (S) increased almost by 45% if compared with the level of 1996, but the GDP index increased by 25.6% during the same period if compared with its lowest level in 1995. However, in the year 2000 despite its excessive increase the indices of the quality of life of the population constituted only 10% of the 1990 GDP level. It indicates a very low decrease of the quality index, consequently also the living standard of the population of Latvia in the 1990s.

The social-economic system of a country, being a “soft” system, exhibits some certain features in case mathematical approach is applied to study it, which substantially differentiates it from the “hard” technical systems. Transformation of the parameters of a “soft” system basically occurs as non-linear dependences, the structure of the social-economic components is non-stationary and constantly changes under the influence of the managerial decisions made by people. The number of temporary and spatial feedbacks in the system is enormously large. On the other hand, in the conditions of transition of the national economy to new management principles and new technologies the human factor becomes highly significant: inertia of earlier models of behaviour and psychology of people quite often interferes with proper evaluation of the situation and making the optimal decisions on the part of managers. The main tasks of administrative bodies of any country are efficient functioning of national economy and optimum protection of welfare of the population during transition periods. However, due to the above-mentioned reasons the adopted regulations in Latvia (as well as in other East European countries) concerning administration of the economy in the 1990s quite often lead to undesirable consequences, to changes to the worse in the life of the population. Application of the method of economic-mathematical modelling is aimed at minimising the harmful consequences of the adoption of inappropriate decisions in economy and social sphere: it is time to pass from experiments on real economics and consequently on people to a scientific prognostication.

It is known that within non-linear dynamic systems with non-stationary structure, a social-economic system might be referred to as such, there can arise negative destructive processes of "catastrophe" type in case stabilising feedbacks are impaired. Stable development of the social-economic system of the country is analogous to the notion of stability in Mathematics. The dynamic system is considered to be stable if it functions in prearranged conditions irrespective of the exerted influences. However, as it was known in the ancient world already, sometimes-even small changes destroying harmonious development, can lead to great cataclysms in society. In the second half of the 20th century the topological theory of dynamic systems was created, describing considerable leaps and transitions of the functioning systems in a mathematical way. One of its trends is the **catastrophe theory**.

There exist no theorems or generally recognised social theories in human society analogous to the rules of mechanics, for example. Therefore on the basis of sociological models there always lie certain paradigms [4]. Assumptions of linearity or convexity of the functions describing the condition of human society in sociological models are simplifying and do not correspond to the real situation in the world. As a matter of fact there manifests a constant non-linear character of behaviour of the basic values, which determine social-economic processes. In the simplest case such phenomena might be described through bifurcation of functions and we cannot do without using the simple catastrophe theory [5].

Certain indirect evidence is usually a sign of the approaching catastrophe – so-called "flags of catastrophe". These are some peculiarities of behaviour from which one can judge of the system approaching the critical point when a catastrophe starts. One of such "flags" was mentioned above: that is "critical slowing down" of the rate of growth of the country and improvement of people's welfare at the turn of 1980s and 1990s despite the increasing amount of investments in social economy of those days. In the given case the social-economic system is treated as a gradient dynamic system or as a movement in the field of potential forces [5]. The issues of the structural stability of such systems are dealt with by catastrophe theory.

Substantial stratification of people according to the levels of their income, appearance of a large number of poor people, high unemployment level and a very low percentage of comparatively wealthy people in society at the beginning of the 1990s are indicators of the following two "flags of catastrophe": difference of the linear response and the anomalous dispersion of the living standard and the welfare of the country's population. The discrepancy is indicative of the fact that the system is in the vicinity of the critical point, and even small changes of the main parameters of the system can lead to destruction of stability and shifts in the development of social-economic situation in the country in one or another direction. During the research the author ascertained that there exists an expressed unevenness of the distribution of national wealth [1,2]. So for example, the coefficient of the funds characterising the correlation among the income of the 10% of the richest part of the country's population and the 10% of its poorest part constituted $K_D = 11.9$ in 1998. The coefficient of the concentration of the income according to Gini calculated on the basis of the average per capita income in Latvia constituted $K_L = 0.387$. This testifies to an unjust distribution of the income in society, practical non-existence of the middle class and indicates anomalous dispersion of the living standards of the population.

Modality and an ordinary discrepancy of the values of the parameters characterising the condition of the system are also standard "flags of catastrophe". Modality means that the potential function describing the system possesses more than one local minimum in a certain area of changes within the outer control parameters. In the case of the social-economic system under discussion it leads to bimodality under certain conditions: presence of a large number of people with a very low standard of living and a small layer of comparatively rich people in society, with actual absence of the middle class, which is a stabilising element of a system. By an ordinary discrepancy we understand instability of the processes in the system in case of changes within the trajectory of the control parameters when slight deviations of the trajectory lead to quite different final values of the variables of the condition than it was planned before. For example, in practice it means that the planned measures aimed at improvement the people's living standard (increase of pensions, allowances and benefits, salaries and others) most often do not bring the desired results due to rise in prices and inflation.

As a sign of the “flags of catastrophe” also irreversibility of the system and unattainability of stability of the social-economic condition in society should be mentioned in the given situation. Irreversibility of the system lies in the impossibility to return it to the previous conditions, to planned economy. But the actual absence of the middle class during the period under discussion -in the 1990s – in Latvia, which stabilises the social-economic situation, indicates unattainability of stability in the system.

It is known that most systems of practical interest the presumption forming the basis of the simple catastrophe theory cannot reach fully [5]. It is connected with the fact that the control parameters are quite often dependent on the time, but variable conditions are subjected to fluctuations. However, following certain principles and acceptance of some assumptions make it possible to use the results of the simple catastrophe theory. Analysis of the evolution of the condition of the balance of the gradient systems is not the concern of the catastrophe theory. Therefore the present paper accepted an agreement that evolution is of quasi-static character, all time derivatives are very small.

In order to even partially describe the condition of the gradient system controlled by the potential a point is used, in which the potential takes the minimal value. Changes in the outer conditions cause changes in the control parameters that lead to the changes of the potential function. In this case the condition of the global minimum determining the condition of the system might experience changes, and the system might change from one minimum into another [5]. On the other hand, the considerable dispersion of the living standards and the welfare of the people, the marked difference of their income taken into consideration the present paper has accepted as a standard a relatively high level of the “noise” of the condition of the variables in comparison with the height of the inner transition barrier in the social-economic system. Therefore the transition point and the minimum corresponding to the stable condition of the system are determined according to Maxwell [5]. This principle implies that the condition of the system is determined by the global minimum of the potential function with the presence of marked fluctuations of the variables of the condition.

Also the histerezis phenomenon and so-called catastrophic leaps refer to the “flags of catastrophe” discussed above. However, on the basis of the agreement accepted before – Maxwell’s principle, no hysteresis arises in the system under discussion. During the transition of one local minimum determined by the change of the control parameters into another there might be observed great changes of the values of the variables of the condition (people’s living standard and their welfare). This is what should be called catastrophic leaps. Certain smoothness of the changes in social-economic sphere taken into account such leaps will be followed by smooth changes in the values of the potential. The set consisting of eight “flags of catastrophe” and discussed above is reasonably sound. Therefore, it can be claimed that there occurred a social-economic “simple catastrophe” in the 1990s in Latvia.

The present paper offers a suggestion that the processes of the transition period under discussion in the social-economic system of Latvia in the 1990s are described with the help of a certain number of control and inner parameters. In a general form the function of the elementary catastrophe Cat (l, k) can be written down in the following way [5]:

Cat (l, k) = CG (l)+Pert (l, k),

where CG (l) is a sprout of the catastrophe or non-Morsian function 1 of the condition of variables; Pert (l, k) – changes of the catastrophe with the number of control parameters equal to k. The sprout of the catastrophe is an organisational centre around which the lower forms of the catastrophe are arranged. This is a type of organisation that all canonical catastrophes have. Whitney’s theory determining the geometry of catastrophes claims that any smooth reflection of the surface on a plane breaks into gather and pleat after some small change [3]. A characteristic feature of projecting the surface on a plane in the form of a gather (gather by Whitney) is stable and is widely used in practical applications of the catastrophe theory. Therefore it is this type of a simple catastrophe that was used in the present paper to create a model.

The multitude of the canonical catastrophe of gather is a smooth sub multitude in a three-dimensional space of the conditions R^3 (Figure 1), where R – standard symbol for a set of real numbers [4].

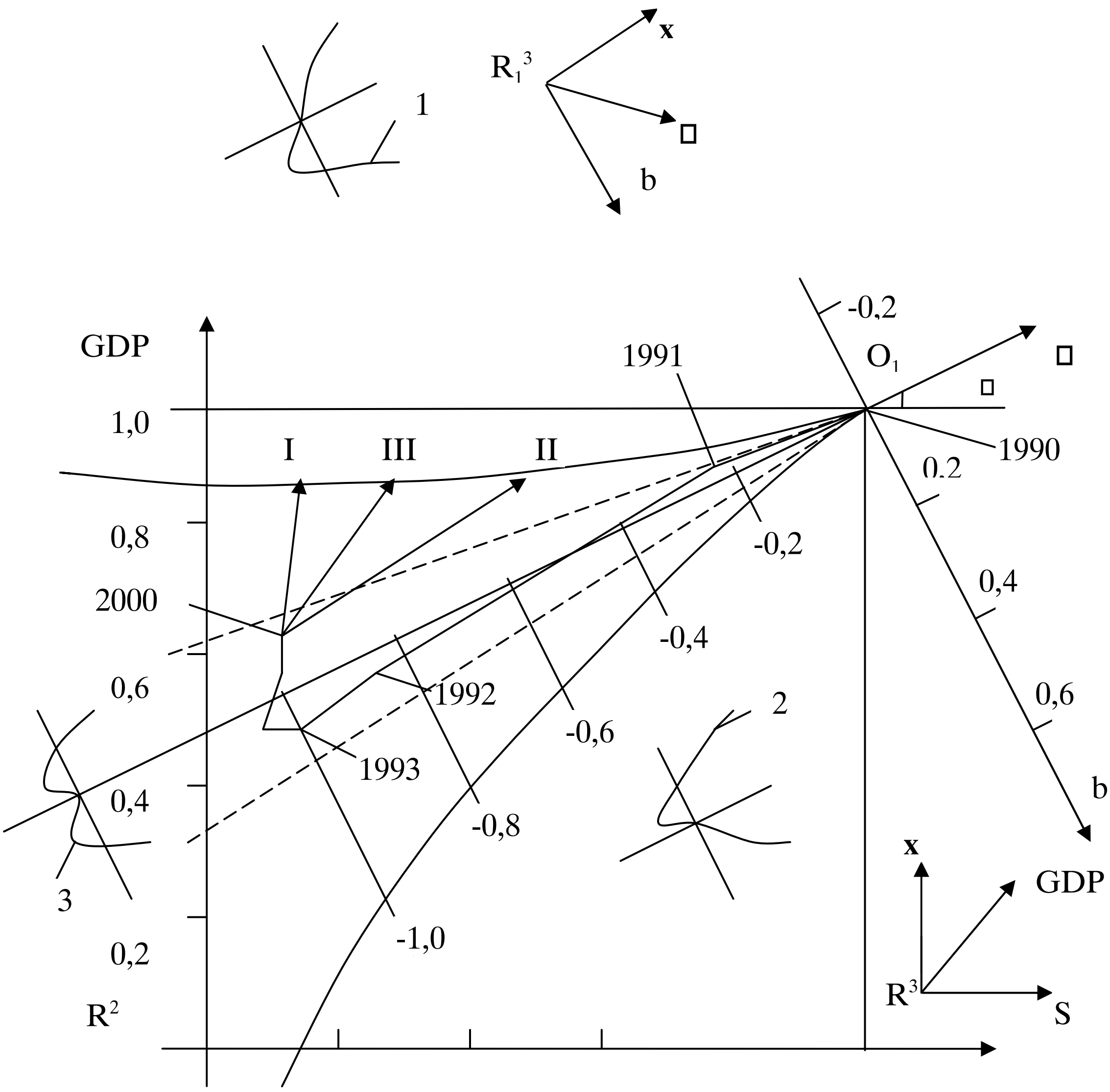


Figure 1. Projection of gather of "a simple catastrophe" on plane of the control parameters and empiric data

The control space R^2 in the given case is a two-dimensional plane of the control parameters on which catastrophe of gather finds its representation. As the dimension of the deformation here is equal to 2, then on the basis of factorial analysis parameters GDP and S have been adopted as control parameters. GDP determines the condition of the country's economy taken as a whole; therefore it is adopted as a splitting factor. As a normal control parameter a generalised index of the quality of the life of the population – S is used. The variety of the given catastrophe gather will be sub multitude all over the space $R^3 x R^2$, which is a surface of balance in the coordinates **x**, S, GDP where **x** is the inner variable of the condition of the system characterising the living standard and welfare of the population.

According to R.Thom's classification of simple catastrophes the catastrophe gather by Whitney under discussion refers to type A_{+3}[5]. The family of potential functions of energy serves as standard deformation:

$$F_{\alpha b}(x)=(1/4)x^4+(1/2)\alpha x^2+bx+C,$$

where C is some constant, α and b – are control parameters in the space R_1^3. The given expression determines the smoothness of the representation of a catastrophe gather in plane R^2 of the control parameters as it is differentiated a sufficient number of times. The constant C is set equal to zero, as the analysis of the critical points with the purpose of getting useful information is performed on the derivatives. The two-dimensional multitude of the catastrophe gather placed in the three-dimensional space x, α, b is calculated by an equation:

$\mathbf{d/dx(F_{\alpha b}(x))=x^3+\alpha x+b=0}$.

This equation gives a possibility to determine the critical points of the potential function $F_{\alpha b}(x)$ with the given parameters α and b. Equalisation of the discriminant of the cubic equation determining the variety of the catastrophe with zero makes it possible to determine parametric connections between α and b:

$\mathbf{D=(\alpha /3)^3+(b/2)^2=0}$.

This is a semi cubic parabola with a return point at the beginning of the coordinates $\alpha O_1 b$ (Figure 1). It is a separatrix of the space R^2 of the control parameters and divides it into two open areas, representing potential functions $F_{\alpha b}(x)$ with a different number of critical points. The starting point of the coordinates O_1 or the point of gather represents the function $x^4/4$ (sprout of the catastrophe) having a critical point degenerated three times. The points with a smaller area (within the separatrix) each have three prototypes, as three points of gather of the conditions of catastrophe are projected in them. The points of the bigger part of the space of the control parameters (outside the separatrix) have one prototype and represent functions with one critical point. The points of the separatrix itself have two prototypes and parameterise the functions with critical points degenerated twice. On the approach to the beginning of the coordinates O_1 from the smaller area all three prototypes merge. In Figure 1 potential functions are shown (1,2,3) that correspond to some points on plane R^2 of the control parameters.

When depicting catastrophe gather on a plane of control parameters the separatrix of the space R^2 viewed in geometrical context is a projection of points, in which the tangents of the plane are situated vertically. The semi-cubic parabola viewed above – is “a shadow” of the pleat of the variety of the catastrophe when exposed to its rays, parallel to axis **x**. The functions parameterised by the semi cubic parabola are structurally unstable with non-Morsian critical points, as in case of changes the points might shift from the inner area of the separatrix to the outer area and vice versa. Therefore the given parabola in a number of cases is treated as a local bifurcational set, i.e. a number of points in which transition from one local minimum to another occurs.

As it was mentioned above when considering the social-economic system of Latvia in its transition stage an agreement was made to use Maxwell’s principle. Therefore, in the case under discussion bifurcational set is non-local and represents Maxwell’s set or non-local separatrix in the plane of control parameters [5]. This is a semi straight line $\alpha<0$, $b=0$ in the plane R^2 (Figure 1). Transition from one minimum to another occurring in the points of the bifurcational set is also called phased transition, which corresponds to qualitative changes of the qualities of the system. It should be noted that in certain cases with certain values of the control parameters GDP and S the level of the “noise” of the variables of the condition **x** might decrease. Then we can say that phased transitions will occur in the points of “indistinct” not strictly determined bifurcational set. It is natural that this will occur during the periods of some regulation, stabilisation of the processes in the social-economic system, when separation from the Maxwell’s bifurcational set is taking place.

In the system of coordinates the life quality index of the population of Latvia – S and GDP adequate points have been inserted on the plane of control parameters beginning with 1990 and the year 2000 including (Table 1, Figure 1). The points are joined by segments of straight lines. The broken line that we obtain crosses the Maxwell’s bifurcational set three times, and all of its points are situated near this set. Thus, the above taken into consideration we can say that the area within which fluctuations of the inner variable **x** of the condition of the system occur is the area on the plane of the control parameters including Maxwell’s set and the “indistinct” set. Dotted semi straight lines originating from the critical point 0_1 which denotes the year 1990 limit this area. The system fluctuates within the bifurcation set of the catastrophe gather, alternately “jumping” from the top plane of the multitude of the catastrophe to the bottom plane and vice versa. The peculiarities of these processes connected with the change of the form of property and privatisation were considered above when the “flags of catastrophe “were described. Projection of the area of pleats of catastrophe gather are superimposed on the empiric data, it is a separatrix of the space R^2 of the control parameters. The equality of the separatrix within coordinates $\alpha O_1 b$ was given above. Transformation of the coordinates with the help of simultaneous shift and bend of the axis of the coordinates allowed expressing coordinates α and b of the separatrix through GDP and S (angle θ=90°-β):

$$\alpha = \frac{S-1}{Sin\theta} - \frac{ctg\theta(Sctg\theta - ctg\theta - GDP + 1)}{Sin\theta + Cos\theta ctg\theta}\ ,\ b = \frac{Sctg\theta - ctg\theta - GDP + 1}{Sin\theta + Cos\theta ctg\theta}\ .$$

It is known that instability of development of extensive complex systems, social-economic system of people's society is among them, does not make it possible to predict their behaviour for long periods [6]. The analysis of the above quantity-quality macroeconomic model of such a system exhibited the following. The model of "simple catastrophe" in itself cannot replace the study of complex social-economic processes and prompt a recipe of a rapid solution of a crisis. It gives an opportunity to deeper understand the developments, their latent regularities and help in finding the ways out of the chaos and a crisis situations. Chaos and crisis are inevitable attributes of transition periods during the existence of complex systems, as it is through them that new order and new relationships come into society.

As Table 1 and Figure 1 above show up to 1996 the GDP and the index of the quality of life of the population kept decreasing; after that a gradual growth of these indices took place. Improvement of the situation in the country shows that the process of straightening out, self-organisation of the social-economic system, stabilisation of the economy and overcoming the chaos has started [6]. During such periods when getting out of the crisis has started it is important to start a stable trajectory of development, to define the desirable trend. First of all the way out of this dangerous zone should be found, as far as possible from the bifurcation set. It is known that formulation of a problem and a unique solution of the optimisation task of managing macro economy is entirely impossible. However, there always exists a possibility to discuss different versions of development of the social-economic situation in the country, among other things using the model of "simple catastrophe" gather the present paper is dealing with.

In the diagram in Figure 1 we can distinguish three feasible directions of prospective development in the nearest future. The first direction (I) leads to rapid growth of GDP and fast withdrawal from the zone of the bifurcation set. However, it is fraught with social cataclysms due to the slow growth of the index S of the quality of life of the population and accordingly low living standard of the people. On the contrary, the second development of growth (II) establishes social protection of the population, improving the living standard of people as priority, but with slower rate of the growth of GDP. The danger here lies in the fact that this direction goes concurrent with the bifurcation set and at an inadequate volume of GDP the bifurcation process might start again and the system is likely to return to the state of chaos, as there will not be sufficient economic resources to increase the index S. The third direction in the development (III) occurring with paralleled balanced growth of GDP and S is the most rational. The development trend existing today more likely corresponds to direction I. To pass over to direction III certain measures should be taken aimed at improving the standard of living, social protection of people, such measures which the government of Latvia is not giving much attention to at present.

Conclusions

- The complex social-economic processes of the transition period in the 1990s in Latvia can be visually depicted as a model of "simple catastrophe" gather (type A_{+3}), which is substantiated by the presence of adequate flags of catastrophe.
- It has been ascertained that that bifurcation set of the catastrophe gather for the social-economic system under discussion is determined more precisely as a complex of Maxwell's set and "indistinct" set.
- In case the continuity of the processes is broken the model of catastrophe gives an opportunity to point out the most rational ways out of the of chaos and crisis state: development of economics and raising GDP is not an end in itself, but a balance should be maintained with the growth of welfare of the population and people's living standard.

References

[1] Kochetkov Yu. (2001) Mathematical Model of Stratification of the Population according to their Income. Proceedings of Riga Technical University*, Economics and Entrepreneurship***, 4**, No 3, Riga, 53-60.

[2] Kochetkov Yu. (2000) Some Statistical Indices of the Poverty of the Population of Latvia, *Computer Modelling and New Technologies,* **4**, No 2, 115-119.

[3] Arnold V. (1990) *Catastrophe Theory.* Moscow: Nauka. *(in Russian)*

[4] Poston T., Stewart I. (1978) *Catastrophe Theory and Application.* London: Pitman.

[5] Gilmore R. (1981) *Catastrophe Theory for Scientists and Engineers.* New York-Toronto: John Wiley & Sons.

[6] Prigogine I., Stengers I. (1984) *Order Out of Chaos.* London: Heinemann.

Received on the 21st of June 2005

Computer Modelling and New Technologies, 2005, Vol.9, No.2, 49-55
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

TOWARDS APPLYING THE METHOD OF AGGREGATIVE FUNCTIONAL DESIGN IN MULTI-USER ENVIRONMENT

E.S. NAPALKOV, V.V. ZARS

CAD Center,
Department of Engineering Science and Transport, Riga Technical University,
Str. Ezermalas 6, Riga LV-1014, Latvia; e-mail: napalkov@latnet.lv

The paper is dedicated to the development of a method for conceptual design based on virtual exchange of users knowledge to be represented in form of the so-called aggregative design components. In order to support aggregative components a frame-based structure of the abstract product is used.

Keywords: *Aggregative Design Component, Abstract Product Structure and Fuzzy Logical Retrieval*

1. Introduction

Advanced technique of synthesizing conceptual design solutions is mainly based on application of methodology of functional design [1]. General statement is to link design functions with the product behaviour, and then this behaviour with the product structural (physical) embodiment to achieve the overall design specification. However, there are some problems of functional design that have not yet explored sufficiently. One of these is design in dynamic environments, in particular, under conditions of Internet/Intranet environment by virtual exchanging knowledge being taken from private experiences of involved partners. The main barrier is incompatibility of information formats used in different Product Support Systems. Moreover, knowledge about emergence of valid information for the current design case is not obvious when data exchange occurs. Therefore the transferred information needs to be managed.

This trend touches upon many questions concerning methods, infrastructure and organization for product data sharing, for distributing work, for detecting and resolving conflicts. The critical issues in sharing and managing design information are:
- patching heterogeneous databases together to create some middleware infrastructure;
- developing a single product data model to create homogeneous design environment.

The first approach is used to exchange product data in a federated manner, while as each of involved partners solves certain subtask in general task of collaborative design [2]. In case of using a single tool for CAD-files generation and visualization (e.g. the VRML format) the involved partners enable to interact with each other through accessing solutions designed. A major disadvantage is that functional structure and a product configuration has to be conformed previously. The second approach is based on global databases concept, standard data packages, or agreed ontology of the design domain needed in significant implementation and customisation effort [3]. Therefore the development of more flexible collaboration models for conceptual design is necessary.

Our analysis revealed that one could support both individual and collaborative design process relying on the federated conception within so-called the abstract product structure (APS). The proposed scheme of user knowledge exchange is represented in the next section.

2. Representation of abstract product structure

In the proposed scheme, APS is considered as a multilevel frame-based network constructed as a result of functional decomposition of some design domain. This enables the users to represent explicitly and to share own knowledge with each other over instances of describing the selected class frames. The feature is a support of alternative views on functional and structural properties of the same design artefacts (design components). So, a common interest of all involved partners is to intensify these knowledge exchanges to reuse them for deducing inferences and improving a quality of products being designed for own needs.

The development of APS is based on distributing all design concepts into five functional layers corresponding to definition of: machine part design features (the 1^{st} layer *C*); machine parts (the 2^{nd} layer *D*);

subassemblies (the 3rd layer *S*), and assemblies (the 4 layer *A*). Each of these layers comprises finite number of class functions used for modelling functionality of associated design concepts. The highest 5 layer defines the overall function of the design domain investigated.

In particular, analysing different types of transferred energy in the mechanic domain *M (*force, torque, pressure, temperature) we have categorized functions of all assemblies into four class functions such as *transference*, *fixing*, *adjusting* and *driving.* Analysing different types of mechanical relations between interacting parts we have categorized functions of all subassemblies into ten class functions such as *transference/move*, *transference/rotate*, *fixing/position*, *fixing/seal*, *adjusting/limit*, *adjusting/control*, *driving/rotate*, *driving/move*, *catching* and *mating*. For functional classification of machine parts, seven classes have been established such as *rotating*, *moving*, *limiting*, *sealing*, *positioning*, *controlling* and *fastening*. At last, for functional classification of machine part features, their influence upon definition of a machine part working function, basing schemes and receptivity to external power loads has been taken into account. As a result, we have restricted by nine class functions of design features such as *operating/move*, *operating/rotate*, *operating/limit*, *reinforcing*, *basing* and others.

A primary model of APS is constructed by establishing rigid hierarchical relations between class functions of adjacent layers. This implies the definition of so-called *abstract class frames* as some two-layer (*A*-*S*), (*S*-*D*), and (*D*-*C*) hierarchical structures, each of which includes the vertex class function and its subclass functions of lower layer [4]. Duplicated from the experimental WEB-page a partial list of such abstract class frames is shown on Fig. 1. It is determined that a number of subclass functions in any abstract class frame can be restricted by four ones to interpret unambiguously the most essential functional and structural properties of existent design components.

The interpretation process consists in using slots such as *Concept Name*, *Image Name*, *Instance Function Name, Instance Function Entity* and others to represent the design component sequentially in the following forms:

- the *conceptual class frame* related to the selected abstract class frame;
- the instance frame related to the selected conceptual class frame.

Add Edit Delete Function Classes: Filter

No	Function Class	Layer	SubClass 1	L1	SubClass 2	L2	SubClass 3	L3	SubClass 4	L4	Select
1	Adjust/Control	S	Controlling	D	Moving	D	Positioning	D	Rotating	D	○
2	Adjust/Limit	S	Limiting	D	Moving	D	Positioning	D	Rotating	D	○
3	Adjusting	A	Adjust/Control	S	Adjust/Limit	S	Catching	S	Mating	S	○
4	Basing	C									○
5	Catching	S	Limiting	D	Fastening	D	Moving	D	Rotating	D	○
6	Controlling	D	Basing	C	Operate/Control	C	Reinforcing	C			○
7	Driving	A	Driving/Move	S	Driving/Rotate	S	Catching	S	Mating	S	◉
8	Driving/Move	S	Moving	D	Limiting	D	Controlling	D	Positioning	D	○
9	Driving/Rotate	S	Rotating	D	Limiting	D	Controlling	D	Positioning	D	○
10	Fastening	D	Basing	C	Operate/Fasten	C	Reinforcing	C			○
11	Fix/Position	S	Positioning	D	Fastening	D	Limiting	D	Moving	D	○
12	Fix/Sealing	S	Sealing	D	Limiting	D	Fastening	D	Moving	D	○

1 2 3

Figure 1. Representation of abstract class frames

At first, it is required to interpret general behavioural aspects by describing the design component in terms of design concepts to be shared between the vertex and subordinate class functions of the selected abstract class frame, for example:

CFR [<Driving, *Hoisting mechanism*>, <Driving/Move, *Driven drum of winch*>,
<Driving/Rotate, *Electric motor*>, <Catching, *Reduction gear*>, Mating, *Brake clip*>],
where *CFR* is a name of conceptual class frame.

Secondly, it is necessary to provide design concepts for instance functions and graphical images in accordance with functional and structural decomposition of the design component, for example:

IFR [<Hoisting mechanism, *Image*, *Provide a hoisting the palletised loads*>,
< Driven drum of winch, *Image, Provide a feed motion of winch cable*>,
<Electric motor, *Image*, *Create a torque on main drive shaft*>,

<Reduction gear, *Image*, *Transform a torque on driven shaft*>,
<Brake clip, *Image*, *Reduce a rotary inertia of drive shaft*>],
where *IFR* is a name of instance frame.

Depending on a purpose of design each graphical image can display a real physical structure, sketch or schematic circuit with application parametric equations, computing algorithms and other mathematical models intended for behaviour simulation of the design component. Therefore, template facets with attributes of function entities (related to instance functions) and design concepts are used to complete the interpretation process. In this case, the user assigns a value space for the most important functional and design attributes. As a result, the interpreted design component is transformed into two-layer function/means structure consisting of the vertex design component and appropriate subcomponents of lower layer (or design organs). These function/means structures can be called by *aggregative design components* (ADCs). Based on user knowledge capture they are stored in separated library.

In synthesizing design solutions, ADCs have to play a role of solution elements. In fact, it required modifying the functional design approach (FD-technology) to develop the method of so-called *aggregative functional design* (AFD-technology).

3. Mathematical model of AFD process

In order to outline main features of the proposed method it is advisable to describe general mathematical model of functional design process. As is known, it is aimed to find those design components whose output functions can achieve the desired output functions. Given a library of design components associated with simple behaviours this task is solved starting with decomposing of the purpose function inquired in the user functional requirements (query).

Let C denote general set of design components and $F(q)$ denote a set of functions inquired in query q; $C = \{c_i\},\ i \in I$. Then, mathematical model of synthesized function/means tree (in general case, we deal with the graph with contours) can be represented as follows:

$$G = < H, F(q), \psi, R >, \qquad (1)$$

where design components $H \subseteq C$ are nodes of the graph; $F(q)$ are its edges; ψ is an incident or that identifies subsets of nodes $H(f)$ incidental with an edge f ($\forall f \in F(q)$); R is subjective mapping on subsets $H(f)$ so as for each component $c_i \in H(f)$, a set of relevant components $c_i^{\,g}$ can be found; at that $g \in N^+$, and $N^+ = \{1,2,\ldots\}$.

The graph G is oriented one. It allows one to determine input-output relations on a set H of design components. The certain disadvantage is a danger of initiating information explosions that can lead to generating entire forest of function/means graphs.

In the considered AFD process, the graph G is structured from ADCs enabling to achieve the design solution in smaller number of iterations. Let S_i be a subset of ADCs connected with a use of the i-th design component; $S_i = \{s_{ij}\},\ j \in M_i$. It follows that we can represent the synthesized graph in extended form like:

$$G^i = < H^i, F^i(q), \psi^j, R^i > , \qquad (2)$$

where $H^i = \bigcup_i \bigcup_j S_i$; $F^i(q)$ is an extended set of edges such that $H(f) = \bigcup_i H^i(f^i)$, $\forall f^i \in F^i(q)$;

ψ^i is an extension of ψ on sets H^i and $F^i(q)$, R^i denotes uncertain subjective mapping.

Thus, in AFD process, the main emphasis is placed of on performing transformation as follows:

$$< H^i, F^i(q), \psi^i, R^i > \to < H, F(q), \psi, R >, \qquad (3)$$

in which two design libraries should be used, such as:
- ADC library for generating function/means structures;
- solution library for optimising function/means structures.

The first one requires the application of auxiliary procedures to avoid an appearance of design solutions with redundant structures. The second one enables at once to select the solution prototype with an irredundant structure for the present situation. AFD-process in more detail is described in the next section.

4. Synthesis of design solutions

In contrast to functional design the AFD process is based on combining of "top-down" and "bottom-up" steps for deducing inferences. These steps are the following:
- retrieving ADCs for the purpose function inquired ("top-down" step);
- retrieving vertex components for the design organ selected ("bottom-up" step);
- coupling relevant vertex components ("top-down" step);
- correcting a structure of design solution being synthesized ("bottom-up" step).

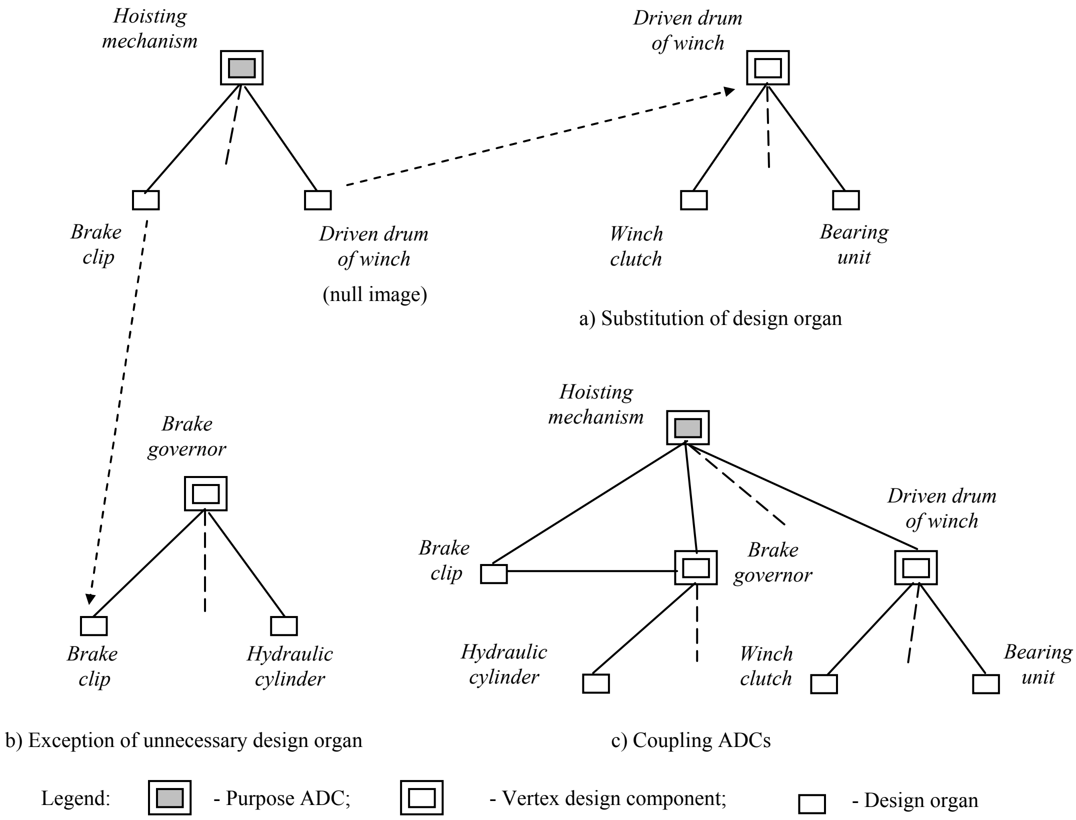


Figure 2. Deducing inferences from ADCs

At the first step the most preference is given to those ADCs whose organ structures contain sub-functions inquired by the user. For retrieval, a library of ADCs is used. Here, one should have in mind that all inquired sub-functions are to belong to the (k–1)-th description layer with respect to the design problem being solved on the k-th description layer. This means that the designed assembly will include only subassemblies and other assemblies, the designed subassembly will include only parts and other subassemblies, and the designed part will include only design features and other parts. If exists some ADC that satisfies all functional requirements, then an attempt is made to retrieve its real prototype in a case library by comparing with the design constraints given. Otherwise, a message is generated about missing or contradictory design parameters to create new prototype.

In order to satisfy uncovered functional requirements the second step concerned with extension of current ADC is executed. For that it is necessary to retrieve additional ADCs whose organ structures are set intersected with current ADC at least by one design organ. The selected organ can have either null or complete graphical image. Null image means that the design organ is defined on (k–1)-th description layer as only the design concept, while it's the behavioural properties should be found on k-th description layer. Thus the design organ is becoming the vertex component of additional ADC. Restricted to reductive description of behaviour (in form of conceptual class frames) such example is shown on Fig. 2a. Other example shown on Fig. 2b is related to finding vertex component for the design organ with complete graphical image. In both examples, the main goal is to select the most preferable ADCs that comprise maximal number of uncovered sub-functions. For retrieval of possible prototypes, the case library can be also used.

The third step is aimed to verify the compatibility of ADCs within a structure being synthesized. According to underlying principles of functional design the connections between design components are specified as input-output relations between their functions. Two components can interact with each other on condition that their functions have the same entity. Therefore it is necessary to analyse entity attributes before two components can be connected together.

The described AFD process solves this task by analogy. The feature is a use of such procedure for only vertex design components. In order to narrow a seek area of design solutions the functional requirements must include entity attributes for each function inquired.

The forth step allows one to modify relations between ADCs coupled. It involves the procedures of substitution and exception of unnecessary design organs. In particular, the substitution procedure is performed with respect to design organs that have null description (Fig. 2a). The exception procedure enables to remove one of two repeatable design organs used for coupling vertex components. As shown on Fig. 2b it leads to resulting in contours into the graph synthesized. Other application of the exception procedure may be a remove of design organs that do not contain sub-functions indicated in requirements. The resulting graph for a modified structure consisting of three ADCs is shown on Fig. 2c.

The described AFD process is cyclic. It is finished when one succeeded in covering all sub-functions inquired. Otherwise, it is necessary to reject the first-choice hypothesis concerning the purpose design fact (in our example it is called by *Hoisting mechanism*) to continue the AFD process by finding other ADC for the purpose function inquired.

5. Retrieval of relevant ADCs

In reality, the described AFD process is one of possible scenarios that the user can select in synthesizing solutions by means of the Reasoning Engine within a frame-based APS. Other scenario (a backward approach) is to synthesize design solutions starting with analysis of given sub-functions to work then a way to the purpose function. Therefore, the development of effective search procedures for retrieving relevant information is required. Since we deal with multiple class frames in APS, it is better to use the fuzzy logic for removing partial uncertainty occurred in selecting relevant ADCs [5].

Suppose that the user query q specifies the relationships $F(q) \subseteq P \times F$, where P is a set of entity attributes p and F is a set of functions f to be satisfied. Let $((p,c),\omega)^{\gamma} \in [0,1]$ be a weight of the pair $(p,c)^{\gamma}$ in which the entity attribute p is matched with the design organ c belonging to γ-th function, $c \in C$. Then the total weight $(c,\omega)^{\gamma}$ of the design organ c about the query q can be represented in form of the Euclidean distance $d\,(c,q)^{\gamma}$ by identifying the specified attributes p of the design organ c.
Allow a set of such design organs $C^{\gamma} = \{(c,\omega)^{\gamma}/\, c\}$, and the membership function μ: $C^{\gamma} \times C^{\gamma} \rightarrow [0,1]$ to evaluate the similarity degree $\mu\,(c,\omega)^{\gamma} = ((c,\omega), l)^{\gamma}$ of each design organ with respect to the user query q, where l is a value of linguistic variable, $C^{\gamma} \subseteq C$.

For that, we divided a set C^{γ} into clusters according to three terms of linguistic variable such as *little-suited*, *almost acceptable* and *acceptable* design organs about the query. These terms and values of linguistic variable l evaluate the similarity degree of design organ c by evaluating its membership degree with each of above-mentioned clusters. For clustering, as shown on Fig.3a, we used two trapezoidal and one triangular membership functions with three critical points (0,2, 0,5, 0,8) within the common interval [0,1] of measuring the Euclidean distance.

Further, let $(((c,\omega), l),^{\gamma} s)^{\eta}$ denote membership degree of design organ c in organ structure of the s-th ADC that belongs to η - th function, $s \in S$. Then the total membership degree $((s,\omega), l)^{\eta}$ of the s-th ADC can be computed by using the superposition operation as following:

$$((s,\omega),l)^{\eta} = \sup_{\gamma} \{(((c,\omega),l)^{\gamma}, s)^{\eta}\} \quad , \tag{4}$$

where superposition operation includes the procedures of interpolation and defuzzification of input membership functions.

For our goal, it is sufficiently to use only one output term represented by a truncated triangular membership function on Fig. 3b. Therefore the restricted number of basic fuzzy rules (like IF – THEN) is required to set all combinations for weighting design organs. One of such general combinations is the following:

IF ((*c*, ω), *Appl.*)^1 $\wedge$ ((*c*, ω), *Appl.*)^2 $\wedge$ ((*c*, ω), *Alm.*appl.)^3 $\wedge$
$\wedge$ ((*c*, ω), *Little-suit.*)^4 *THEN* ((*s*, _), _),

where upper indexes correspond to listing design organs in organ structure of ADC evaluated.

In the process of defuzzification, a computed value of output membership function is automatically transformed in Euclidean distance, for example:

IF ((*c*, 0.18), *Appl.*)^1 $\wedge$ ((*c*, 0.12), *Appl.*)^2 $\wedge$ ((*c*, 0.45), *Alm.*appl.)^3 $\wedge$
$\wedge$ ((*c*, 0.80), *Little-suit.*)^4 *THEN* ((*s*, 0.489), *Less accept.*)

that corresponds to selecting ADC with insignificant organ structure (subject to all membership degrees are computed with a threshold of applicability equal to 0.6).

Thus, in order to select relevant ADCs it is necessary to aim at:

$$((s,\omega), l)^{\eta} \leq (s,0{,}4)^{\eta}, \qquad (5)$$

where $\omega = 0{,}4$ is an extreme value of Euclidean distance defuzzificated.
Besides, one should proceed from the assumption that vertex components of ADCs certainly satisfy the input functional requirements. It follows that the final task can be a finding optimal design solution (S^*, W^*) with minimal weight-average Euclidean distance W about the query $F(q)$ on total set of solution variants $\{(S,W) / S\}$, $S^* \subseteq S$.

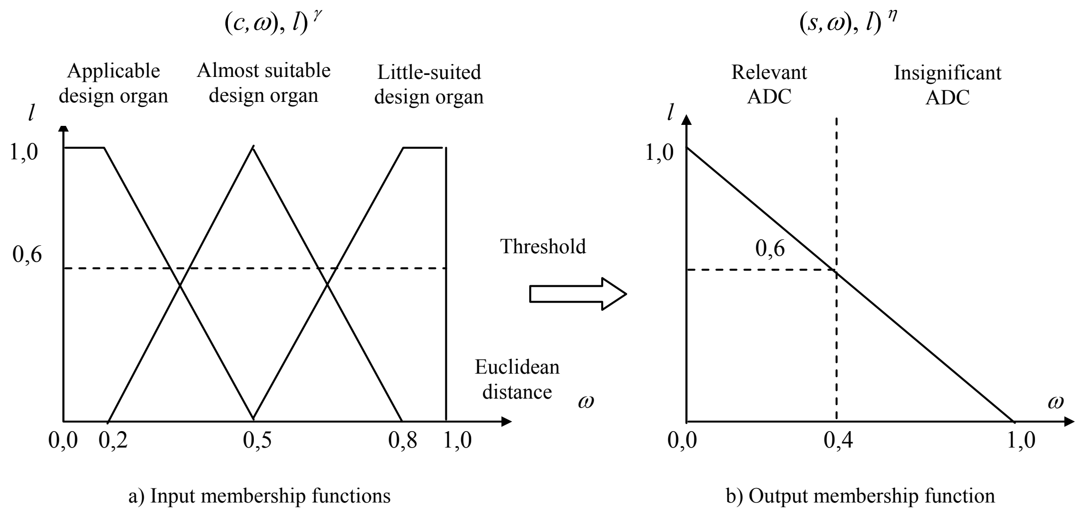


Figure 3. Membership functions used in fuzzy logical rules

In order to avoid the complete enumeration of possibilities it is required to generate additional matrixes that specify relations on pairs of elements ($F(q)$, S) and (S,C). In this case, optimal design solution is achieved in depending on total set of design organs used. Formally, this task can be referred to a finding optimal coverage for three-fraction graph specified on these matrixes.

6. Conclusions

In this paper we have proposed an approach for individual and collaborative conceptual design of mechanical products in multi-user environment. Allowing the notions of abstract product frame-based structure and the aggregative design component we have elaborated the way for sharing the user functional and structural knowledge over the system of product data virtual management. The use of these notions has led to the development of AFD-technology based on combining and modifying the methods of functional design and case-based design in deducing inferences.

It is indicated that the main advantages are:
- essential reducing iterations in the process of structuring design solutions;
- more easy adoption of design solutions in the process of their prototyping.

We believe that the proposed method of conceptual design offers good opportunities especially for SME to build virtual cooperation and thereby maintain competitiveness within the global market.

References

[1] Pahl G., Beitz W. (1996) *Engineering Design – A Systematic Approach*. 2nd edition. London: Springer Verlag.

[2] Huang G.O., Mak K.L. (2001) Issues in the development and implementation of Web applications for product design and manufacture, *Journal of Computer Integrated Manufacturing,* **14**(1), 125-135.

[3] Wang L., Shen W., Xie H., Neelamkavil J., Pardasari A. (2002) Collaborative conceptual design: a state-of-the-art survey, *Journal CAD,* **34**(13), 981-996.

[4] Napalkov E., Zars V. (2003) Model of Graphical Interpretation of Fuzzy Design Patterns, *Proceedings of Riga Technical University,* **5**, 89-96.

[5] Napalkov E. (2000) Knowledge Capture and Reuse. In: *Proceedings of Nordic-Baltic-Russian (NBR'2000) Summer School "Applied Computational Intelligence".* St-Peterburg, 192-207.

Received on the 21st of June 2005

Computer Modelling & New Technologies, 2005, Volume 9, No.2
Transport and Telecommunication Institute, Lomonosov Str.1, Riga, LV-1019, Latvia

Authors' index

Yuri N. Shunin (born in Riga, March 6, 1951)

- Vice-rector on innovation work (Information Systems Management Institute), professor, Dr.Sc. Habil.
- *Director of specialities*: Semiconductor Electronics & Technologies, Computer simulation of semiconductor technologies (Transport and Telecommunication Institute, Riga)
- *Director of speciality:* Information Systems (Information Systems Management Institute)
- **University study**: Moscow physical and technical institute (1968-1974)
- Ph.D. (physics & mathematics) on solid state physics (1982, Physics Institute of Latvian Academy of Sciences), Dr. Sc. Habil (physics & mathematics) on solid state physics (1992, Ioffe Physical Institute of Russian Academy of Sciences).
- **Publications:** 290 publications, 1 patent
- **Scientific activities**: solid state physics, physics of disordered condensed media, amorphous semiconductors and glassy metals, semiconductor technologies, heavy ion induced excitations in solids, mathematical and computer modelling, system analysis

Igor V. Kabashkin (born in Riga, August 6, 1954)

- Vice-rector for Research and Development Affairs of Transport and Telecommunication Institute, Professor, Director of Telematics and Logistics Institute
- PhD in Aviation (1981, Moscow Institute of Civil Aviation Engineering), Dr.Sc.Habil. in Aviation (1992, Riga Aviation University), Member of the International Telecommunication Academy, Member of IEEE, Corresponding Member of Latvian Academy of Sciences (1998)
- **Publications:** 320 scientific papers and 67 patents
- **Research activities:** information technology applications, operations research, electronics and telecommunication, analysis and modelling of complex systems, transport telematics and logistics

Alexander Grakovsky, Dr.Sc.Ing., Associate Professor,
Transport and Telecommunication Institute

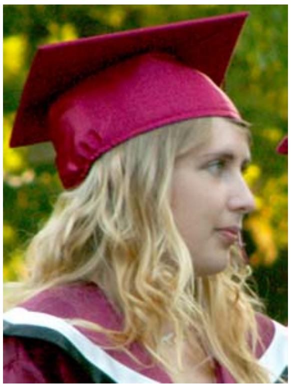
Education

- 1985 Degree of Electrical Engineering from Riga Institute of Civil Aviation
- 1989 Doctor of Philosophy Degree in Engineering from Moscow Energetic Institute
- 1992 Doctor Degree in Engineering from Riga Aviation University

Professional Interests:

- Mathematical Simulation, Differential Geometry Methods in Digital Signal and Image Processing, Patten Recognition, Information Technologies

Publications: 30



Nadeghda Kniga, born 18.11.82. in Riga, MBA,
Assistant of Natural Sciences and Computer Technologies Department of Information Systems Management Institute

Education:

- 2005 MBA, Information Systems Management Institute

Professional Interests:

- computer modeling of business situation
- neural networks

Publications: 8

Eduard Napalkov, Dr.sc.eng., CAD Center of Riga Technical University leading expert

Education:

- 1965 – Moscow Bauman Higher Technical School, systemengineering
- 1967-1987 – assistant, Dozent of Computer design and technology Department of Moscow Bauman Higher Technical School

Professional interests:

Decision-making under uncertainty
Cluster analysis
Concurrent design
WEB conceptual design

Publications: 70

Yu.A. Kochetkov (born 26.03.47, Chebocksary, Russia)
Dr.Sc.Ing., as. Professor, Riga Technical University

University study: Riga Polytechnical Insitute (1971), post-graduation (Moscow Steel Equipment Institue (1981)
Publications: 36, 3 patents
Scientific interests: social economical statistics, mathematical modeling

Edmundas Kazimieras ZAVADSKAS, Doctor Habil, Professor, Dr honoris causa multi, Vice-Rector of Vilnius Gediminas Technical University. Member of Lithuanian Academy of Sciences, President of Lithuanian Operational Research Society, President of Alliance of Experts of projects and buildings of Lithuania.

In 1973 Doctor of Science (building structures). Professor at the Department of Construction Technology and Management. In 1987, Dr Habil degree (problems of building technology and management). Research visits to Moscow Civil Engineering Institute, Leipzig and Aachen Higher Technical Schools. He maintains close academic links with the universities of Aalborg (Denmark), Salford and Glamorgan (UK), Poznan University of Technology (Poland), Leipzig Higher School of Technology, Economics and Culture (Germany). Member of international organizations. Member of steering and programme committees of many international conferences. Member of editorial boards of some research journals. Author of monographs in Lithuanian, English, German and Russian.
Research interests: building technology and management, decision-making theory, automation in design, expert systems.

CUMULATIVE INDEX

COMPUTER MODELLING and NEW TECHNOLOGIES, volume 9, No. 2, 2005
(Abstracts)

E.K. Zavadskas, Z. Turskis, T. Vilutienė. Simulation of Multi-Criteria Selection of Buildings' Maintenance Contractor Using the Game Theory, *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 7–16.

In the paper the comparative analysis of dwelling maintenance contractors by applying the methods of game theory is presented. The decision-making methods Wald's rule and Bayes's rule for solving different problems with incomplete information are applied in the research. To illustrate the application of the aforementioned methods, we consider the problem of maintenance contractor selection. To compare the performance of various maintenance contractors, the data from 15 dwelling maintenance organizations are used. Contractors are evaluated by a set of criteria characterizing them from various perspectives. The analysis is made taking into account the standpoints of building owners. Experts determine the initial weights of criteria. Multi-criteria analysis of the performance of maintenance contractors allows us to determine the importance of particular contractor characteristics for achieving the aim to meet the needs of different participants of the maintenance process.

Keywords*:* *game theory, multi-criteria selection, decision-making methods, efficiency*

Yu.N. Shunin, N. Kniga. Neural Networks Modelling of Business Situations and Decision-Making Analysis, *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 17–26.

An actuality of "neural networks modelling of business situations and decision making analysis" is connected with the increasing and intensity of business activity in modern society. Most enterprises aspires to that their activity was carried out maximally productively. Besides, the correctly accepted decision acts enormous part in any business. In the process of achieving the put purpose firms and companies permanently get risk situations, breaking the desired development of entrepreneurial activity. One of such problems is insufficient estimation of risk. The task is to decline risk at an acceptance of enterprise decisions by managers; namely, research the newest neural technologies and methodology development of risk sets in business situations. In particular, we consider: a) a prognostication at the fund market; b) an application of the intelligence system in marketing researches, namely, in the questionnaire; c) the task of classification of credit extension to physical persons.

Keywords: *forecasting, classification, the credit, neural network, genetic algorithm, questionnaire*

V. Butakov, A. Grakovsky. Estimation of the Stochastic Level of the Temporary Set of Arbitrary Rise by Hurst's Indicator, *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 27–32. (in Russian)

The algorithm carrying out an estimation of Hurst parameter with the help of statistics cut-linear approximation is offered. The variant of a fast method and method with averaging on the processed period is provided. The definition of various meanings of a parameter for different sites of the characteristic enables in passing to estimate potentially possible depth of the forecast, if researched a temporary set has a due degree of self-similarity.

Keywords: *Hurst parameter, forecasting, cut-linear approximation*

V.V. Mushko. MAP/M/C System with Addressed Strategy of Retrials and Identical Equipment, *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 33–40. (in Russian)

Multiserver retrial model in which arrivals occur according to a Markovian Arrival Process is considered. The service time has exponential distribution. The intensity of retrials linearly depends on the number of the customers in the orbit. The continuous-time multi-dimensional Markov chain describing the behavior of the system belongs to the class of multi-dimensional asymptotically quasi-Toeplitz Markov chains. Sufficient condition for stationary state distribution is proven. Several system performance characteristics are obtained and numerical illustrations are provided.

Keywords: *retrial queue, Markovian Arrival Process, addressed retrial, asymptotically quasi-Toeplitz Markov chains, stationary distribution*

Yu. Kochetkov. Transition Period in Latvia as a Social-Economic "Simple Catastrophe", *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 41–48.

The paper describes the transition period of the social-economic system in Latvia in the 1990s. For analysis of the period the macroeconomic quality-quantity model of "simple catastrophe" of gather is offered. The flags of the catastrophe are analysed. The offered model permits to better understand the point of the course of events and show the most rational way out of the chaos and crisis state, which is an inevitable attribute of the existing complex systems in transition periods.

Keywords: *flag of the catastrophe, simple catastrophe of gather, bifurcational multitude, living standard of population*

E.S. Napalkov, V.V. Zars. Towards Applying the Method of Aggregative Functional Design in Multi-User Environment, *Computer Modelling and New Technologies,* vol. 9, No 2, 2005, pp. 49–55.

The paper is dedicated to the development of a method for conceptual design based on virtual exchange of users knowledge to be represented in form of the so-called aggregative design components. In order to support aggregative components a frame-based structure of the abstract product is used.

Keywords: *Aggregative Design Component, Abstract Product Structure and Fuzzy Logical Retrieval*

COMPUTER MODELLING and NEW TECHNOLOGIES, 9.sējums, Nr.2, 2005 (Anotācijas)

E.K. Zavadskas, Z. Turskis, T. Vilutienė. Ēku apkalpes līgumdarbinieka izvēles multikritēriju simulācija, pielietojot spēles teoriju, *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 7.–16. lpp.

Rakstā dota mājokļu uzturēšanas līgumdarbinieku salīdzinošā analīze, pielietojot spēles teorijas metodes. Rakstā dažādu problēmu risināšanā ar nepilnīgu informāciju tiek izmantotas tādas lēmumu pieņemšanas metodes kā Valda likums un Beija likums. Lai ilustrētu iepriekšminēto metožu pielietojumu, autori piedāvā apkalpes līgumdarbinieka izvēles problēmu. Rakstā tiek lietoti 15 mājokļu apkalpes organizāciju dati. Analīze tiek veikta no mājokļu īpašnieku redzes viedokļa.

Atslēgvārdi: *spēles teorija, multikritērija izvēle, lēmumu pieņemšanas metodes, efektivitāte*

Yu.N. Shunin, N. Kniga. Biznesa situāciju un lēmumu pieņemšanas analīzes neironu tīklu modelēšana, *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 17.–26. lpp.

"Biznesa situāciju un lēmumu pieņemšanas analīzes neironu tīklu modelēšanas" aktualitāte ir saistīta ar biznesa aktivitāšu palielināšanos un intensificēšamos mūsdienu sabiedrībā. Lielākoties visi uzņēmumi ir ieinteresēti maksimāli sekmīgās aktivitāšu norisēs. Ļoti lielu lomu biznesā ieņem pareizu lēmumu pieņemšana. Bieži vien, lai sasniegtu izvēlēto mērķi, uzņēmumi nokļūst dažādās riska situācijās, kas pārtrauc vēlamo attīstību uzņēmējdarbībā. Viens no šādiem riska momentiem ir nepietiekama riska novērtēšana.

Atslēgvārdi*: paredzēšana, klasifikācija, kredīts, neironu tīkli, ģenētisks algoritms, anketa*

V. Butakovs, A. Grakovskis. Patvaļīgas laika rindu izcelšanās ar Hērsta indikatora palīdzību stohastiskā līmeņa novērtējums, *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 27.–32. lpp.

Autori piedāvā algoritmu, kas veic Hērsta indikatora novērtējumu ar grieztas lineāras aproksimācijas statistikas palīdzību. Ātras metodes variants un metode ar apstrādājamā perioda viduvējošanu tiek nodrošināts. Indikatora dažādu nozīmju noteikšana raksturojuma dažādiem laukumiem dod iespēju novērtēt prognozes potenciāli iespējamo dziļumu, ja pētāmai laika rindai ir līdzība kaut kādā mērā pašai sev.

Atslēgvārdi: *Hērsta indikators, prognoze, griezti lineāra aproksimācija*

V. Muško. *MAP/M/C* sistēma ar adrešu stratēģiju atkārtotiem izsaukumiem un identiskām iekārtām, *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 33.–40. lpp.

Autori rakstā izskata daudzkanālu sistēmu, kurā izsaukumi parādās saskaņā ar *MAP* (Markovian Arrival Process). Apkalpes laikam ir eksponenciāla distribūcija. Atkārtotu izsaukumu intensitāte lineāri atkarīga no izsaukumu skaita orbītā. Šādas sistēmas darbība tiek aprakstīta ar multi-dimensionālas Markova ķēdes nepārtrauktu laiku, kas pieder pie daudzkārtējām kvazi-*Toeplitz* Markova ķēdēm. Tiek parādīti daži sistēmas darbības raksturojumi, kā arī tiek doti skaitliski piemēri.

Atslēgvārdi*: daudzkanālu sistēma, atkārtota izsaukuma adrešu stratēģija, daudzkārtējas kvazi-Toeplitz Markova ķēdes, stacionāra distribūcija*

Yu. Kochetkov. Pārejas periods Latvijā kā sociāli-ekonomiska "Vienkārša katastrofa", *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 41.–48. lpp.

Rakstā autori pievēršas sociāli-ekonomiskas sistēmas pārejas periodam Latvijā 90. gados. Šo pārejas periodu autori klasificē kā "vienkāršu katastrofu" sociāli-ekonomiskajā sistēmā. Tiek izskatīti tās galvenie iemesli. Tiek izstrādāts makroekonomisks kvalitātes-kvantitātes modelis.

***Atslēgvārdi**: katastrofas cēloņi, ļaužu masu bifurkācija, iedzīvotāju dzīves līmenis*

E.S. Napalkov, V.V. Zars. Par funkcionālā agregātdizaina metodes pielietošanu multilietotāju vidē, *Computer Modelling and New Technologies,* 9.sēj., Nr.2, 2005, 49.–55. lpp.

Rakstā tiek izskatīta metode par konceptuālo dizainu, kas pamatojas uz lietotāju zināšanu virtuālām izmaiņām un kas tiek pārstāvētas ar tā saucamiem funkcionālā agregātdizaina komponentiem. Tiek lietota abstraktā produkta režģa struktūra, lai atbalstītu šos apkopotos komponentus.

***Atslēgvārdi:** funkcionālā agregātdizaina komponents, abstraktā produkta struktūra*

COMPUTER MODELLING & NEW TECHNOLOGIES

ISSN 1407-5806 & ISSN 1407-5814(on-line)

Host Organization:
Transport and Telecommunication Institute – Eugene Kopytov, Rector

Co-Sponsor Organization:
PAREX Bank, Latvia – Valery Kargin, President

Supporting Organizations:
Latvian Transport Development and Education Association – Andris Gutmanis, President
Latvian Academy of Sciences – Juris Ekmanis, Vice-President
Latvian Operations Research Society – Igor Kabashkin, President
University of Nebraska at Omaha, USA – Brent Bowen, Director of Aviation Institute
“The Khaim Kordonsky Charitable Foundation” – Inna Kordonsky-Frankel

THE JOURNAL IS DESIGNED FOR PUBLISHING PAPERS CONCERNING THE FOLLOWING FIELDS OF RESEARCH:

- mathematical and computer modelling
- mathematical methods in natural and engineering sciences
- physical and technical sciences
- computer sciences and technologies
- semiconductor electronics and semiconductor technologies
- aviation and aerospace technologies
- electronics and telecommunication
- navigation and radar systems
- telematics and information technologies
- transport and logistics
- economics and management
- social sciences

Articles can be presented in journal in English (preferably), Russian, German and Latvian (at the option of authors). All articles are reviewed.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)-7100593. Fax: (+371)-7100535
E-mail: journal@tsi.lv, http:// www.tsi.lv

COMPUTER MODELLING AND NEW TECHNOLOGIES, 2005, Vol. 9, No.2

Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

The Camera-Ready Copies

PREPARATION OF CAMERA-READY TYPESCRIPT: COMPUTER MODELLING AND NEW TECHNOLOGIES

A Guide for Authors

A.N. AUTHOR
Affiliation
Institute address

Abstract reviews the main results and peculiarities of a contribution. Abstract is presented always in English or in English and the second (presentation) language both.
Keywords: main terms, concepts

1. Introduction

These instructions are intended to provide guidance to authors when preparing camera-ready submissions to a volume in the **CM&NT**. Please read these general instructions carefully before beginning the final preparation of your camera-ready typescript.

Two ways of preparing camera-ready copy are possible:
(a) preparation on a computer using a word processing package;
(b) printed copy fitted for scanning.

2. Printer Quality, Typing Area and Fonts

IMPORTANT:

If you produce your camera-ready copy using a laser printer, use a 15 x 23 cm typing area (in A4 format: 30 mm – left, 30 mm – right, 30 mm – top, 30 – bottom, line spacing – single), as in these instructions, in combination with the **10 points Times** font. The pages will then be reproduced one to one in printing.

Fonts

The names and sizes of fonts are often not the same on every computer system. In these instructions the Times font in the sizes 10 points for the text and 8 points for tables and figure legends are used. The references section should be in the 10 points font.

3. Format and Style

The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (***British English***), headings and the style of referencing.

Camera-ready copy will be printed exactly as it has been submitted, so please make sure that the text is proofread with care.

In general, if you prepare your typescript on a computer using a word processing package, use styles for the font(s), margin settings, headings, etc., rather than inserting these layout codes every time they are needed. This way, you will obtain maximum consistency in layout. Changing relevant style(s) can make changes in the layout.

4. Layout of the Opening Page

A sample for the opening page of a contribution is shown in Figure 1 on page 3.
Requirements for the opening page of a contribution are (see also Figure 1): the titles should always be a centred page and should consist of: the title in capital letters, bold font, flush centre, on the fourth text line; followed by the subtitle (if present) in italics, flush centre, with one line of white above. The author's name(s) in capitals and the affiliation in italics should be centred and should have two lines of white space above and three below, followed by the opening text, the first heading or the abstract.

5. Headings

Please distinguish the following four levels of headings:

1. First-order Heading
This heading is in bold, upper and lowercase letters, numbered in Arabic figures, and has two lines of space above and one line below. The text begins full out at the left margin.
1.1. SECOND-ORDER HEADING IN CAPITALS
This heading is in roman capitals, numbered in Arabic figures and has one line of space above and below. The text begins full out at the left margin.
1.1.1. *Third-order Heading in Italics*
This heading is in italics, upper and lower case letters, numbered in Arabic figures and has one line of space above and no space below. The text begins full out at the left margin.
Fourth-order Heading is in Italics. This heading is in italics, upper and lowercase letters, with one line of space above the heading. The heading has a full stop at the end and the text runs on the same line.

↕ 3 blank lines

TITLE OF CONTRIBUTION
Subtitle of Contribution

↕ 2 blank lines

A.N. AUTHOR
Affiliation
Institute address

↕ 3 blank lines

Abstract

↕ 2 blank lines

First text line

Figure l. Example of an opening part of contribution to a Volume of CM&NT

6. Figures and Photographs

- *Line drawings* must be submitted in original form, on good quality tracing paper, or as a glossy photographic print.
- *Halftone photographs* must be supplied as glossy prints.
- *Colour illustrations.* Colour illustrations are more expensive and the author is expected to cover the extra costs. Please consult with Editors about this.

Mount all illustrations directly into the text at the appropriate places. Alternatively, it is acceptable to leave the appropriate space blank in the text, and submit the illustrations separately. In this case you must put the figure numbers in pencil in the open spaces in the text and on the back of the figures. Also indicate the top of the illustration.

For computer plotting the ORIGIN Software is preferable.

- Legends for figures/illustrations should not be incorporated in the figure itself and they should be listed in numerical order (headed as "*Figure 1.*", "*Figure 2.*" etc.). The legends should be set centred, below the figure.

7. Displayed Equations

Displayed equations should be in the left side of the page, with the equation number in parentheses, flush right.

$$E_{int} = \iint \psi^{+}(\mathbf{x})\psi(\mathbf{x})K(\mathbf{x}-\mathbf{x}')(-div\mathbf{P}(\mathbf{x}'))d^3xd^3x' , \quad (1)$$

$$K(\mathbf{x}-\mathbf{x}') = C_0 \frac{exp(-\lambda(|\mathbf{x}-\mathbf{x}'|)}{|\mathbf{x}-\mathbf{x}'|} . \quad (2)$$

Font sizes for equations are: 12pt – full, 7pt – subscripts/superscripts, 5pt – sub-subscripts/superscripts, 18pt – symbols, 12pt – subsymbols.

8. Tables

Please centre tables on the page, unless it is necessary to use the full-page width. Exceptionally large tables may be placed landscape (90^0 rotated) on the page, with the top of the table at the left-hand margin. An example of a table is given below:

TABLE 1. National programs of fusion research [1]

Experiment	Type	Laboratory	Task	Begin of operation
JET	tokamak	Joint European Torus, Culham, UK	Plasma physics studies in the region close to ignition	1983
TEXTOR	tokamak	FA, Jülich. Germany	Studies of plasma-wall interaction	1982
TORE SUPRA	tokamak	CEA, Cadarache, France	Testing of super-conducting coils, stationary operation	1988
ASDEX Upgrade	tokamak	IPP, Garching, Germany	Plasma boundary studies in diverter plasmas	1990
WENDELSTEIN 7-AS	stellarator	IPP, Garching, Germany	Testing the principles of ”advanced stellarator”	1988
WENDELSTEIN 7-X	stellarator	IPP, Greifswald, Germany	Testing feasibility of ”advanced stellarator” for power station	2004

9. References

The References should be typeset in a separate section as a numbered list at the end of your contribution in the following style:

Journal articles should consist of as follows: author's name, initials, year, title of article, journal title, volume number, inclusive page numbers, e.g.:

[1] Dumbrajs O. (1998) Nuclear Fusion. *RAU Scientific Reports & Computer Modelling & New Technologies* **2***,* aa-zz
[2] Kiv A.E., Polozovskaya I.A., Tavalika L.D. and Holmes S. (1998) Some problems of operator-machine interaction. *RAU Scientific Reports & Computer Modelling & New Technologies* **2***,* aa-zz
[3] Shunin Yu.N. (1996) Elementary excitations and radiation defects in solids induced by swift heavy ions. *RAU Scientific Reports & Solid State Electronics & Technologies* **1**, 15-35
[4] Schwartz K. (1996) Excitons and radiation damage in alkali halides. *RAU Scientific Reports & Solid State & Electronics & Technologies* **1**, 3-14

Book references should consist of as follows: author's name, initials, year, title of book, publisher, place of publication, e.g.:

[5] Schwartz K. (1993) The Physics of Optical Recording. Springer-Verlag, Berlin Heidelberg New York
[6] Shunin Yu.N. and Schwartz K.K. (1997) Correlation between electronic structure and atomic configurations in disordered solids. In: R.C. Tennyson and A.E. Kiv (eds.). Computer Modelling of Electronic and Atomic Processes in Solids. Kluwer Academic Publishers, Dordrecht, pp. 241-257 .

Unpublished papers should consist of as follows: author's name, initials, year (or: in press), title of paper, report, thesis, etc., other relevant details, e.g.:

[7] Shunin Yu.N. (1995) Elementary Excitations in amorphous solids accompanying the swift heavy ions passages. Private communication. GSI Seminar. Darmstadt

The references above should be cross-referenced by numbers within square brackets:
...as cited in [1], or Kiv *et al.* [2]... The use of author's initials for cross-references is not encouraged.

10. Authors Index

Editors form the author's index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.

11. Submission

Check your typescript very carefully before it is submitted. Submit two copies of the typescript to the Editors of the Volume. Always retain a copy of all material submitted as backup.

11.1. DISK FORMATS AND WORD PROCESSING PACKAGES

If you want to present contributions electronically please before submitting accord with the Editors the details on your computer system, word processing package and version (MS Word 6 and above versions are preferable) and the way of transfer on the information (disk or Internet).

Acknowledgements

Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper. The first page of the contribution should start on page 1 (right-hand, upper, without computer page numbering). Please paginate the contributions, in the order in which they are to be published. Use simple pencil only.

NATURE AND COMPUTER WORLD

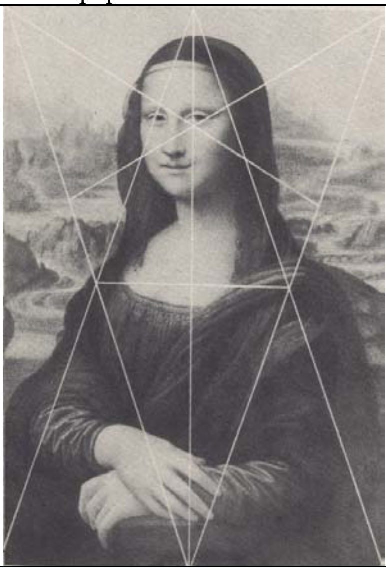
Scientific popular journal

ПРИРОДА И КОМПЬЮТЕРНЫЙ МИР

Научно-популярный журнал

DABA UN DATORPASAULE

Zinātniski populārais žurnāls



PUBLISHERS:
TRANSPORT AND TELECOMMUNICATION INSTITUTE
***TRANSPORTA UN SAKARU INSTITŪTS** (TSI)*
&
INFORMATION SYSTEMS INSTITUTE
***INFORMĀCIJAS SISTĒMU AUGSTSKOLA** (ISMA)*

NATURE AND COMPUTER WORLD,
PUBLISHED SINCE 2001
ISSN 1407-8422
ISSN 1407-8422 - **on-line**

Editorial office:
Nature and Computer World,
Lomonosov 1, Build. 4, LV-1019, Riga, Latvia
shunin@tsi.lv, kiv@tsi.lv

N&CW is the new scientific popular journal addressed to senior school students. It pays attention to some actual fields of undergraduate studies:

- Mathematics
- Physics
- Computers
- Programming and Computer Modelling
- Nature Phenomena

We are open for collaboration in these directions in the framework of N&CW and ready to consider corresponding materials. All articles are reviewed.