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MEIA SYSTEMS: MEMBRANE ENCRYPTED INFORMATION APPLICATIONS SYSTEMS

Nuria Gomez, Alberto Arteta, Luis Fernando Mingo

***Abstract**: Membrane computing is a recent area that belongs to natural computing. This field works on computational models based on nature's behavior to process the information. Recently, numerous models have been developed and implemented with this purpose. P-systems are the structures which have been defined, developed and implemented to simulate the behavior and the evolution of membrane systems which we find in nature. What we show in this paper is a new model that deals with encrypted information which provides security the membrane systems communication. Moreover we find non deterministic and random applications in nature that are suitable to MEIA systems. The inherent parallelism and non determinism make this applications perfect object to implement MEIA systems.*

***Keywords**: P-systems mapping, MEIA systems, membrane systems.*

Introduction

Natural computing is a new field within computer science which develops new computational models. These computational models can be divided into three major areas:.

- Neural networks.
- Genetic Algorithms
- Biomolecular computation.

Membrane computing is included in biomolecular computation. Within the field of membrane computing a new logical computational device appears: The P-system. These P-systems are able to simulate the behavior of the membranes on living cells. This behavior refers to the way membranes process information. (Absorbing nutrients, chemical reactions, dissolving, etc)

In this paper, we design a MEIA system just by explaining the process of encrypting the information that membrane systems process.

In order to do this we will take the following steps:

- Introduction to P-systems theory.
- Introduction to encryption algorithms
- Integration of the encryption with membrane systems
- Description of MEIA
- Applications of MEIA

Introduction to P-systems theory

I. A P-system is a computational model inspired by the way the living cells interact with each other through their membranes. The elements of the membranes are called objects. A region within a membrane can contain objects or other membranes. A p-system has an external membrane (also called skin membrane) and it also contains a hierarchical relation defined by the composition of the membranes. A multiset of objects is defined within a region (enclosed by a membrane). These multisets of objects show the number of objects existing within a region. Any object 'x' will be associated to a multiplicity which tells the number of times that 'x' is repeated in a region.

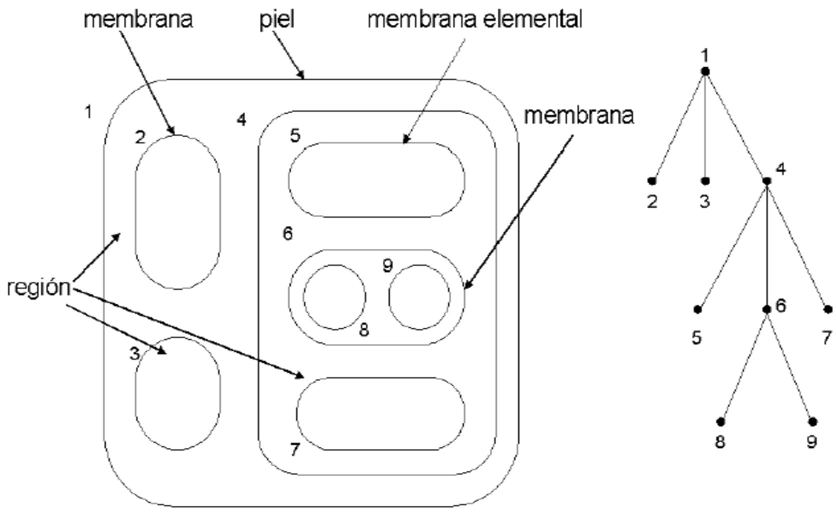

Fig. 1. The membrane's structure (left) represented in tree shape (right)

According to Păun 's definition, a transition P System of degree n, n > 1 is a construct: [Păun, 1998]

$$\Pi = \left(V, \mu, \omega_1, .., \omega_n, (R_{1,}\rho_1), ..(R_{n,}\rho_n), i_0\right)$$

Where:

1. *V* is an alphabet; its elements are called objects;
2. µ is a membrane structure of degree n, with the membranes and the regions labeled in a one-to-one manner with elements in a given set ; in this section we always use the labels 1,2,..,n;
3. $\omega_i \; 1 \le i \le n$, are strings from V^* representing multisets over V associated with the regions 1,2,..,n of µ;
4. $R_i \; 1 \le i \le n$, are finite set of evolution rules over V associated with the regions 1,2,..,n of µ; ρ_i is a partial order over $R_i \; 1 \le i \le n$, specifying a priority relation among rules of R_i . An evolution rule is a pair (u, v) which we will usually write in the form $u \to v$ where u is a string over V and v=v' or v=v'δ where v' is a string over $(V \times \{here, out\}) \cup (V \times \{in_j \; 1 \le j \le n\})$, and δ is a special symbol not in. The length of u is called the radius of the rule $u \to v$
5. i_o is a number between 1 and n which specifies the output membrane of Π

Let *U* be a finite and not an empty set of objects and N the set of natural numbers. A *multiset of objects* is defined as a mapping:

$$M : V \rightarrow \mathrm{N}$$

$$a_i \rightarrow u_1$$

Where a_i is an object and u_i its multiplicity.

As it is well known, there are several representations for multisets of objects.

$$M = \{(a_1, u_1), (a_2, u_2), (a_3, u_3)...\} = a_1^{u_1} \cdot a_2^{u_2} \cdot a_n^{u_n} ......$$

Evolution rule with objects in *U* and targets in *T* is defined by $r = (m, c, \delta)$ where

$$m \in M(V), c \in M(VxT)\ and\ \delta \in \{to\ dissolve, not\ to\ dissolve\}$$

From now on *'c'* will be referred to as the consequent of the evolution rule *'r'*

The *set of evolution rules* with *objects* in *V* and targets in *T* is represented by R *(U, T).*

We represent a rule as:

$$x \rightarrow y \quad or \quad x \rightarrow y\delta$$

where x is a multiset of objects in M((*V*)xTar) where Tar ={here, in, out} and y is the consequent of the rule. When δ is equal to "dissolve", then the membrane will be dissolved. This means that objects from a region will be placed within the region which contains the dissolved region. Also, the set of evolution rules included on the dissolved region will disappear.

P-systems evolve, which makes it change upon time; therefore it is a dynamic system. Every time that there is a change on the p-system we will say that the P-system is in a new transition. The step from one transition to another one will be referred to as an evolutionary step, and the set of all evolutionary steps will be named computation. Processes within the p-system will be acting in a massively parallel and non-deterministic manner. (Similar to the way the living cells process and combine information).

We will say that the computation has been successful if:

- The halt status is reached.
- No more evolution rules can be applied.
- Skin membrane still exists after the computation finishes.

Encryption algorithms

Most weak points are reached when there is data exchange in any communication process. The methods to exchange information are targets for attacks. It is normal that hackers trying to break into these methods to get the data. The amount of risk responds to an equation. This equation determines our decisions to take when protecting our system. B=P X L

- B: is the load or expenses that we invest in prevention of an specific loss due to a vulnerability.
- P: is the probability that such vulnerability is affected and that specific loss happens.
- L: is the impact or total cost that means the specific loss due to the vulnerability that has been affected.

If the value B<= P+L we need to set up a security system to prevent attacks otherwise it won't be needed. However this is an equation that not always suits reality. It can be an orientation but in the end common sense will apply. The equation gives us an idea about how much protection we want to set up in our system.

Creating an access control list can be interesting too. That way we can set up rights for users and establish the way the access to the system. As we can see in the slide, we can customize the rights.

Not only intentional threat can put our data in danger. Nature can give us a hard time. Natural disasters are often responsible for data loss. It is important put to allocate sensitive data in a safe place.

Information has been defined in many ways. In order to encrypt information we need to know some concepts of number theory. Congruency is an important operation used in info encryption.

Apart from congruency we are interested in finding numbers with divisibility properties. These are really important in cryptography. In particular, numbers that are only divided by either number 1 or by themselves are widely used (Prime numbers). In cryptography, given 2 numbers we might need to calculate the great common divisor

Inverses in a field (Field is referred as a number). This is a major concept to understand how public/private key systems (asymmetric systems).

Important fact:

- If n the field is prime, then any number has an inverse in the field.
- If the n is not prime, It might happen than a number doesn't have inverse in the field. (That is why in cryptography we will work with (n prime numbers).

The concept RSR is important as this let us have the prime numbers within a field 'n'. Some asymmetric systems such as RSA use it.

This operation has a high computational cost. That is why algorithms of rapid exponentiation have been created. The slides show a trick to reduce the computational operations

For any type of system we can find the most popular algorithms to encrypt information.

(DES, RSA, IDEA, R5......)

Public keys involve the use of one way functions. These functions are easy to calculate. However obtaining the inverse of the function is very difficult.

For instance the function that multiplies 2 big prime numbers is easy to implement.

Example: The product 6399999 and 89558745 is easy to calculate with a computer (573175878441255). However if we have this number, obtaining the 2 numbers that multiplied by each other is equal to it, (573175878441255) involves a high computational cost. This is the concept behind the public key cipher

The most common trapdoor functions are product of two big primes and the problem of the discrete logarithm.

Integration with Transition P-systems

This section explains the encryption protocol used by the membrane systems.

We can encrypt words by selecting its corresponding bit sequence. For example Let's the imagine that we have the membrane 'A' and we want to encrypt the info end to membrane B. Imagine the info is the code ‘A.’ The ASCII code for A is 65 and representation for 65 is 1000001.

Then we will be encrypting bit by bit.

In order to encrypt bit a bit we have to:

1) Convert the text we want to encrypt into binary code (0’s and 1’s). (in the end the info are sequences of 0 and 1);
2) Selecting a random number in binary code: Example 0010001;
3) Apply the XOR function to 1) and 2) i.e.
   0 XOR 0=0
   0 XOR 1=1
   1 XOR 0=1
   1 XOR 1=0

If we want to encrypt the text: “xxaaci” which is the standard information shared in every membrane.

We could divide the text into data blocks and then encrypt those.

Considering that a character has 1 byte size, we would need 2 data blocks to encrypt the message.

Then the algorithm encrypts every block.

We might use a secret key for encrypting every block. In the next slides we show advantages and disadvantages of secret key management blocks

In order to prevent the problems of using private keys, we can use a combination of the two (public/private) keys.

This example shows an algorithm that encrypts with only private keys.

MEMBRANE A only knows his private key. So Only MEMBRANE A can encrypt /decrypt a message.

MEMBRANE B only knows its private key. Only MEMBRANE B can encrypt /decrypt with that key.

The problem of the integrity arises. Anyone can encrypt with a different private key. MEMBRANE A can never be sure that B is really MEMBRANE B or someone else. Anyone can intercept the message in the system and then encrypt it with their own key. That is why the use of public keys is needed.

Here it explains how someone can steal the identity in the membrane communication phase.

In this case if B encrypts a message with a private key and provides the public key to A, if A receives the message she knows for sure that B is the real B and not someone else. However anyone can obtain the public key and decrypt the message.

Now we use a combination of public and private keys.

A has a private key (PRa) and gives B their public one (PUa) (Anyone can have the public one).

B has a private key (PRb) and gives A their public one (PUb) (Anyone can have the public one)

1st) B performs a first encrypting operation to the info processed with the public key of A (PUa) so only A can decrypt it because it is required the private key of A(PRa) because only A knows it.

Let's say that the obtained cryptogram is X.

2st) B performs another encryption (now over X) and he does it with his private key (PRb) and send the cryptogram through a channel (this is used to start the session of communication. In this case anyone who has (PUb) can intercept it and decrypt it but the maximum they could do is getting X (which is a cryptogram itself encrypted with PUa) which means that it is necessary to have also (PRa) In this case A is the only MEMBRANE who can decrypt it because they have PuB and PuA.

In this case A is sure that the message can from B because B use PRb and only B knows it.

Also we make sure that no one can decrypt the message but A because PRa is required

3st) By doing this we make sure no one can steal A and B identity (integrity) and no one can intercept the message (confidentiality).

The 2 main characteristics in information security are preserved.

Randomly dimensioned applications

The concept of MEIA arises when applying the encrypted membrane systems to nature random applications. Thus it makes sense to apply these encrypted systems in security areas that must have non known size and can be often redimensioned.

Several applications as E-grid, diseases patterns, raid clustering, etc can use a MEIA system to protect data and speed up problems solving.

Conclusion

In this paper, we have studied some topics of membrane computing. As a part of this study, we have explained some concepts of the p-systems. Concepts such as:

- Components;
- Interactions between the components;
- The evolution of a p-system;
- Encriyption information;
- Applications of encrypted membrane systems (MEIA systems).

Nowadays we work with the p-system as an entire compacted block of components that are going through an evolutionary process. The p-system functioning is treated under a global perspective. The intregration qith application of nature can empower much more the use of p-systems in the future.

Besides, security is a must when using technology.

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ABOUT CRITERIA FOR AN ESTIMATION OF NONLINEAR PARAMETERS IN MODELS OF MONITORING

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***Abstract**: In the problem of optimal estimation of model parameters using risk criteria we propose an approach of separation of linear parameters from the nonlinear ones. In the problem of finding a global minimum of risk criteria our approach leads to a decrease of the dimension of the space of free variables up to the dimension of the space of the nonlinear parameters. This allows one to obtain a simpler minimization problem, which can be solved more efficiently via Monte Carlo methods. Such an improvement is very significant in estimation of the models of the object “aging” while investigation of geophysical objects, models of which typically have high dimensionality. We illustrate the proposed method with processing and analysis of data obtained during the field observations in the regime of monitoring.*

Keywords: math model, active monitoring, risk criteria, linear and nonlinear parameters.

ACM Classification Keywords: G. 1. 6. Mathematics of Computing, Numerical Analysis, Optimization.

Introduction

Often monitoring systems are described by complicated models with the big size of dimension of the free parameters vector of these models. And only the part of these parameters are linear ones, and the biggest part of parameters are nonlinear ones.

In such case the essential role belongs to an aprioristic level of processes scrutiny. It allows to simplify an estimation process of free parameters. In such cases it is natural to build such procedure of an estimation of these parameters which is based on Bayesian estimations. It considers the aprioristic information which is available for the researcher.

As a result of monitoring there is a chance to analyze the changes in time of set of free parameters of model. It allows to draw conclusions on a status of object of research and to predict its behavior in the future. Such approach is fruitful in an estimation of a status of historically valuable architectural monuments and their possible reaction to earthquakes and creations concerning an optimum level of resistance to seismic events [Tassios, 2010].

Mathematical model of an estimation of parameters

Dynamic systems are modeled by superposition periodic or are quasi periodic processes which represent a subject of the analysis as enable to predict on background behavior of system in the future.

The essential role in creation of analysis algorithms is played with that fact, that in model of dynamic process there is even a part of free parameters which enter into model linearly, It allows to accelerate process of processing and the analysis of the data received as a result of monitoring. Model of process we build in the form of manifold [Виноградов, 1977]. It displays model in a point N - dimensional space $\mathbb{R}_N$ by means of free parameters of model.

Here N is a quantity of these parameters. $M(\mathbf{\Lambda},t)$ is a model of dynamic process which depends from time, but also from set of free parameters $\mathbf{\Lambda}$. The result of monitoring of process $y(t,\mathbf{\Lambda},\alpha)$ can be presented in the form of equality:

$$y(t,\mathbf{\Lambda},\alpha)=M(\mathbf{\Lambda},\alpha,t)+n(t)\ ,t\in\left[0,T\right] \tag{1}$$

In (1) $\mathbf{\Lambda}$ is a set of parameters which are reflected in model of process, are ordered in a rectangular matrix as the free parameters which are a subject an estimation, $\alpha(t)$ is a source of stochasticity- the fluctuating disturbance which are not allowing precisely to reproduce set $\mathbf{\Lambda}$. T is an area of supervision in time. A source of stochasticity except for an additive noise are also fluctuations of parameters of model.

We choose such model, at which set of its free parameters is contained by a subset of nonlinear parameters. We will put in order it to on and, putting in order it in a vector $\mathbf{h}=\left\{h_k\right\},k=\overline{1,n}$ and selecting from the set of parameters $\mathbf{\Lambda}$ it subset. In $\mathbf{\Lambda}$ remain only nonlinear parameters, so come to the model of such kind:

$$M(\mathbf{\Lambda},t)=\sum_{k=1}^{n}h_k\exp\left\{-\lambda_{k,1}t\right\}\sin(\lambda_{k,2}t-\lambda_{k,3}). \tag{2}$$

$\mathbf{\Lambda}^{\langle k\rangle}=\left\{\lambda_{k,1},\ldots,\lambda_{k,3}\right\}^T,\quad k=\overline{1,n},$ -columns are in the matrix of nonlinear parameters $\mathbf{\Lambda}$.

The purpose of analysis is a construction of optimum estimations $\tilde{\tilde{\mathbf{\Lambda}}}$ by a set $\tilde{\tilde{\mathbf{\Lambda}}}=\left\{\tilde{\mathbf{\Lambda}}_r(y(t,\alpha(t))\right\}$ decision rules. At the choice of decision rule as a criterion of optimality on some set of R decision rules and observed data $y(t,\alpha(t)$ choose the average risk criterion $R(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha))$ [3]

$$R(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha))=\sum_{r=1}^{R}L(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha),\mathbf{\Lambda}))P(\mathbf{\Lambda}/y(t,\alpha)). \tag{3}$$

Here $L(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha),\mathbf{\Lambda}))$ is a loss function. Loss function depends on the estimation of free parameters which are accepted as a solution by decision rule $\tilde{\mathbf{\Lambda}}_r(y(t,\alpha)$ and truth value of these parameters $\mathbf{\Lambda}$. Here r is a rule number.

The type of function $L(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha),\mathbf{\Lambda}))$ is not determined by a theory, it gets out from the engineering or intuitional considering. If accepted decision closer to the «truth», the value of loss function have to less, or even no more. $\tilde{\tilde{\mathbf{\Lambda}}}(y(t,\alpha)$ is the set of R decision rules. In formula (3) $P(\mathbf{\Lambda}/y(t,\alpha)$ is conditional probability of value of nonlinear free parameters on condition of realization $y(t,\alpha)$.

According to Bayes formula [Большаков, 1969] average risk, accurate within constant, appears in a kind:

$$R(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha)) = C\sum_{\mathbf{\Lambda}\in\tilde{\mathbf{\Lambda}}} L(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha),\mathbf{\Lambda}))P(y(t,\alpha)/\mathbf{\Lambda})P(\mathbf{\Lambda})) \tag{4}$$

Here $C=(P(y(t,\alpha)))^{-1}$ is the inverse to the total probability $P(y(t,\alpha)$ value. This value depends only on the realization $y(t,\alpha)$. The optimal estimation $\tilde{\mathbf{\Lambda}}^*$ of model parameters is obtained by minimization of average risk at the set of decision rules $\tilde{\mathbf{\Lambda}}_r(y(t,\alpha)$:

$$\tilde{\mathbf{\Lambda}}^* = \min_{\tilde{\mathbf{\Lambda}}_r(y(t,\alpha)\in\tilde{\tilde{\mathbf{\Lambda}}}} R(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha)); \quad r=\overline{1,R} \tag{5}$$

Loss function of next kind was used in a calculations:

$$L(\tilde{\mathbf{\Lambda}}_r(y(t,\alpha),\mathbf{\Lambda})) = \begin{cases} 0, & \text{при} \quad \left\|\tilde{\mathbf{\Lambda}}_r - \mathbf{\Lambda}\right\| \le \Omega \\ \dfrac{1}{\Omega}, & \text{при} \quad \left\|\tilde{\mathbf{\Lambda}}_r - \mathbf{\Lambda}\right\| > \Omega \end{cases} \tag{6}$$

If the norm of difference of vector of estimations of model parameters does not excel the fixed value Ω, the observer of losses does not carry, otherwise the losses is Ω^{-1}.

Model of the research object

Such approach was applied by authors for data processing and analysis, got in the field of supervisions of monitoring of object with it spectral characteristics in seismic frequencies band (0,1 Hz – 8 Hz). The feature of experiment was that in monitoring duration the object characteristics were changed by the certain program, and the purpose of experiment was to estimate these changes in space of parameters of object model. The dimension of vector of free parameters changed depending on a selectable model from 12 to 20. Object was described a great number of linear and nonlinear model parameters, and the search of global a minimum of criterion of optimality of estimations for each of decision rules was carried out depending on a hypothesis about an additive background noise $\alpha(t_i)$. This background noise was designed, in general case, by non-stationary Gaussian noise. A decision rule was following: an estimation was accepted as minimum deviation of model from observed data in a norm of Hilbert spaces. Dot product for two functions $\langle y(t), f(t)\rangle_r$ in their discrete presentation got out for two vectors thus:

$$\langle y(t), f(t)\rangle_r = k(\boldsymbol{\sigma}_r)\sum_{i,j} y(t_i)f(t_j)W_r(t_i,t_j) \quad , i,j=\overline{1,M},\ r=\overline{1,R} \tag{7}$$

Here - $W_r(t_i,t_j)$ is inverse matrix to the covariance matrix of additive background $n(t)$, $\boldsymbol{\sigma}_r$ - parameters of this matrix. $k(\boldsymbol{\sigma}_r)$ are coefficient, depending on the determinant of covariance matrix $\boldsymbol{\sigma}_r$. $M\Delta = T$ here

M is dimension of vector of discrete presentation of functions on a time interval with a length T, Δ - quantization interval, thus $M\Delta = T$.

The considered algorithm in calculations was described by two types of decision rules. One of them was based on supposition about a high-frequency background noise with a fixed number of values of power of such process. For example - white noise [Виноградов, 1977] in this case kernel in (7) will be:

$$k(\boldsymbol{\sigma}_r)W_r(t_i,t_j) = \frac{1}{\sigma_r}\delta(t_i - t_j) \tag{8}$$

Norma of deviation of one function from other (norm of difference) will be:

$$\sqrt{\langle y(t)-f(t), y(t)-f(t)\rangle_r} = \frac{1}{\sigma_r}\sqrt{\sum_{i=1}^{M}(y(t_i)-f(t_i))^2} \tag{9}$$

The second decision rule is based on a hypothesis about low-frequency stationary normal noise with fixed a number of determining parameters of this noise [Амиантов,1971]. Calculations of the data of monitoring of object, show that the hypothesis about a high-frequency background noise gave the best goodness of fit of model of object with observed data.

Model of monitoring object

We will consider hypothesis that an object is described by linear combination from n oscillators, each of which is submodel (case (2)):

$$M_k(\boldsymbol{\Lambda}^{\langle k\rangle},t) = h_k \exp\left\{-\lambda_{k,1} t\right\}\sin\left(\lambda_{k,2}t-\lambda_{k,3}\right). \tag{10}$$

In this case the model (2) appears in a kind:

$$M(\boldsymbol{\Lambda},t) = \sum_{k=1}^{n} h_k \exp\left\{-\lambda_{k,1} t\right\}\sin\left(\lambda_{k,2}t-\lambda_{k,3}\right) \tag{11}$$

Using the metrics of decision rule with the number of *n*, we get the system of linear equalizations regard to a vector $\mathbf{h}$ and observed date $y(t)$, at the fixed values of matrix $\boldsymbol{\Lambda}$:

$$\boldsymbol{\Psi}_r\mathbf{h}_r = \mathbf{I}_r;\ r=\overline{1,R} \tag{12}$$

Here a matrix with the index of *r* has elements:

$$\Psi^r_{k,s} = \frac{1}{\sigma_r}\sum_{i=0}^{M}\sum_{k=1}^{n} M_k(\boldsymbol{\Lambda}^{\langle k\rangle},t_i)M_s(\boldsymbol{\Lambda}^{\langle s\rangle},t_i),\quad s=\overline{1,n}. \tag{13}$$

The vector of right side of equation $\mathbf{I}_r$ was calculated by the following formula:

$$\mathbf{I}_r = \{I^r_s\};\ I^r_s = \frac{1}{\sigma_r}\sum_{i=0}^{M} y(t_i)M_s(\boldsymbol{\Lambda}^{\langle s\rangle},t_i). \tag{14}$$

It is necessary to mark that Bayesian approach to the decision-making is used widely in geophysics. It is enough to mark recent published work [Imoto, 2010].

Processing of observed data

Processing of observed data was carried out by a next algorithm: by the method of Monte Carlo, on a prior distribution, a pseudorandom point was thrown out in space of nonlinear parameters. In the model of object (formula (10)) for these point and observed data the root of the system of linear equations (D12) for linear parameters was calculate a point in subspace of linear parameters. The set of nonlinear and linear free parameters of model, got thus used for the estimation of local minimum in a nonlinear problem as an initial point for an algorithm of Livenberga-Makvardta [Levenberg, 1944; Marquardt, 1963]. This procedure was executed recursively, the estimation of a minimum of minimoruma was as a result calculated on the set of pseudorandom points. Such estimation approach stochastically to the global minimum. In 12 dimensional space of free parameters of model an object was reflect in to a point with such components:

$\lambda^T =$

0	1	2	3	4	5	6	7	8	9	10
$7.313 \cdot 10^{-3}$	2.962	0.698	0.94	0.114	9.028	0.452	-0.203	-0.231	11.284	$6.07 \cdot 10^{-3-}$

Here 0, 4 and 8 components are an index of decrement of exponent to the first, the second, and the third harmonics. First, fifth and ninth components is circular frequency according to the first the second and the third harmonic (given in radians). Second, sixth and tenth components is amplitudes of harmonics) given in relative units). Third, seventh and eleventh harmonic is a phase change in radians. Third, seventh and eleventh components is a phase change (given in radians).

Conclusions

Proposed an approach of division of linear and nonlinear parameters of model, at their optimum evaluation by the criteria of risk. It allows to decrease the dimension of space of the estimated parameters in the Monte Carlo method at the search of global a minimum of risk criteria to the dimension of space only of nonlinear parameters. It is specially important at the estimation of models with the large dimension of free parameters, that typically for the tasks of geophysics. Data processing of object monitoring with changing characteristics by the offered algorithm allowed to estimate even insignificant changes in a state of object in space of free parameters of model, i.e. position of point in space of it characteristics.

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INDIVIDUAL-OPTIMUM EQUILIBRIUMS IN GAMES WITH FUSSY PURPOSES OF PLAYERS

Sergiy Mashchenko

***Abstract**: The notion of fuzzy individual-optimal equilibrium, where every player is considering the interests of fuzzy set of other players, was defined. The notion of a union of fuzzy set of clear relations is put in for this purpose. Structural formulas for the construction of a function of belonging of this relation are developed. The Connection of fuzzy equilibrium with the set of individual-optimal equilibriums was researched and the existence of maximizing fuzzy equilibrium was defined.*

***Keywords:** fuzzy set, fuzzy goal, fuzzy game, membership function, fuzzy set of type 2, decision making.*

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Introduction

The notion of Nesh's equilibrium found wide application in the decision of many applied problems in conflict conditions. Its “absolute absence of compromise” is the peculiarity of Nesh's equilibrium. If there is the sole situation of a game which allows players to adhere to “optimum strategies”, it can indisputably be the basis of stable agreement between players. But, firstly, numerous examples show that there can be situations which are “better” than Nesh's equilibrium, and in order for these situations to become stable, players must agree to the compromise. Secondly, when Nesh's equilibriums doesn't exist, or, opposite, them – much, on the basis of compromise between players it is possible to build a stable agreement between them. Thirdly, often enough in the real conflicts players a priori are in compromise relations and the question lies in how to make it more stable.

As the classic theory of compromises is created only for the collective conduct of players, the problem of its expansion in case of their non-cooperative conduct is topical. In the work, non-cooperative games in which players can choose the strategies individually are explored, but, unlike the classic theory, fussy interests of the partners are taken into account.

Individual-optimal equilibriums

Let's consider the general game G in the normal form $(X_i, R_i; i \in N)$, where $N = \{1,2,...,n\}$ - is a set from n players; X_i - a set of player $i \in N$'s strategies; R_i - a complete binary preference relation of player $i \in N$, which is definite on the set $X = \prod_{i \in N} X_i$ of situations. Let's consider that the game takes place in the conditions of being completely informed. We will also consider that players operate not cooperatively, that is, everybody chooses the strategies independently.

One of optimum principles in non-cooperative games is the concept of individual optimum [Mashchenko, 2009].

According to this concept every player chooses the strategies individually (non-cooperatively), but takes into account the interests of all other players (compromise for the sake of resolution of conflict).

The players' binary preference relations $R_i, i \in N$, are shown by the aggregated relation $R = \bigcup_{i \in N} R_i$ for the formalization of the individual-optimum equilibrium notion. Obviously, the relation R will also be full. Let S - be the prevailing relation, induced by the aggregated preference relation R. Then $S = \overline{R^{-1}} = \bigcap_{i \in N} S_i$, where $S_i = \overline{(R_i)^{-1}}$ - is the player prevailing relation is induced by the preference relation R_i.

We will say that situations $x, y \in X$ are in relation of a strong *NE*-prevailing of player $i \in N$, that is generated by the aggregated prevailing relation *S*, and to mark it $xS^{NE(i)}y$, if $xSy \wedge (x_{N \setminus i} = y_{N \setminus i})$.

We will name a situation x^* the weak individual-optimum equilibrium of game *G* [Mashchenko, 2009] (we will mark their set through *WIOE*), if $y\overline{S^{NE(i)}}x^*$, $\forall y \in X$, $\forall i \in N$. Stability of individual-optimum equilibriums is grounded in a so called one-purpose game. In this game at all players have one purpose, but it is characterized for every player by the preference relation. Ideally, this purpose consists in the choice player strategies so that there is a most preferable situation for all players. Because such situations do not exist often enough, players agree to go on a compromise for the sake of the general purpose. Because the players operate non-cooperatively, each of them can see this compromise in his or her own way, which leads to conflict.

In that and only in that case, when a weak individual-optimum equilibrium x^* will be the basis of an agreement between players, the change by any player $i \in N$, agreed with other players, strategies x_i^* to another, will always result in a situation which will not prevail x^* at least for one player (him in particular). That is player $i \in N$'s purpose, which consists of his personal interests and interests of other players which he takes into account, can be not satisfied and an attained during previous negotiations compromise can be blasted.

In this work the notion of weak individual-optimum equilibrium is summarized for the case, when players can fuzzily take into account their partners' interests. In other words, every player cannot confidently say that he will search for a compromise with the other players, but he can set the fuzzy set of players, the interests of whom he is going to take into account. Let $\eta_i : N \to [0,1]$ - be a belonging function of players $\tilde{N}_i$ fuzzy set, the interests of which player $i \in N$ is going to take into account. For the formalization of the individual-optimum equilibrium notion in the general game *G* for every player $i \in N$ we aggregate players' $j \in \tilde{N}_i$ preference relation R_j in the preference relation of their association $\tilde{R}_{N_i} = \bigcup_{j \in \tilde{N}_i} R_j$. The acquired relation is a fuzzy set $\tilde{N}_i$ union of clear relations R_j, $j \in N$, is a new notion, requires determination and research.

The union of fuzzy set of clear relations

Let's formalize the operation of union $\tilde{R} = \bigcup_{i \in \tilde{N}} R_i$ of the fuzzy set $\tilde{N}$ of clear relations R_j, $j \in N$, where $\tilde{N}$ - is a fuzzy set with the belonging function $\eta : N \to [0,1]$. Let $r_j : X \times X \to \{0,1\}$ - be characteristic function of relation R_j, $j \in N$ (that is $xR_jy \Leftrightarrow r_j(x,y) = 1$). For each $x, y \in X$ we will mark:

$$N^{PO}(x,y)=\{i\in N \mid \not\exists j\in N:(r_j(x,y),\eta(j))\succ(r_i(x,y),\eta(i))\} \quad (1)$$

- set players indexes which do not get better in a increasing characteristic functions $r_i(x,y)$ of relations R_i, $i\in N$, and belonging functions $\eta(i)$ of fuzzy set $\tilde{N}$;

$$\tilde{\eta}(x,y,i)=\begin{cases}\eta(i), & i\in N^{PO}(x,y),\\ 0, & i\notin N^{PO}(x,y),\end{cases} \quad (2)$$

-fuzzy subset of set N belonging function with a transmitter $N^{PO}(x,y)$.

A next definition will be related to the known [Mashchenko, 2010] fuzzy set of type 2 notion, the value of belonging function of which is the fuzzy set in classic sense (type 1).

By the union of fuzzy set $\tilde{N}$ of fuzzy relations, according to [Mashchenko, 2010] we will name - fuzzy relation of type 2, which is defined on the set X and fixed by the three $(x,y,r(x,y,z))$, where

- $r:X\times Y\times Z\to[0,1]$ - is the unclear reflection $\Re$ belonging function, which executes the role of fuzzy belonging function of which is definite thus:

$$r(x,y,z)=\begin{cases}\max\limits_{i\in N}\{\tilde{\eta}(x,y,i)) \mid r_i(x,y)=z\}, & \exists i\in N: r_i(x,y)=z,\\ 0, & r_i(x,y)\neq z,\forall i\in N.\end{cases} \quad (3)$$

- $x,y\in X$ - pair of game situations;
- z - element of the universal set $Z=\{0,1\}$ of belonging reflection $\Re$ values of type 2 fuzzy relation $\tilde{R}$.

Values of fuzzy belonging reflection $\Re$ for the fixed situations $x^0,y^0\in X$ pair form a fuzzy subset $\Re_Z(x^0,y^0)$ of the $Z=\{0,1\}$ set with the belonging function $r(x^0,y^0,z)$. The value $r(x^0,y^0,1)$ can be understood as a degree of that the x^0,y^0 pair is in the relation $\tilde{R}$. Accordingly the value $r(x^0,y^0,0)$ has the sense of not belonging degree of the pair x^0,y^0 to the relation $\tilde{R}$.

On the other hand, if in the functions $r(x,y,z)$ are fixed $z=1$, then we will get the belonging function $r(x,y,1)$ of alternatives x,y pairs fuzzy set which are found in the relation $\tilde{R}$. Let's indicate this set $\Re_X(1)$. Analogical, for the fixed value $z=0$ we will get the alternatives x,y pairs fuzzy set which are not found in the relation $\tilde{R}$, with the belonging function $r(x,y,0)$. We will indicate it $\Re_X(0)$. Interestingly, that in the general case $\Re_X(0)\neq\overline{\Re_X(1)}$, and, accordingly $r(x,y,0)\neq 1-r(x,y,1)$.

A next theorem allows structurally to build the belonging function $r(x,y,z)$.

Theorem 1. Let R_i, $i\in N$, - be clear relations which are set on the set X by the appropriate characteristic functions $r_i(x,y)$, $x,y\in X$, $i\in N$; $\eta(i)$, $i\in N$, - fuzzy set $\tilde{N}$ belonging function. For the fuzzy set $\tilde{R}$ of type 2, which is set by the fuzzy reflection $\Re$ with the belonging function $r(x,y,z)$; $x,y\in X$; $z\in[0,1]$, to be the union of fuzzy set $\tilde{N}$ relations R_i, $i\in N$, that is $\tilde{R}=\bigcup\limits_{i\in\tilde{N}}R_i$, it is necessary and it is enough, for $x,y\in X$:

$$r(x,y,1)=\begin{cases}\max\limits_{r_i(x,y)=1}\eta(i), & \exists i\in N: r_i(x,y)=1,\\ 0, & r_i(x,y)=0,\forall i\in N,\end{cases}$$
$$r(x,y,0)=\begin{cases}\max\limits_{i\in N}\eta(i), & r_i(x,y)=0,\forall i\in \mathrm{Arg}\max\limits_{i\in N}\eta(i),\\ 0, & \exists i\in \mathrm{Arg}\max\limits_{i\in N}\eta(i): r_i(x,y)=1.\end{cases} \tag{4}$$

Proof. We will show at first, that formula (3) is equivalent to such

$$r(x,y,z)=\begin{cases}\max\limits_{i\in N^{PO}(x,y,z)}\eta(i), & N(x,y,z)\neq\varnothing,\\ 0, & N(x,y,z)=\varnothing,\end{cases} \tag{5}$$

where for $\forall x,y\in X\ \ \forall z\in[0,1]$

$$N(x,y,z)=\{i\in N\mid\ z=r_i(x,y)=\max_{\eta(j)\geq\eta(i)} r_j(x,y),\ \eta(i)=\max_{r_j(x,y)\geq r_i(x,y)}\eta(j)\} \tag{6}$$

We will note that from (2), (3) follows, that

$$\tilde{R}=\bigcup_{i\in\tilde{N}}R_i \Leftrightarrow r(x,y,z)=\begin{cases}\max\limits_{i\in N^{PO}(x,y)}\{\eta(i)\mid\ r_i(x,y)=z\}, & \exists i\in N^{PO}(x,y): r_i(x,y)=z,\\ 0, & r_i(x,y)\neq z,\forall i\in N^{PO}(x,y),\end{cases} \tag{7}$$

$x,y\in X\ \ z\in[0,1]$. Therefore for the proving of equivalence (3) and (5) it is enough to show that (7) is equivalent to (5), (6). Let's show that

$$N^{PO}(x,y)=\{i\in N\mid r_i(x,y)=\max_{\eta(j)\geq\eta(i)} r_j(x,y),\ \eta(i)=\max_{r_j(x,y)\geq r_i(x,y)}\eta(j)\}\ ,\ x,y\in X \tag{8}$$

Assume that for some $x,y\in X$, $i\in N$, the correlation is executed:

$$r_i(x,y)=\max_{\eta(j)\geq\eta(i)} r_j(x,y),\ \eta(i)=\max_{r_j(x,y)\geq r_i(x,y)}\eta(j) \tag{9}$$

We will assume the opposite, that $i\notin N^{PO}(x,y)$. Then according to (1) $\exists l\in N$, for which $r_l(x,y)>r_i(x,y)$, $\eta(l)\geq\eta(i)$, or $r_l(x,y)\geq r_i(x,y)$, $\eta(l)>\eta(i)$. In the first case, from here follows, that $r_l(x,y)>\max\limits_{\eta(j)\geq\eta(i)} r_j(x,y)$. In the second case, we get $\eta(l)>\max\limits_{r_j(x,y)\geq r_i(x,y)}\eta(j)$, which contradicts (9).

Assume that $i\in N^{PO}(x,y)$. We will assume the opposite, that $r_i(x,y)<\max\limits_{\eta(j)\geq\eta(i)} r_j(x,y)$ or $\eta(i)<\max\limits_{r_j(x,y)>r_i(x,y)}\eta(j)$. In the first case from here follows, that $\exists l\in N$, for which $\eta(l)\geq\eta(i)$, $r_l(x,y)>r_i(x,y)$. Then $(r_l(x,y),\eta(l))\succ(r_i(x,y),\eta(i))$ and $i\notin N^{PO}(x,y)$ from (1). Analogical in the second case, $\exists k\in N$, for which $r_k(x,y)>r_i(x,y),\ \eta(k)\geq\eta(i)$. Then $(r_k(x,y),\eta(k))\succ(r_i(x,y),\eta(i))$ and $i\notin N^{PO}(x,y)$ from (1). Thus, we have obtained the contradiction and there is (8). As from (8) follows $N(x,y,z)=N^{PO}(x,y)\bigcap\{i\in N\mid\ r_i(x,y)=z\}$, then (7) is equivalent to (5), (6), and therefore (3) and (5) are equivalent.

Now for proof of theorem it is sufficient to show the equivalence between formulas (4) and (5).

At first we will write down (6) for $z=1$ in two possible cases. Let's assume at first $r_i(x,y)=0,\forall i\in N$. Then from (4) $r(x,y,1)=0$. On other hand, from (6) directly follows, that $N(x,y,1)=\varnothing$ and then from (5) $r(x,y,1)=0$.

In the second case, assume that $\exists i \in N : r_i(x,y) = 1$. We will indicate $\eta_1^*(x,y) = \max_{r_j(x,y)=1} \eta(j)$, $I_1^*(x,y) = \{j \in N \mid \eta(j) = \eta_1^*(x,y)\}$. We will define the value $r(x,y,1)$ from (5). For this purpose we will build from (6) $N(x,y,1) = \{i \in N \mid 1 = r_i(x,y) = \max_{\eta(j) \geq \eta(i)} r_j(x,y),\ \eta(i) = \eta_1^*(x,y)\}$. We will show that $N(x,y,1) = I_1^*(x,y)$. Assume that $i \in I_1^*(x,y)$. Then $\eta(i) = \eta_1^*(x,y)$ and $\max_{\eta(j) \geq \eta(i)} r_j(x,y) = \max\{\max_{\eta(j) = \eta_1^*(x,y)} r_j(x,y), \max_{\eta(j) > \eta_1^*(x,y)} r_j(x,y)\} =$ $= \max\{1, \max_{\eta(j) > \eta_1^*(x,y)} r_j(x,y)\} = 1 = r_i(x,y)$. From here it is obvious that $i \in N(x,y,1)$.

On the contrary, assume that $i \in N(x,y,1)$. Then $1 = r_i(x,y) = \max_{\eta(j) \geq \eta(i)} r_j(x,y)$ and $\eta(i) = \eta_1^*(x,y)$. From here follows $i \in I_1^*(x,y)$. Then from (5) $r(x,y,1) = \eta_1^*$. Therefore formulas (4), (5) are equivalent for $z = 1$.

Now we will write down (6) for $z = 0$ in two possible cases. We will indicate $\eta_0^* = \max_{j \in N} \eta(j)$, $I_0^* = \{i \in N \mid \eta(i) = \max_{j \in N} \eta(j)\}$. Assume at first that $r_i(x,y) = 0, \forall i \in I_0^*$. Then from (4) $r(x,y,0) = \eta_0^*$. We will define the value $r(x,y,0)$ from the formula (5). For this purpose we will build the set $N(x,y,0) = \{i \in N \mid 0 = r_i(x,y) = \max_{\eta(j) \geq \eta(i)} r_j(x,y),\ \eta(i) = \max_{j \in N} \eta(j)\} = \{i \in I_0^* \mid 0 = r_i(x,y) = \max_{j \in I_0^*} r_j(x,y)\} = I_0^*$ from the formula (6). From here according to (5) also $r(x,y,0) = \eta_0^*$.

In the second case, assume that $\exists i \in I_0^* : r_i(x,y) = 1$. Then according to (4) $r(x,y,0) = 0$. We will define the value $r(x,y,0)$ from (5). For this purpose we will build $N(x,y,0) = \{i \in N \mid 0 = r_i(x,y) = \max_{\eta(j) \geq \eta(i)} r_j(x,y),$ $\eta(i) = \max_{j \in N} \eta(j) = \eta_0^*\} = \{i \in I_0^* \mid 0 \neq r_i(x,y) = \max_{j \in I_0^*} r_j(x,y) = 1\} = \varnothing$ from the formula (6). From here according to (5) also $r(x,y,0) = 0$. Therefore formulas (4), (5) are equivalent for $z = 0$. The theorem has been proved.

For the illustration of a fuzzy set of clear sets union notion we will consider such an example.

Example. Assume that $N = \{1,2\}$ - is a set of players. We will set on N a fuzzy set $\tilde{N}$ by the belonging function with the values: $\eta(1) = 0{,}3$, $\eta(2) = 0{,}7$. We will find the union of a fuzzy set $\tilde{N}$ of clear relations R_1, R_2, which are defined on the set $X = \{A,B\}$ and set by characteristic functions, according to $r_1(x,y)$, $r_2(x,y)$ (tabl. 1).

Table 1. Union of fuzzy set of clear relations.

Functions and sets	(A,A)	(A,B)	(B,A)	(B,B)
$r_1(x,y)$	1	0	1	0
$r_2(x,y)$	1	1	0	0
$N^{PO}(x,y)$	{2}	{2}	{1,2}	{2}
$\tilde{\eta}(x,y,1)$	0	0	0.3	0
$\tilde{\eta}(x,y,2)$	0.7	0.7	0.7	0.7

In table 1 the set $N^{\cup}(x,y)$ and belonging function $\tilde{\eta}(x,y,i)$ are also indicated. The values of the fuzzy relation of type 2 belonging function are indicated in table 2.

Table 2. Value of belonging function.

Belonging function	(A,A)	(A,B)	(B,A)	(B,B)
$r(x,y,0)$	0	0	0.7	0.7
$r(x,y,1)$	0.7	0.7	0.3	0

The obtained result, also corresponds with theorem 1.

Fuzzy individual-optimum equilibriums and their choice

Assume that $S=\overline{R^{-1}}$ - prevailing relation which is induced by the aggregated preference relation $R=\bigcup_{i\in N}R_i$; $S^{NE(i)}$ - relation of player $i\in N$ *NE*-prevailing, which is generated by S. We will present the set of weak individual-optimum equilibriums *WIOE* of the general game G in a as $WIOE=\bigcap_{i\in N}BR_i$, where $BR_i=\{x\in X\mid y\overline{S^{NE(i)}}x,\ \forall y\in X\}=\{x\in X\mid (y_i,x_{N\setminus i})\overline{S}x,\ \forall y_i\in X_i\}$, $i\in N$. Thus, the individually optimal player's $i\in N$ conduct with a fixed other players' strategies set $x_{N\setminus i}=(x_j)_{j\in N\setminus\{i\}}$ consists in the choice of strategies which form situations, that are not prevailed according to $S=\overline{R^{-1}}$.

We will pass on to the fuzzy individual-optimum equilibrium notion formalization. Assume that $\tilde{P}_i=\bigcup_{j\in\tilde{N}_i}R_j$ - is a fuzzy preference relation of all the player's association (as shown higher than type 2), the interests of which player $i\in N$ is going to take into account. Let it be set by the fuzzy reflection with the belonging function $p_i(x,y,z)$, $x,y\in X$, $z\in[0,1]$. We will build for a player $i\in N$ the fuzzy set (we will indicate it ND_i) of situations x which are not prevailed after the relation $\tilde{S}_i=\tilde{P}_i\setminus\tilde{P}_i^{-1}$ (which is asymmetric part of $\tilde{P}_i$) by other situations $(y_i,x_{N\setminus i})$, that are obtained from situation x by the change of the strategy x_i by this player on other $y_i\in X_i$.

The fuzzy relation of type 2 $\tilde{S}_i=\tilde{P}_i\setminus\tilde{P}_i^{-1}=\tilde{P}_i\cap\overline{\tilde{P}_i^{-1}}$ belonging reflection (asymmetric part of preference relation $\tilde{P}_i$) is set by function $s_i(x,y,z)=\max_{\substack{z_1,z_2\in\{0,1\},\\ z=\min\{z_1,z_2\}}}\min\{p_i(x,y,z_1),p_i(y,x,1-z_2)\}$ according to operations on the fuzzy sets of type 2 according to [Zadeh, 1973].

We will express $s_i(x,y,0)=\max\{\min\{p_i(x,y,0),p_i(y,x,1),\ \min\{p_i(x,y,0),p_i(y,x,0),\ \min\{p_i(x,y,1),p_i(y,x,1)\}$ in terms of player's $i\in N$ preference relation by means of (4). For this purpose we will consider the following cases.

We will assume that $r_j(x,y)=0$, $\forall j\in N$. Then because of the completeness of player's $j\in N$ preference relation R_j, we will get $r_j(y,x)=1$ for $\forall j\in N$. From here according to (4) $p_i(x,y,0)=\max_{j\in N}\eta_i(j)$, $p_i(x,y,1)=0$, $p_i(y,x,0)=0$, $p_i(y,x,1)=\max_{j\in N}\eta_i(j)$. Therefore $s_i(x,y,0)=\max_{j\in N}\eta_i(j)$.

We will assume that $r_j(y,x)=0$, $\forall j\in N$. Then because of completeness of player's $j\in N$ preference relation R_j, $j\in N$, obsessed $r_j(x,y)=1$, $\forall j\in N$. From here after (4) $p_i(x,y,1)=\max_{j\in N}\eta_i(j)$, $p_i(x,y,0)=0$, $p_i(y,x,1)=0$, $p_{ii}(y,x,0)=\max_{j\in N}\eta_i(j)$. Therefore $s_i(x,y,0)=0$.

We will assume that $\exists j \in N$: $r_j(x,y)=1$ and $\exists k \in N$: $r_k(y,x)=1$. Then it is quite clear, that $p_i(x,y,1)=\max\{\eta_i(j) \mid j \in N, r_j(x,y)=1\}$ and also $p_i(y,x,1)=\max\{\eta_i(k) \mid k \in N, r_k(y,x)=1\}$. We will indicate $K_i=\{k \in N \mid \eta_i(k)=\max_{j\in N}\eta_i(j)\}$ and we will consider following cases.

In the first case, assume that $r_j(y,x)=0$, $\forall j \in K_i$. Then because of the completeness of player's $j \in N$ preference relation R_j, $j \in N$, we get $r_j(x,y)=1$, $\forall j \in K_i$. Therefore $p_i(x,y,0)=\max_{j\in N}\eta_i(j)$, $p_i(y,x,0)=0$. Hence we have $s_i(x,y,0)=\max\{\max_{r_k(y,x)=1}\eta_i(k), 0, \min\{\max_{r_j(x,y)=1}\eta_i(j), \max_{r_k(y,x)=1}\eta_i(k)\}\}$. Because $\max\{a,\min\{a,b\}\}=a$, then finally we get $s_i(x,y,0)=\max_{r_k(y,x)=1}\eta_i(k)$.

In the second case, assume that $r_j(x,y)=0$, $\forall j \in K_i$. Then because of the completeness of players' $j \in N$ preference relation R_j, $j \in N$, we have $r_j(y,x)=1$, $\forall j \in K_i$. Therefore $p_i(y,x,0)=\max_{j\in N_i}\eta_i(j)$, $p_i(x,y,0)=0$. Then we get $s_i(x,y,0)=\max\{0,0, \min\{\max_{r_k(y,x)=1}\eta_i(k), \max_{r_j(x,y)=1}\eta_i(j)\}\}$. Because there is $r_j(y,x)=1$, $\forall j \in K_i$, then $\max_{r_k(y,x)=1}\eta_i(k) \geq \geq \max_{r_j(x,y)=1}\eta_i(j)$. Therefore $s_i(x,y,0)=\max_{r_k(y,x)=1}\eta_i(k)$.

In the third case, assume that $\exists j \in K_i$: $r_j(x,y)=1$ and $\exists k \in K_i$: $r_k(y,x)=1$. Then $p_i(x,y,0)=0$, $p_i(x,y,0)=0$. Therefore $s_i(x,y,0)=\max\{0,0, \min\{\max_{r_j(x,y)=1}\eta_i(j), \max_{r_k(y,x)=1}\eta_i(k)\}\}$. Because according to condition $\exists j \in K_i$, for which $r_j(x,y)=1$, then $\max_{r_k(x,y)=1}\eta_i(k)=\max\{\eta_i(j) \mid j \in N\}$. Therefore $s_i(x,y,0)=\max_{r_k(y,x)=1}\eta_i(k)$.

From the above considered cases it is obvious, that

$$s_i(x,y,0)=\begin{cases} \max_{r_j(y,x)=1}\eta_i(j), & \exists j \in N : r_j(y,x)=1, \\ 0, & r_j(y,x)=0, \forall j \in N, \end{cases} \tag{10}$$

It would be logical to define the set ND_i based on the following reasoning.

Because the value $s_i(x,y,0)$ is a degree, with which situation y is not prevailed by x, then with the fixed variable $y \in X$ the function $s_i(y,x,0)$ can be considered a fuzzy set belonging function of all situations x which are not prevailed by situation y. From here follows, that the subset of situations, each of which is not prevailed by any of the situations of set X, can be the set by the belonging function $\min_{y\in X} s_i(y,x,0)$, $x \in X$. Thus, we see that the fuzzy set ND_i will be set by the belonging function $\mu_i : X \to [0,1]$ of such a kind

$$\mu_i(x)=\min_{y_i\in X_i} s_i((y_i, x_{N\setminus i}),x,0), \ x \in X \tag{11}$$

The value $\mu_i(x)$ can be understood as a "degree of not being prevailed" of the situation $x \in X$ for the player $i \in N$ by another situation $(y_i, x_{N\setminus i})$ which is obtained by his change of strategy x_i to other $y_i \in X_i$. The idea of the set $FIOE=\bigcap_{i\in N} ND_i$ which consists of not prevailed situations by fuzzy relations S_i, $i \in N$, results in the following definition.

The fuzzy set with the belonging function $\mu: X \to [0,1]$ of kind $\mu(x) = \min_{i \in N} \mu_i(x)$, $x \in X$, we will name the set of fuzzy individual-optimum equilibriums of the game $\tilde{G}$ and mark $FIOE$. We will name the set $\text{supp}(FIOE) = \{x \in X \mid \mu(x) > 0\}$ a transmitter of $FIOE$.

We will set the connection of sets: $FIOE$ - fuzzy individual-optimum equilibriums of the game $\tilde{G}$ and $WIOE$ - weak individual-optimum equilibriums of the game G.

Theorem 2. The transmitter $\text{supp}(FIOE)$ of fuzzy individual-optimum equilibriums set of the game $\tilde{G}$ coincides with the weak individual-optimum equilibriums set $WIOE$ of the game G.

Proof. Assume that $x \in WIOE$. We will assume the opposite, i.e. that $x \notin \text{supp}(FIOE)$. Then according to the definition $\exists i \in N$: $\mu_i(x) = 0$. From here according to the formula (11) $\exists y_i \in X_i$, that $\min_{y_i \in X_i} s_i((y_i, x_{N \setminus i}), x, 0) = 0$. Therefore according to (10) $r_j\,(x,(y_i, x_{N\setminus i})) = 0,\ \forall j \in N$. Then relations $x\bar{R}_j\,(y_i, x_{N\setminus i})$, $\forall j \in N$, are executed. From here $x\bar{R}(y_i, x_{N\setminus i})$. Therefore, because of completeness of relation R, we will get $(y_i, x_{N\setminus i})Sx$. Then for the situation $y = (y_i, x_{N\setminus i})$ the relation $yS^{NE(i)}x$ takes place and according to the definition $x \notin WIOE$. We have a contradiction and therefore $WIOE \subseteq \text{supp}(FIOE)$.

Assume that $x \in \text{supp}(FIOE)$. We will assume opposite, that $x \notin WIOE$. Then according to the definition $\exists i \in N\ \exists y = (y_i, x_{N\setminus i})$, for which $yS^{NE(i)}x$. It means that $\exists y_i \in X_i$, for which $(y_i, x_{N\setminus i})Sx$. Therefore $x\bar{R}(y_i, x_{N\setminus i})$. From here follows $x\bar{R}_j\,(y_i, x_{N\setminus i})$, $\forall j \in N$, that means $r_j\,(x,(y_i, x_{N\setminus i})) = 0,\ \forall j \in N$. From here according to formula (10) $s_i((y_i, x_{N\setminus i}), x) = 0$. Therefore according to (11) $\mu_i(x) = 0$. Then according to the definition $x \notin \text{supp}(FIOE)$. A contradiction was obtained. Thus $\text{supp}(FIOE) \subseteq WIOE$ and therefore $\text{supp}(FIOE) = WIOE$. The theorem has been proved.

Because players, as a rule, are interested in the choice of some sole situation of a game which would become the basis of stable agreement between them, they need to choose the fuzzy individual-optimum equilibrium x^* with the maximal degree $\mu(x^*)$ of not prevailing. This reasoning leads to the following notion.

We will name $x^* \in X$ the maximizing fuzzy individual-optimum equilibrium of game $\tilde{G}$, if $\mu(x^*) = \max_{x \in X} \mu(x)$.

It is easy to check that for the general game $\tilde{G}$ there is always a maximizing fuzzy individual-optimum equilibrium. Indeed, according to definitions $\mu(x^*) = \max_{x \in X} \min_{i \in N} \mu_i(x) = \ = \max_{x \in X} \min_{i \in N} \min_{y_i \in X_i} s_i((y_i, x_{N\setminus i}), x, 0)$. From the formula (10) it is easy to see that for $\forall x \in X\ \ \forall i \in N\ \ \forall y_i \in X_i$ the function $s_i((y_i, x_{N\setminus i}), x, 0)$ adopts a finite set of volumes. From here follows, that there is always $\max_{x \in X} \min_{i \in N} \min_{y_i \in X_i} s_i((y_i, x_{N\setminus i}), x, 0)$.

It should be noted that although a maximizing fuzzy individual-optimum equilibrium x^* exists always, it can be that $\mu(x^*) = 0$. Therefore we will consider the following theorem.

Theorem 3 . Assume that $\eta_i(j) \neq 0$, $\forall i \in N$. If a situation x^* meets condition

$$\mu(x^*) = \max_{x \in X} \min_{i \in N} \min_{y_i \in X_i} \max_{r_j((y_i, x_{N\setminus i}), x) = 1} \eta_i(j) \tag{12}$$

then it is the maximizing fuzzy individual-optimum equilibrium of game $\tilde{G}$, thus $\mu(x^*) > 0$.

If a situation x^* is the maximizing fuzzy individual-optimum equilibrium of game $\tilde{G}$, then it satisfies (12).

Proof. We will consider the problem

$$\mu(x) = \min_{k\in N} \min_{y_k\in X_k} \max_{r_i^j((y_i,x_{N\setminus i}),x)=1} \eta_i(j) . \tag{13}$$

We will mark Q the set of its decisions. For proof of the theorem it is sufficient to show that $Q = \text{supp}(FIOE)$.

Assume that $x \in Q$, and values i , y_i^* , j^* satisfy (13). We will show that $x \in WIOE$. From (13) follows, that $\eta_i(j^*) \geq \eta_i(j)$, $\forall j \in M_i(x,(y_i^*,x_{N\setminus i}))$, where $M_i(x,(y_i^*,x_{N\setminus i})) = \{j \in N \mid r_j(x,(y_i^*,x_{N\setminus i})) = 1\}$. Thus

$$M_k(x,(y_k,x_{N\setminus k})) \supseteq M_i(x,(y_i^*,x_{N\setminus i})) ,\ \forall x \in X ,\ \forall k \in N ,\ \forall y_k \in X_k \tag{14}$$

We will consider the following cases.

1. Let's assume that $M_i(x,(y_i^*,x_{N\setminus i})) = N$. Then $r_j(x,(y_i^*,x_{N\setminus i})) = 1$ for $\forall j \in N$. Because $M_k(x,(y_k,x_{N\setminus k})) \supseteq M_i(x,(y_i^*,x_{N\setminus i}))$ for $\forall k \in N$, $\forall y_k \in X_k$, then $r_j(x,(y_k,x_{N\setminus k})) = 1$ for $\forall k \in N$, $\forall j \in N$, $\forall y_k \in X_k$. Therefore $xR_j(y_k,x_{N\setminus k})$ for $\forall k \in N$, $\forall j \in N$, $\forall y_k \in X_k$. From here $xR(y_k,x_{N\setminus k})$ for $\forall k \in N$, $\forall y_k \in X_k$. Thus, $y\overline{S^{NE(k)}}x^*$, $\forall y \in X$, $\forall k \in N$ and according to the definition $x \in WIOE$.

2. Assume that $M_i(x,(y_i^*,x_{N\setminus i})) \subset N$. We will assume opposite, that $x \notin WIOE$. Then according to the definition $\exists i \in N\ \exists y = (y_i,x_{N\setminus i})$, for which $yS^{NE(i)}x$. It means that $\exists y_i \in X_i$, for which $(y_i,x_{N\setminus i})Sx$. Therefore $x\overline{R}(y_i,x_{N\setminus i})$. From here follows, that $x\overline{R}_j(y_i,x_{N\setminus i})$, $\forall j \in N$, that means $r_j(x,(y_i,x_{N\setminus i})) = 0,\ \forall j \in N$. From here we will get $M_i(x,(y_i,x_{N\setminus i})) = \varnothing$ that contradicts (14). Therefore $x \in WIOE$. Thus $Q \subseteq WIOE$.

Assume that $x \in WIOE$. We will show that $x \in Q$. If $x \in WIOE$, then according to the definition $y\overline{S^{NE(k)}}x^*$, $\forall y \in X$, $\forall k \in N$. Therefore for $\forall k \in N$, $\forall y_k \in X_k$ $(y_k,x_{N\setminus k})\overline{S}x$ takes place. From here, because of asymmetric of the relation S , the preference relation $R = \overline{S}^{-1}$, therefore $xR(y_k,x_{N\setminus k})$. Because $R = \bigcup_{j\in N} R_i$, then $\exists j \in N$: $xR_j(y_k,x_{N\setminus k})$. That is $\forall k \in N$ $\forall y_k \in X_k$ $\exists j \in N$: $r_j(x,(y_k,x_{N\setminus k})) = 1$. Hence according to (9) $s_k(x,y,0) = \max\{\eta_k(j) \mid r_j((y_k,x_{N\setminus k}),x) = \ = 1\}$ for $\forall k \in N$, $\forall y_k \in X_k$. Thus, according to the definition of fuzzy individual-optimum equilibrium and formula (13) we will see, that x satisfies (13). Hence $x \in Q$. Thus $Q \supseteq WIOE$, therefore $Q = WIOE$. Then after the theorem 2 $Q = \text{supp}(FIOE)$. The theorem has been proved.

Conclusion

The fuzzy individual-optimum equilibriums considered in the given work allow players to make the stable agreement in which they can fuzzily take into account the interests of one other. It allows substantially simplifying the problem of choice of concrete individual-optimum equilibrium due to the use by the player of subjective estimations of importance of interests of partners which are expressed by a fuzzy set belonging function of players' interests which he is going to take into account. It should also be mentioned that the notion of fuzzy individual-optimum equilibriums will be correct and also has definite interest in games with the purposes of players, which are set by fuzzy preference relations.

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PORTABLE BIOSENSOR: FROM IDEA TO MARKET

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***Abstract**: In the article it is described the family of portable biosensors for express-diagnostics of plant state developed in V.M.Glushkov Institute of Cybernetics from scientific idea to serial production, produced on modern contract manufacture.*

***Keywords**: chlorophyll fluorescence induction; fluorometer; portable biosensor; contract manufacture.*

***ACM Classification Keywords**: J.3 Life and Medical Sciences - Biology and Genetics*

Introduction

In the modern world scientific-technical progress plays an important role in development of economy and different areas of human activities. It means that supporting of innovations has very important sense. In the general case under innovation we may understand the process of initiation and development of some idea with the following development of new products, services and technologies or their modernization. Exactly in this case the emphasis has to be made on prototype or model development, confirmation of possibility and expediency of innovation application in practice, but not in theory. The following transfer to industrial production manufacture, which is claimed by market and profit making from selling of this production (or license) may be considered as process of commercialization.

In the article it is described the family of portable biosensors for express-diagnostics of plant state developed in V.M. Glushkov Institute of Cybernetics from scientific idea to serial production, produced on modern contract manufacture. It is important to note, that during moving portable biosensor to serial production it is necessary to pay a significant attention not only to design and creation of device hardware, but and to development of optimal and convenient applied methodical and software support. Preparation of quality construction documentation on whole biosensor and its separate parts helps to reduce cost, system design time, and board space on run-up of contract manufacture to serial production. Presence of well prepared software and user documentation causes decreasing costs of supporting of devices moved into market and are in active using of costumers.

There were two aims for preparing serial production of portable biosensors. The first aim was creating technical documentation of smart biosensor device according to requirements of advanced contract manufacture. It was selected electronic contract manufacture of Scientific production firm VD MAIS (Kyiv, Ukraine) [VDMais, 2012] for creating of serial party of the device which consists of Surface mount technology assembly line. According to this technology the bare Printed circuit boards with solder paste, applied in the right places, take the several steps towards becoming fully-fledged boards here.

The second aim was manufacturing serial party of portable biosensor on the mentioned above contract manufacture with modern high-performance equipment.

The work of portable biosensor [Romanov, 2007] is based on measurements of chlorophyll fluorescence induction. One of the most important properties of the molecule of chlorophyll which is the basic pigment of plant cell is ability to fluoresce. For the first time this phenomenon was researched by Kautsky [Kautsky, 1931]. Dependence of chlorophyll fluorescence induction on time passed after start of lightning of plant's leaves is known as an induction curve or a chlorophyll fluorescence induction curve. The form of this curve is rather sensible to changes in the photosynthetic apparatus of plants during adaptation to different environmental conditions. This fact is a basic for extensive usage of Kautsky effect in photosynthesis research. The advantages of the method of chlorophyll fluorescence induction are the following: high self-descriptiveness, expressiveness, noninvasiveness and high sensibility. It gave possibility to develop in the V.M. Glushkov Institute of Cybernetics of NAS of Ukraine the portable biosensor "Floratest", which estimates in several seconds the plant state after drought, frosts, pollution, herbicides etc. without plant damage. Like human cardiogram device builds chlorophyll fluorescence induction curve estimated photosynthesis process, which is the base of plant vital activity.

Portable biosensor kit

For microprocessor unit it was selected polyamide hand held enclosure with monitor opening Beluga 180. The features of the enclosure are following: ingress protection – IP 65, weight – 0.16 kg, temperature range - from -40 up to +60 C°, color – black. Enclosure Beluga 180 was updated to install printed circuit board of microprocessor unit (see fig. 1), printed circuit board for connector remote sensor, monitor Fordata firm FDCG12864 and control buttons.

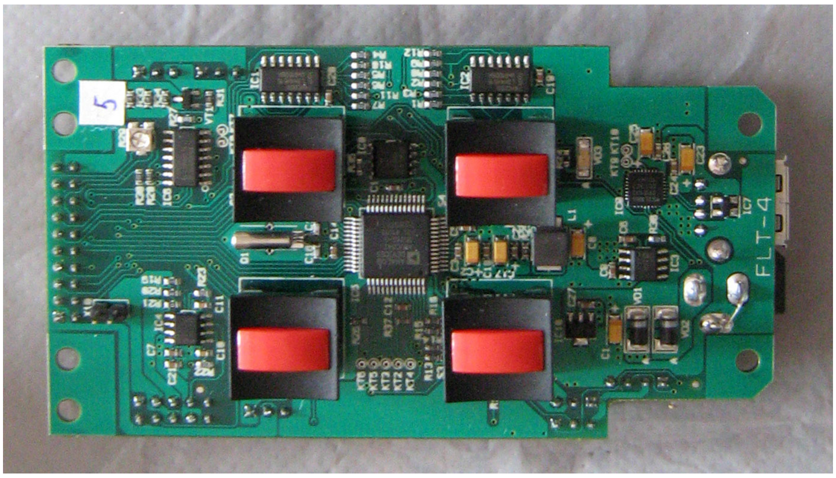
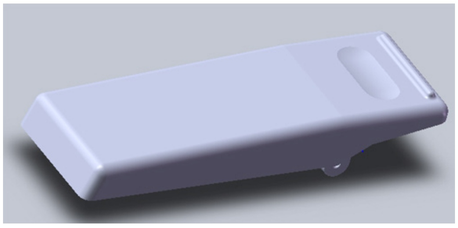
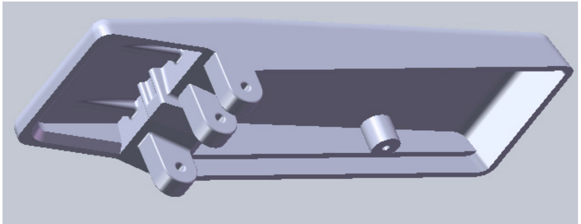


Fig. 1. Printed circuit board of microprocessor unit

It was used Laser prototype technology for designing and manufacturing remote sensor enclosure. This technology can offer the competitive edge in getting products to the market faster from early design and concept models through to skilfully finished engineering models and low volume production runs. 3D-model of remote sensor enclosure is shown on fig. 2. Manufactured remote sensor enclosure is shown on fig. 3.



a



b

Fig. 2. 3D-model of remote sensor enclosure: a – top, b – bottom

Fig. 3. Manufactured remote sensor enclosure

Smart biosensor "Flaratest" kit is shown in fig. 4. It consists of microprocessor unit, remote optical sensor with cable, data cable, power supply unit and four rechargeable batteries.

Also as part of biosensor kit it was prepared and replicated CD with software and user documentation for supporting work biosensor users. The appearance of CD is shown on fig. 5.

Contract manufacture

It was used electronic contract manufacture of VD MAIS firm (Kyiv, Ukraine) [VDMais, 2012] for creating serial party of the portable biosensor.

So the main features of technical documentation were matching functional diagrams of device units with interoperability of Surface mount technology assembly line. There were selected Surface mount technology electronic components such as resistors, capacitors, inductances, diodes, transistors, and integrated circuits for device units and on this base it was designed technical documentation of the Printed circuit boards of microprocessor unit and remote optical sensor.

According to Surface mount technology assembly the bare Printed circuit boards with solder paste, applied in the right places, take several steps towards becoming fully-fledged boards here. The Surface mount technology machines pick and place the tiny resistors, solid-state capacitors and other Integrated Circuit chips onto the Printed circuit boards at ultra high speeds. If you look for example at the motherboard in computer, some of these small components are no more than 1 mm square. Each board passes through two sets of Surface mount technology high-speed machines, the 'small pick and place' and 'large pick and place' devices. Each machine in the set adds a few components, from tiny resistors up to Integrated circuit chips. Using belt fed from tape-like cartridges of components the Surface Mount Technology gear places components like a machine gun, taking as little as an eighth of a second to place a component with exact precision on the Printed circuit boards.

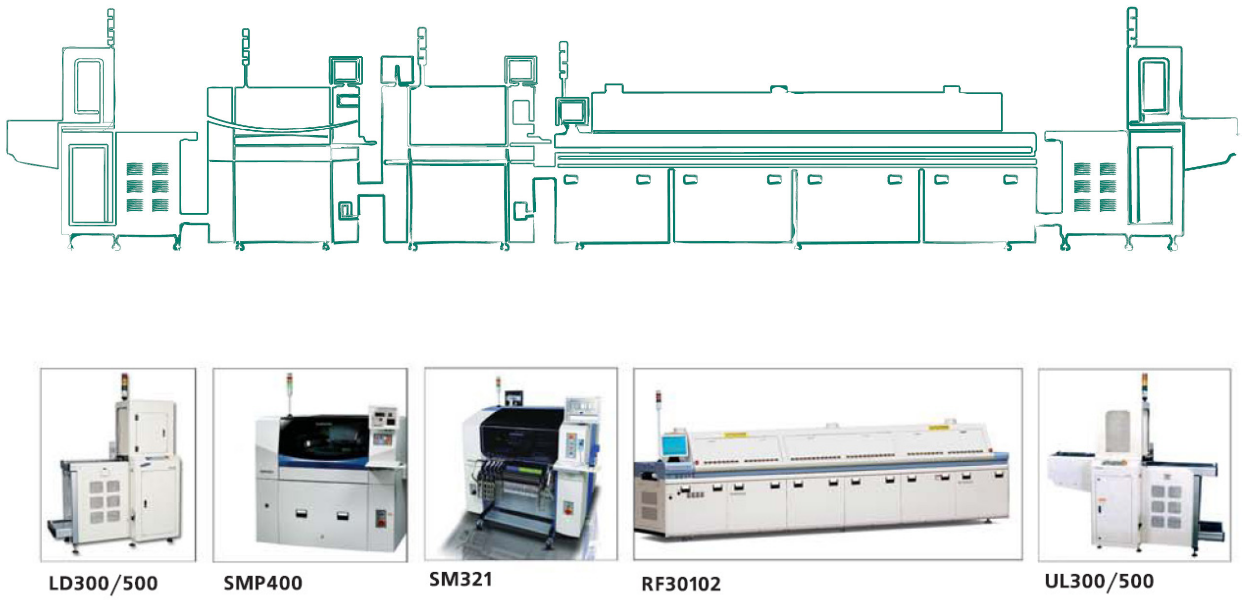
During the manufacturing of printed circuit boards of all units of the device it was fine-tuned assembly technological processes and technical documentation too. For the perfecting of documentation and manufacture technology it was creating more than one hundred printed circuit boards of all types.

Fig. 4. Biosensor "Floratest" kit:

1 – microprocessor unit, 2 – cable of remote optical sensor, 3 – remote optical sensor, 4 – data cable, 5 – power supply unit, 6 – four rechargeable batteries

Fig. 5. The appearance of CD with software and user documentation

Structure of contract manufacture technological line and its composition are shown on fig. 6.



1 2 3 4 5

Fig. 6. Structure and composition of contract manufacture technological line:

1 – automatic loader of boards, 2 – stencil printer, 3 – automatic placer,

4 – conventional-conveyor oven, 5 – automatic unloader of boards

Conclusion

It is clear, that neither state nor research organizations have possibility to full finance development and implementation of new innovation products. In this case the unifying element between innovation and commercialization may be business structures and private financial funds interested in such researches. As example of such approach is Science and Technology Center in Ukraine, financed the preparation of portable biosensor to serial production and manufacturing the first serial party of this biosensor. Integration of scientific capacity of research organization and financial capacity of business structure gave possibility to prepare and serial produce modern competitive portable cost-effective biosensor for express-diagnostics of plant state.

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OPTIMIZATION OF FIRE ALARM SYSTEMS BASED ON EVOLUTIONARY METHODS

Alexandr Zemlyansky, Vitaliy Snytyuk

Abstract: *The formalized raising of task of optimization of structure of the system of the fire monitoring is executed. Objective functions are worked out for apartments with the sources of enhanceable fire hazard, with the uneven fire loading and for a general case. The method of search of optimal structure of fire sensors is offered on the basis of evolutional design.*

Keywords*: evolutional design, objective function, monitoring.*

ACM Classification Keywords*:* I.2.1 Applications and Expert Systems.

Introduction

The last decade marked by a relatively constant annual number of fires and trend growth in the number of those killed and injured, and the amount of material losses. Not least, this fact is due to low efficiency of fire and automation, including fire detection systems - fire alarm systems. Despite the fact that a number of quantitative indicators of such systems to CIS countries and Ukraine, in particular, the group leading the world, quality indicators that reflect the level of technical solutions in this area in the CIS countries on one or two orders of magnitude is lower than in the world.

In particular, the world's main development conducted by the Office for Research in Construction (BRE, UK), Laboratory of Building and Fire Research (BERL, USA), Institute of Fire Research (FRI, Japan), FGU VNIIPO of EMERCOM of Russia and others. In Ukraine, on a similar theme running Ukrainian Research Institute of Fire Safety Ministry of Ukraine, and many firms as a "Meridian", "Arthon", "Tiras", "Gamma".

The vast majority of these studies dealt with only one element Signalling - the detector and its improvement. Beyond consideration of the remaining problems of the optimal structure fire alarm system of "binding" to a particular item. Neglecting its features, the use of standard approaches and regulatory requirements leads to an increase in casualties, volume losses, as well as false positives. And the main reason for such negative effects is to increase the time fire detection inefficiency due to fire alarms.

The objective is to optimize fire alarm system through the development and use of models that will determine the number and placement of the structure fire detectors using an evolutionary simulation.

Problem

Let the number of detectors are available N . Horizontal areas of responsibility overlap, forming a region Ξ_i with different multiplicity detectors responsibility, $i=\overline{1,k_\Xi}$, where k_Ξ - number of areas. Known as the target function [1] and problem

$$F(W) = F(X,Y) = \sum_{i=1}^{k_\Xi} \frac{1}{p_c^i} \cdot t_c^i \to \min, \quad (1)$$

where W - the structure of the detectors $X = (x_1, x_2, ..., x_N)$, $Y = (y_1, y_2, ..., y_N)$, (x_i, y_i) - the coordinates of the detector, $i = \overline{1,N}$, p_c^i - the probability of operation of the detector or detectors in a fire based redundancy, t_c^i - the average time from the beginning of the fire that occurred at the point region Ξ_i by the time the detector response time.

Optimization of placement of detectors based on genetic algorithm

It is known that the structure of the detectors is determined by the set of coordinates of their location. To install this set to be the solution of problem (1), we use elements of the genetic algorithm (GA) [3]. According to the GA steps necessary to form a general set of potential solutions. Assume that they all belong to the field $\Xi = \{(x_1, x_1) / x_1 \in [0, a], x_2 \in [0, b]\}$. The number of potential solutions n by setting up resolution of the problem (1). Assume that the specified accuracy of solution on the axis x_1 and axis x_2 - ε_1 and ε_2. Traditionally impose $\varepsilon = \min\{\varepsilon_1, \varepsilon_2\}$ and further ε considered accurate result. Then the area Ξ is divided by horizontal and vertical lines, forming a square the side ε. Their peaks and will determine the general population of potential solutions. We propose a modified way. In determining the set of potential solutions will take into account that the room is rectangular in shape with sides a and b Then find $c = \max\{\frac{a}{\varepsilon_1}, \frac{b}{\varepsilon_2}\}$. And if $c = \frac{a}{\varepsilon_1}$, the distance between lines is equal ε_1, otherwise - ε_2. But this separation inevitably creates redundancy information, as part of the solutions outside the region Ξ. In many cases, redundancy can be avoided $\varepsilon = НОД(\varepsilon_1, \varepsilon_2)$. Then put the number of potential solutions will be

$$\left(\left[\frac{a}{\varepsilon}\right]+1\right)\cdot\left(\left[\frac{b}{\varepsilon}\right]+1\right) - 2\left(\left[\frac{a}{\varepsilon}\right]+1\right) - 2\left(\left[\frac{b}{\varepsilon}\right]+1\right) + 4 = \left[\frac{ab}{\varepsilon^2}\right] - \left[\frac{a+b}{\varepsilon}\right] + 1.$$

The encoding potential solutions of binary numbers to consider a different number of bits to encode the ordinates and abscissas solution. To reserve ordinates $\left[\log_2 \frac{a}{\varepsilon}\right] + 1$ digits for abscissas - $\left[\log_2 \frac{b}{\varepsilon}\right] + 1$ digits. Structure solution is:

$$X = (X_1, X_2, ..., X_n) = (x_1^1, x_2^1, x_1^2, x_2^2, ..., x_1^n, x_2^n) = (\underbrace{\overbrace{00111..1}^{x_1^1}}_{\substack{[\log_2 \frac{a}{\varepsilon}]+1 \\ digits}}\underbrace{\overbrace{10110..0}^{x_2^1}}_{\substack{[\log_2 \frac{b}{\varepsilon}]+1 \\ digits}}\,\underbrace{\overbrace{00110..0}^{x_1^2}}_{\substack{[\log_2 \frac{a}{\varepsilon}]+1 \\ digits}}\underbrace{\overbrace{01011..1}^{x_2^2}}_{\substack{[\log_2 \frac{b}{\varepsilon}]+1 \\ digits}}...\underbrace{\overbrace{10101..1}^{x_1^n}}_{\substack{[\log_2 \frac{a}{\varepsilon}]+1 \\ digits}}\underbrace{\overbrace{01110..0}^{x_2^n}}_{\substack{[\log_2 \frac{b}{\varepsilon}]+1 \\ digits}})$$

Thus defined the general population of potential solutions. The number of its elements is

$$2^{n\left(\left[\log_2 \frac{a}{\varepsilon}\right]+1\right)} \cdot 2^{n\left(\left[\log_2 \frac{b}{\varepsilon}\right]+1\right)} = 2^{n\left[\log_2 \frac{ab}{\varepsilon^2}\right]+2n}.$$

This number is large and even at the present level of development of computer technology to solve practical problems by exhaustive search is often impossible.

That is why you need to select a custom set of solutions. Its capacity ranges from 10 to 50 elements. Fewer solutions minimizes "genetic diversity" sample and considerable time finding the solution. Otherwise, however, "diversity" is present in full, but the complexity of calculations than even the first time.

To form the sample to realize the mapping

$$\{(x_i, y_i) / x_i, y_i \in R\} \leftrightarrow \{(x_i, y_i) / x_i, y_i \in Z^+\} \leftrightarrow$$
$$\{(x_i, y_i) / x_i, y_i \in B\},$$

where - R the set of real numbers, Z^+ - the set of integral whole numbers, B - a set of binary numbers.

Assuming without loss of generality that the number of elements of the sample 20, play the 20 pairs of random numbers (x_1^i, x_2^i), where

$$x_1^i \in \left\{0, 1, 2, ..., \left[\frac{a}{\varepsilon}\right] + 1\right\},\ x_2^i \in \left\{0, 1, 2, ..., \left[\frac{b}{\varepsilon}\right] + 1\right\},\ i = \overline{1, 20}.$$

An important step is the formation of the target function [4]. We use the target function of problem (1). Then to determine the parameters p_c and t_c. Note that the objective function somehow simplified because it does not need to analytically determine the zone of responsibility of different multiplicity detectors.

Number the elements of the sample and then they can be written as a trio $(X_1^i, X_2^i, n(i) = i), i = \overline{1, 20}.$ Then in order to avoid possible bias, make the following steps. Generate a sample of possible points of fire. Power depends on sample size of the room. Again, without limiting the generality, suppose that the following points 10: $(y_1^i, y_2^i), m(i)),\ i = \overline{1,10}$. Let us form the matrix of distances from points of fire for fire detectors

$$D = \begin{pmatrix} d_{1\,1}\ d_{1\,2} \ldots d_{1\,20} \\ d_{2\,1}\ d_{2\,2} \ldots d_{2\,20} \\ ------ \\ d_{10\,1}\ d_{10\,2} \ldots d_{10\,20} \end{pmatrix},$$

where $d_{ij} = \sqrt{(y_1^i - x_1^j)^2 + (y_2^i - x_2^j)^2}, i = \overline{1,10}, j = \overline{1,20}$.

The radius of the cone base area of the detector consider known and equal r. Obviously, the average time from start fires that occurred in the area of responsibility of the detector, the time of its operation depends on the distance from the point of fire to coordinate horizontal and the detector is located directly on the matrix D (Fig. 1). Make use of the fact that appropriate time is directly proportional to distance. We consider also a known probability p of correct operation of the detector. Then, to i-th point of fire to find value $v_i = \sum_{j=1}^{20} \chi\left(d_{ij} < r\right), i = \overline{1,10}$. The appropriate value $p_c{}^i = 1 - (1 - p)^{v_i}$.

Thus, the modified objective function will be the

$$F(w) = \sum_{i=1}^{10} \frac{1}{1 - (1 - p)^{\sum_{j=1}^{20} \chi(d_{ij} < r)}} \cdot \min_j d_{ij}. \quad (2)$$

Formation of the objective function (2) completed preparatory operations to find its minimum by using GA. But, as discussed above, the choice of one possible set of points of fire, including fire load balancing facilities, leading to displacement of the solution.

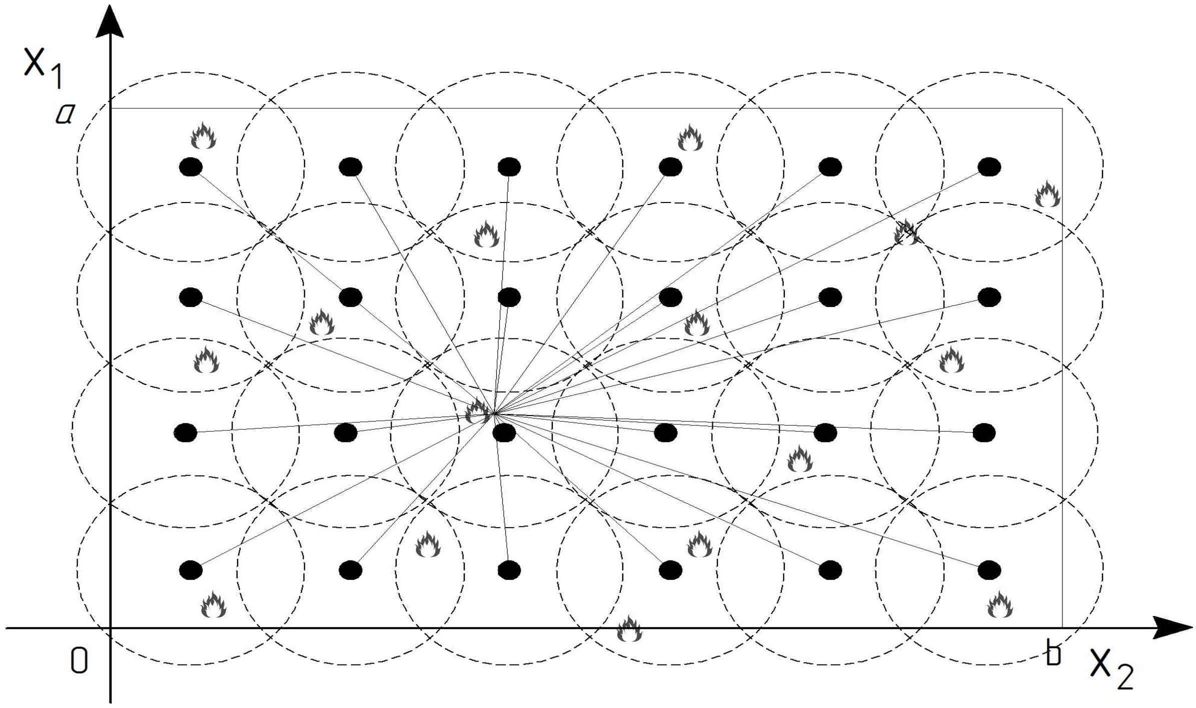

Fig. 1. Placement of detectors and possible points of fire

Will make some changes to the method of finding the optimal placement of fire detectors. The method will have several such stages. The first of them generate a sample of potential points of fire A_1^1 and find the corresponding optimal placement of detectors. In the second phase generate two samples A_1^2 and A_2^2, and again we find the optimal placement of detectors. The process to continue until the stopping condition fails, which may be one of the following:

1. $\left|F^k(w) - F^{k-1}(w)\right| < \varepsilon$, where $\varepsilon > 0$ – a small predefined number.

2. $\sum_{i=1}^{20} \min_j \left[(x_1^{ik} - x_1^{jk-1})^2 + (x_2^{ik} - x_2^{jk-1})^2 \right] < \delta,$ where $\delta > 0$ – a small predefined number.

3. $\exists k : F^k(w) > F^{k-1}(w)$.

The above conditions indicate that the process of finding the optimal placement is completed, since the value of objective function at different stages are not significantly different, or placing the same sensor at different iterations, or worse objective function.

The proposed method is not only to solve this problem under no differential, polls extreme and objective function. In addition, the drawback of the method is the need to encode in different number systems that are too time-consuming process.

Using the objective function (2) is not always adequate. In ideal conditions, each point belongs to the space area of at least one detector. In practice, this condition is not always done. To target function did not lose its meaning, as in this case, the denominator is zero, we introduce the term, which means meaningful penalty part. Target function will take this form:

$$F(w)=\sum_{i=1}^{10}\chi((\sum_{j=1}^{20}\chi(d_{ij}<r))>0)\cdot\frac{1}{1-(1-p)^{\sum_{j=1}^{20}\chi(d_{ij}<r)}}\cdot\min_j d_{ij}+ \\ +\sum_{i=1}^{10}\chi((\sum_{j=1}^{20}\chi(d_{ij}<r))=0)\cdot\min_j d_{ij}. \quad (3)$$

The first term in (1) meet when a point of fire is the area of responsibility at least one detector, the second term is the penalty and the objective function value will increase if this point does not belong to any area of responsibility.

A series of experiments that demonstrated the effectiveness of the proposed methods. The first experiment was devoted to the study of the dynamics of the target function. Fig. 2 and 3 show how changing its value depending on the number of detectors and their level of reliability.

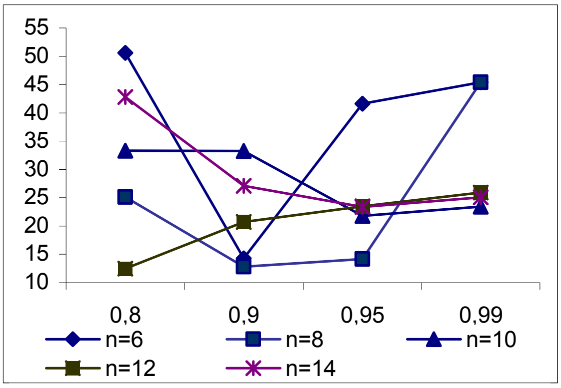

Fig. 2. Dynamics of the objective function for different numbers of detectors

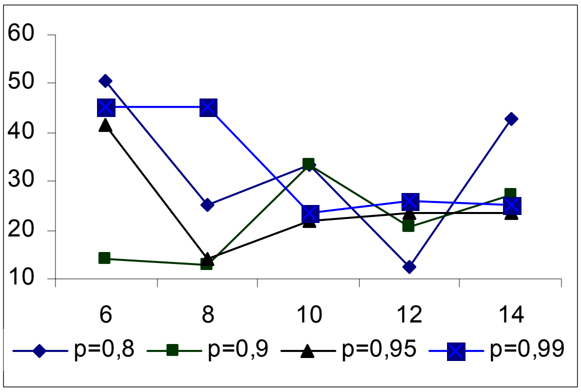

Fig. 3. Dynamics of the objective function for different values of the reliability of detectors

The results of other experiments indicate a relatively equal accuracy using the methods based on evolutionary strategies and genetic algorithms. These minor differences with classical triangular and rectangular schemes explained uniform fire load space. If the number of detectors is inadequate or excessive, the results of the proposed methods are more effective. Proposed methods of rational use in the case of low reliability of detectors or detectors of differences that get installed in the standard. The proposed objective function is not the only one.

An important task is a "generalizing" the objective function (3) for a more general case, which includes:

- Availability of high-risk;
- Uneven permanent fire load;
- Alternating irregular fire load.
- Consider one of these cases.

In the room with the uniform fire load is a source of increased danger. In this case, it is important to consider the priority placement of fire detectors closer to these sources, while trying not to leave without protection of other areas of the room. We write the target function as follows

$$F(w)=\alpha\cdot\sum_{i=1}^{M}\chi(\sum_{j=1}^{N}\chi(d_{ij}<r)>0)\cdot\frac{1}{1-(1-p)^{\sum_{j=1}^{N}\chi(d_{ij}<r)}}\cdot\min_{j} d_{ij}+$$
$$+\beta\cdot\sum_{k=1}^{K}\chi(\sum_{j=1}^{N}\chi(d_{kj}<r)=0)\cdot\frac{1}{1-(1-p)^{\sum_{j=1}^{N}\chi(d_{kj}<r)}}\cdot\min_{j} d_{kj}+ \quad (4)$$
$$+\gamma\cdot\sum_{i=1}^{M}\chi(\sum_{j=1}^{M}\chi(d_{ij}<r)=0)\cdot\min_{j} d_{ij}+\delta\cdot\sum_{k=1}^{K}\chi(\sum_{j=1}^{M}\chi(d_{kj}<r)=0)\cdot\min_{j} d_{kj},$$

where K - number of sources of increased danger, $\alpha,\beta,\gamma,\delta$ - weights corresponding fragments of the target function. The first term of objective function indicates the minimum time of operation of the detectors from the point of fire and the magnitude, the inverse reliability of alarm system. The second term is similar to the first, but had to fire that caused the source of increased danger. The third and fourth terms (4) is a penalty function in case of fire or point source of increased danger is not in the area of responsibility of a single detector.

Odds α,β,γ and δ included in (4), easily found using the method of analysis of hierarchies T. Saaty [6]. To find the minimum (4) applied genetic algorithm and evolutionary strategy [4]. The difference from the previously considered case is that it is necessary to form another matrix of distances $D^K=\left\{d_{kj}\mid k=\overline{1,K}, j=\overline{1,N}\right\}$, whose elements are the distances from the k source of fire hazard to the j detector. Note that in our problem such sources are stationary. Potential solutions are the coordinates of the points placing detectors (fixed number of them), and point of fire have uniform distribution in the region Ξ.

These models are designed for areas with uneven and variable fire load and proposed evolutionary method for determining the optimal structure fire detectors [7], the task is to optimize the structure of fire detectors is to find

$$\min_{w} F(w),$$

where $w=(x_d^1,y_d^1,x_d^2,y_d^2,\dots,x_d^N,y_d^N)$ - the location coordinates of the points of fire detectors.

Conclusion

The problem of optimizing the structure of the fire monitoring, part of which is a fire alarm system is extremely important given the dynamics of those killed and injured in fires, as well as the current shortage of resources and finance. Designed target the answers to practical cases with the presence of buildings and structures sources of increased danger and irregular fire load space. Given the nature of the dependencies obtained, the proposed optimization objective functions make based on evolutionary methods. The peculiarity of the developed technology is the use of expert opinions and relevant methods of analysis. The result of its implementation are the coordinates placement of fire detectors that will improve the reliability of fire alarm system and minimize the time of its operation in case of fire.

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A SEMANTIC INDEXING OF ELECTRONIC DOCUMENTS IN OPEN FORMATS

Vyacheslav Bessonov, Viacheslav Lanin, George Sokolov

***Abstract**: Currently many issues related to the development of semantic indexing methods remain open. The problem of search pertinence increasing with a low time-complexity is one of the major research issues in Computer Science. Semantic search as an alternative solution to this problem has a high time complexity. This paper describes the use of agent-based approach to reduce the time complexity of constructing semantic indexes used for searching. Obvious, once created index must be stored in document. The second part of this paper describes an approach for inclusion of metadata in electronic documents which have such open document format as OpenXML or Open Document Format. The proposed approach enables to perform an effective semantic indexing and the semantic searching. Semantic indexing of electronic documents is intended to include special structure associated with the content of documents in its metadata. Most of the currently used electronic document formats do not permit the inclusion of additional information, on the contrary electronic documents open formats Office Open XML and OpenDocument Format allow to solve this problem.*

***Keywords**: Semantic indexing; Agent; Ontology; Document, Open XML; OpenDocument Format; Metadata.*

***ACM Classification Keywords**: I.2 ARTIFICIAL INTELLIGENCE: I.2.11 Distributed Artificial Intelligence; I.7 DOCUMENT AND TEXT PROCESSING: I.7.2 Document Preparation; I.7.3 Index Generation.*

Introduction

Nowadays the information retrieval (from the Internet and off-line sources) is one of the major research areas in Computer Science. The main criteria of a successful search are the high relevance of search query information and fast response time. Traditional search engines typically use an approach «Bag of words» based on statistical methods to search for information. This approach takes precedence over semantic search methods is due to low time-complexity, low implementation complexity and satisfactory degree of relevance. One of the main areas of modern researches in the information retrieval is an increasing of search pertinence with a low time-complexity.

In syntactic search some indexes are built to find quickly the information required on some key words. By analogy let’s introduce a concept of a semantic index. In this paper the semantic index is one-one correspondence between elements of the text and concepts from some ontological resource. There are different formats of the semantic indexes. Some of them are primitive (such as microformats hCard, Geo, microdata html5) and other formats are advanced (such as RDF, OWL, underlying the Semantic Web). In the semantic indexing there are two directions: the construction of semantic indexes and search for information on a semantic index. In this paper we will consider the construction of the semantic index (or the so-called semantic markup) for electronic documents.

The main problems of constructing semantic indexes are

1) high time-complexity (is due to various kinds of ambiguity that require paying respect of a context),

2) the problem of choosing ontology, which would be sufficiently complete to satisfy all search queries in an electronic document,

3) large amount of constructed semantic indexes and the problem of storage.

In this paper, the authors offer one approach of solving the first problem (the problem of time-complexity). Obviously, increase in the rate of the semantic indexing operation is required not one but several calculators, i.e. the parallelization of this operation is needed. The execution of the semantic markup operation requires the coordination of actions to resolve ambiguities. That's why simple asynchronous calculators aren't capable to solve the problem. According to the authors the most appropriate solution is using agent-based approach.

Existing Approaches

Solution to the agent-based semantic indexing problem can be obtained in two ways:

1) using of generic agent-based platforms that can decide a wide range of tasks,

2) using of specialized semantic indexing systems based on the multi-agent paradigm.

Let us consider each of these methods. Most popular agent platforms are JADE [1], MASDK [2], Zeus [3].

Table 1. Generic agent-based platforms

	JADE	MASDK	ZEUS
Developer community	Telecom Italia Lab	SPIIRAS	BT Laboratories
License	LGPL	LGPL	LGPL
Description	This is the platform for rapid development of multi-agent systems, which implements FIPA standards [4]. JADE provides base classes for creating agents and infrastructure for the operation of multi-agent system.	This is the software environment for multi-agent application development that supports the full life cycle application development of MAS. The agent platform, which is the part of MASDK, works on the principle of P2P.	This is the agent platform designed for rapid development of multi-agent applications. Zeus provides a library of agent components.
Description of the agent behavior	Set in the code of the agent class that inherits from Agent.	Set with language ASML. This language is used for generating applied MAS.	Set in an environment for building agents, from which the agent code is generated.

Each of these agent platforms allows one way or another to describe the behavior of the agent. Depending on the platform we can define almost any behavior of an agent, programming or describing it using specific language. So we can determine the behavior of the agent that implements mechanisms of semantic indexing. The key problem of this approach is the high overhead of run-time. This is due to a complex infrastructure applications received applications. This can be compared with a programming in high level language and Assembler. The actions are the same, but the performance is significantly different. Therefore, such an approach to the problem is not satisfactory.

As noted above, the second approach to the problem of semantic indexing is the use of specialized semantic indexing systems based on the multi-agent paradigm. In this area, it was found only one solution – Magenta Toolkit [5]. This software solution is commercial, so there is no legal possibility to evaluate the effectiveness of work and, especially, to study the mechanisms of their internal functioning. Magenta Toolkit developers have written a number of publications [6, 7], which describe the principles of the system in outline without specifics. This decision is also not satisfactory.

Therefore, the task of the research is development of an open (open source and detailed descriptions of the principles) and an effective method of semantic indexing based on the multi-agents paradigm. In addition, you also need the option to apply this method to all electronic records. So the agent platform must be developed.

Document Analyses Steps

On Fig. 1 text mining process steps are shown. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar.

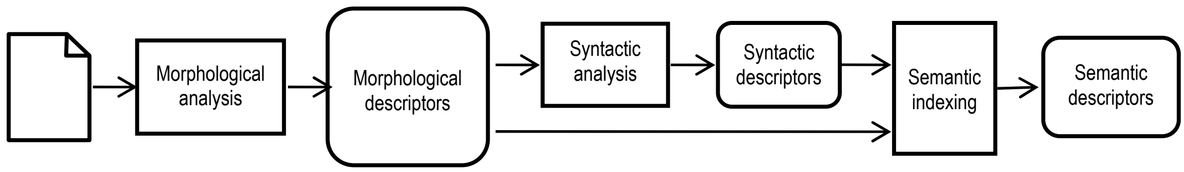

Figure 1. Steps of document analyses

Simplifying the problem we assume that first two steps of text mining process have been made, i.e. a set of syntactic and morphological descriptors for each sentence have been obtained. The result of semantic analysis (indexing) is a semantic descriptor of text that binds the syntactic descriptors of sentences to the elements of the domain ontology which is used for semantic search.

Descriptors (morphological, syntactic, and semantic) are a set of tags which marks words in the sentence. Syntactic and morphological descriptors will be put into relational tables for two reasons. Firstly, syntactic and morphological descriptors will be actively used for semantic indexing. Secondly, we don’t want to pile up document by tags. Each word in the text (except for a different kind of stop words) will be assigned a unique identifier. Each identifier corresponds to a separate table row.

Thus, *i*-th row of the table looks like (id_i, $\{a_j\}_i$), where id_i – the identifier of the word, $\{a_j\}_i$ – set of attributes (tags) that have been assigned to a given word during morphological and syntactic analysis process. In each row of syntactic descriptor table an identifier of applicable syntactic rule is indicated. The syntactic rule is a rule for constructing syntactically correct sentences. The semantic descriptor is represented as set of tags (semantic markup) within the indexed document.

Agent-based Solution

Further let us consider the process of building a semantic based on multi-agent approach (see Fig. 2).

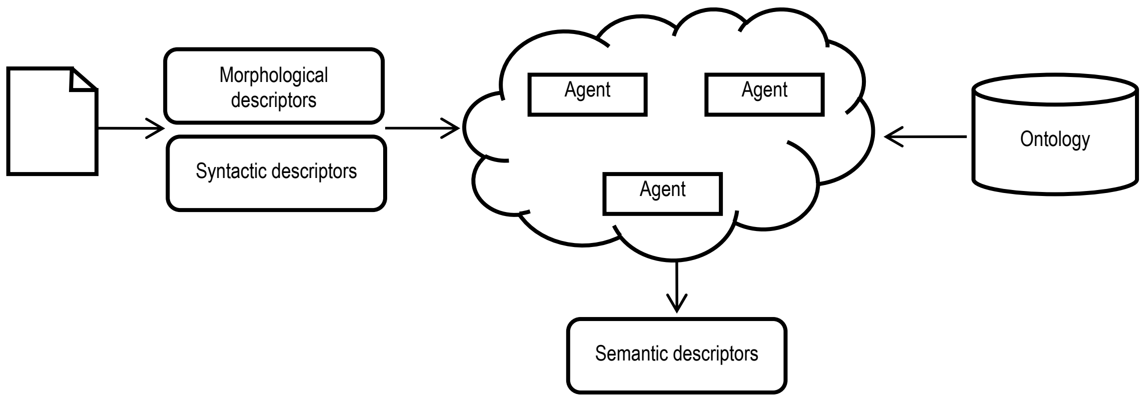

Figure 2. Architecture of agent platform

Each agent will have access to a common ontology, syntactic, morphological descriptors and electronic documents which will be indexed. Then analysis will be produced on the sentences in the text. Each agent is attached to a particular word (agent worker) in a sentence, for which there is a description in the descriptor tables (morphological and syntactic). Sentences are processed sequentially by agents. The agents form a "team" to index the particular sentence. If the number of words in a sentence greater than the number of active agents then two options could be: the agent of the analyzed sentence takes a few words, vacant agent of another sentence helps to analyze sentence. Thus, agents in the system after the start of the indexing are divided into teams. The number of agents in teams depends on the structure and content of the sentences in the document. Each team has a team leader agent. The team leader agent determines when the indexing of a sentence is completed and next sentence could be indexed. Besides the team leader agent resolves various kinds of the ambiguities by the auction.

Let us consider two levels of supervisors: team leader agent first-level, team leader agent second level. Team leader agent first-level aims to index all the sentences in the document. Team leader agent second level has a goal to index a specific sentence. Agent-worker has a goal to index a particular word in a sentence.

Agents are constantly involved not only in the form of communication "team leader agent – agent worker", but also in communications "agent worker – agent-worker" within the team. In addition, supervisors of different teams communicate with each other for the redistribution of available resources.

XML Based Document Format

Office Open XML (OOXML) is a set of open formats based on ZIP and XML technologies intended for representation of electronic documents package of office applications such as spreadsheets, presentations, text documents.

In 2006 the Office Open XML was recognized as the standard ECMA-376 and 2008 as the international standard ISO/IEC 29500:2008.

Since 2007 version of Microsoft Office OOXML is the default format for all applications included in the package of Microsoft Office.

For each document type its own markup language is used:

- WordprocessingML for text documents;
- SpreadsheetML for spreadsheets;
- PresentationML for presentations.

OOXML also includes a set of specialized markup languages that can be used in documents of various types:

- Office Math Markup Language is used to represent mathematical formulas;
- DrawingML is used to represent vector graphics and diagrams.

Office Open XML uses Open Packaging Convention (OPC), created by Microsoft and intended for storing a combination of XML and binary files (eg, BMP, PNG, AVI and etc.) in a single container file.

OpenDocument Format (ODF) is an open document file format intended for storing and exchanging editable office documents such as spreadsheets, text documents and presentations.

ODF standard is created and supported by Committee ODF Technical Committee organization OASIS (Organization for the Advancement of Structured Information Standards). OASIS published ODF 1.0 in May 2005, Commission International Organization for Standardization / International Electrotechnical Commission ratified it in May 2006 as ISO/IEC 26300:2006, so ODF become the first international standard for office documents.

ODF was accepted as the national standard in the Russian Federation, Brazil, Croatia, Italy, Korea, South Africa, Sweden and Venezuela.

Although both formats are based on open technologies, and are actually ZIP-archives that contain a set of XML-files defining the contents of the documents, they use very different approaches to solve the same problems and have radically different internal representation.

Format ODF reuses existing open XML standards, and introduces new ones only if it is really necessary. For example, ODF uses a subset of Dublin Core to represent document metadata, MathML to present mathematical expressions, SMIL to present multimedia content of the document, XLink to provide hyperlinks, etc. It means primarily it is easy to use this format by people already familiar with the existing methods to process XML.

The Office Open XML Format uses solutions developed by Microsoft to solve these problems, such as, Office Math Markup Language, DrawingML, etc.

OFFICE OPEN XML AND OPENDOCUMENT FORMAT APIS

As mentioned above, despite the same set of used technologies – XML and ZIP, Office Open XML Format and the OpenDocument Format have very different internal representation. Besides over the formats are under permanent development, there are currently several revisions of each format with very different possibilities.

For the Office Open XML they are:

- ECMA-376;
- ISO / IEC 29500:2008 Transitional;
- ISO / EC 29500:2008 Strict.

For the OpenDocument Format they are:

- ISO / IEC 26300;
- OASIS ODF 1.1;
- OASIS ODF 1.2.

Existing software solutions designed to work with this formats are quite different. We will consider some of them.

All libraries and other software tools for working with documents in the Office Open XML Formats can be divided into two broad categories. We will reference these technologies next way:

- OPC API – low-level API, allowing to work with OPC-structure of OOXML documents, but do not provide opportunities to work with markup languages Office Open XML. Examples of those APIs are shown in Table 2.

Table 2. OPC APIs comparison

	ECMA-376	ISO/IEC 29500:2008	ISO/EC 29500:2008 Strict
Packaging API	+		
System.IO.Packaging	+		
OpenXML4j	+		
libOPC		+	

- OOXML API – high-level API, designed to work with specific markup languages (WordprocessingML, SpreadsheetML, PresentationML). Libraries and tools of this category typically are based on OPC API. Examples of OOXML APIs are shown in Table 3.

Table 3. OOXML APIs comparison

	ECMA-376	ISO/IEC 29500:2008	ISO/EC 29500:2008 Strict
Microsoft Office 2007 Automation		+	
Microsoft Office 2010 Automation		+	
Open XML SDK 2.0	+		
Apache POI		+	

Libraries for operating with electronic documents in the ODF format can be divided into two broad categories too:

- Libraries in the ODF Toolkit. ODF Toolkit Union is the community of open source software developers. Its goal is simplifying document and document content software management.

- Third-party organizations libraries.

Table 4. ODF APIs comparison

	ISO/IEC 26300	OASIS ODF 1.2
AODL		
odf4j	+	
ODFDOM	+	+
Simple Java for ODF		
lpOD	+	

SemanticLib Project

It is obvious that there should be a universal approach, allowed to work with electronic documents in various formats in a standardized way. Library SemanticLib was developed to solve this problem. The library provides a unified API for working with documents in two formats: Office Open XML and OpenDocument Format. The core library contains an abstract model of an electronic document that is a generalization of the models used in the Office Open XML and OpenDocument Format. Schematic representation of the model is shown in Fig. 3.

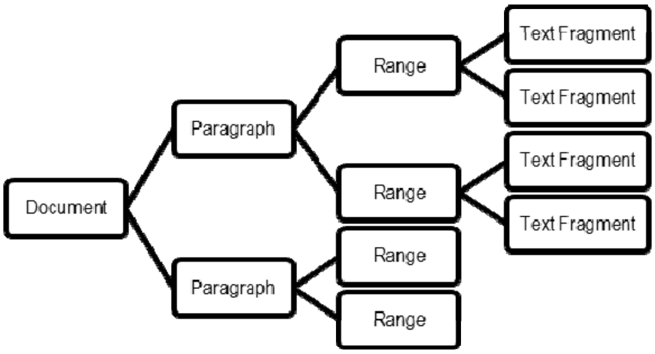

Figure 3. The model of the document used in SemanticLib

Fig. 4 shows a software implementation of DOM SemanticLib.

IMarkupable interface contains properties and methods that are used for semantic markup.

ITextDocument interface contains methods and properties for working with text documents, presented in a format like OOXML, and in the format ODF.

IParagraph interface contains properties and methods for working with particular paragraphs of the document.

IRange interface is used for working areas with continuous text contained in paragraphs.

IText interface is designed to work with particular text fragments contained in the text fields. The reason for the separation is the necessary to provide an opportunity for semantic markup of particular words in a text document.

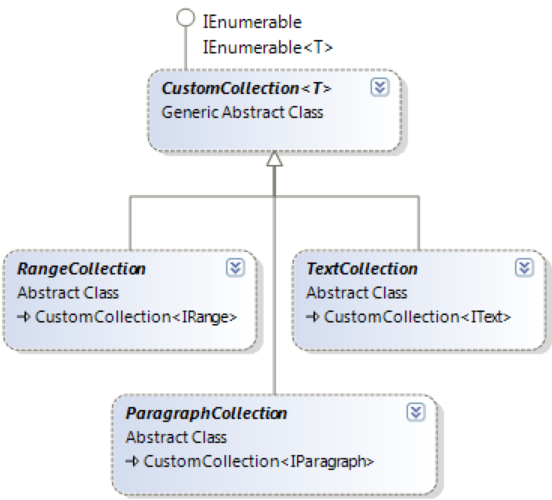

Figure 4. SemanticLib.Core.dll interfaces to work with OOXML and ODF documents

It is worth to note that all mentioned interfaces inherit from interface IMarkupable, so the semantic markup can be used as well as at the level of the document and to its particular elements such as paragraphs, text fields and text fragments.

It was mentioned that a text document and its fragments are containers, i.e. they contain other elements:

- a text document contains a collection of paragraphs;
- each section contains a collection of text fields;
- each text area contains a collection of text fragments.

Fig. 5 shows the hierarchy of abstract classes that represent collections of text documents.

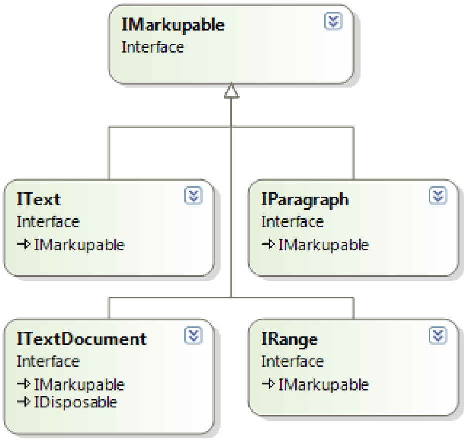

Figure 5. Collections of DOM SemanticLib

CustomCollection is the base class for all collections *SemanticLib*. It contains the common set of properties and methods, such as, for example, adding a new item in a collection, inserting a new item in a collection, removal element of the collection, etc. *ParagraphCollection* represents a collection of paragraphs. *RangeCollection* represents a collection of text fields. *TextCollection* represents a collection of text fragments.

SEMANTICLIB PLUG-IN SYSTEM

In SemanticLib implementation plug-ins based architecture is used. The library core contains only a description of the document model (DOM) and implementation of the methods for processing documents of any format is contained in the plug-ins. Typically each plug-in is an implementation of SemanticLib DOM with some libraries described in paragraph V. For example, a plug-in SemanticLib.OpenXmlSdkPlugin.dll uses API Open XML SDK 2.0, a plug-in SemanticLib.LibOpcPlugin.dll contains API libOPC.

Using plug-ins using makes possible a high degree of flexibility and extensibility. If a library expire or a new one appears, developer can just replace or add a plug-in without changing the basic functions of libraries and existing code.

However, plug-in development becomes significant difficult because of the existing the variety and diversity libraries. For example, the library Office Open XML SDK 2.0 is created on the platform .NET, while the library ODFDOM is created in Java, which means a significant difficulty trying to promote interoperability between these libraries. It is also difficult to ensure interoperability between C/C++ and .NET libraries. Let's consider how these issues are resolved in SemanticLib.

Let’s see the interoperability between C/C++ and .NET code by the example LibOpcPlugin, which is the implementation of DOM SemanticLib with libraries libOPC, written in ANSI C.

It was decided to use C++/CLI to enable interoperability between managed and unmanaged code. The main advantage of this solution is the ability to use object-oriented programming style even interacting with procedural code of libOPC. In this case plug-in consists of a set of classes that implement the interfaces of DOM SemanticLib.

Interoperability between Java and .NET code will be considered on the example plug-SemanticLib.OdfDomPlugin.

There are some solutions to ensure interaction between Java and .NET applications. For example, there are products of JNBridge company, which provide both in-process and inter-process (network cloud) communication.

However, in SemanticLib Open Source project jni4net was selected. Its aim is providing an in-process communication.

Deal with jni4net has several stages:

- Creating a proxy for a Java library with a special utility proxygen, which is part of jni4net.
- Creating a .NET stub, which provides the work with Java-proxy. This step is also performed using proxygen.
- Implementation of a plugin functional using the resulting stub.

This process is quite complex and requires specific skills, so it is necessary to create automation tools in future versions of SemanticLib.

One of the significant advantages offered by SemanticLib, is the ability to work with a dynamic plug-ins. This feature is important if you work with a large number of different plug-ins. Plug-in manager, which is part of SemanticLib, helps user to manage the plug-ins loading process.

Plugin Manager provides the following features:

- Find the required plug-ins in accordance with certain criteria, such as the name of the plug-in or the format of the document.
- Loading and unloading plug-ins.
- Viewing the meta-information about the loaded plug-ins (name, manufacturer, document format, etc.).

Conclusion

So, in this paper we have discussed various approaches to solving the problem of document semantic indexing based on multi-agent paradigm. We propose a variant of the solution of that problem and describe it in terms of morphological, syntactic and semantic descriptors of the text. Specialized types of agents are introduced and the general principle of multi-agent system is described.

Semantic indexing of documents in Open XML Formats and Open Document Format can be implemented on the basis of the described solutions. The developed library is a part of the intelligent document processing project, but also can be used to solve other problems that require metadata inclusion.

Acknowledgement

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AN ESTIMATION OF TIME REQUIRED FOR MODELING OF AN ALGORITHM CALCULATE A NON-CONFLICT SCHEDULE FOR CROSSBAR SWITCH NODE BY MEANS OF GRID-STRUCTURE

Tasho Tashev

Abstract: The problem of calculating a non-conflict schedule by packets commutation in crossbar switch node is one of the foremost problems at the stage of node design. From a mathematical point of view this task is NP-complete. Constantly rising levels of traffic communication require developing of new algorithms. These algorithms must be correctly compared with known algorithms. In this paper we presented the investigations on the time execution of known PIM-algorithm for crossbar switch by means of CERN's grid-structure. By computer simulation of switching and using synthesized Generalized Nets (GN) model of the PIM-algorithm the execution time is obtained. Its assessment is based on the modeling of the throughput in the presence of uniform incoming traffic. It is shown that direct receiving of the characteristics of simulation time with the required accuracy would require the introduction of strictly defined control points.

Keywords*: Modeling, Generalized Nets, Communication Node, Crossbar Switch, Algorithm, Simulation.*

ACM Classification Keywords*: B.4.4 Performance Analysis and Design Aids, C.2.1 Network Architecture and Design, C.4 Performance of Systems*

Introduction

In information exchange networks the essential nodes are commutation nodes called switches and routers. Crossbar packet switches route traffic from input to output where a message packet is transmitted from the source to the destination.

The randomly incoming traffic must be controlled and scheduled to eliminate conflict at the crossbar switch. The goal of the traffic-scheduling for the crossbar switches is to minimize packet blocking probability and packet waiting time and to maximize the throughput of packet through a switch [Elhanany, 2007]. So achieving a maximum throughput of the switch depends on the calculation of non-conflict plan for switching incoming packets.

The problem for calculating of non-conflict schedule is NP-complete [Chen et al, 1990]. Algorithms are suggested which solve the problem partially. The origin of a series of parallel algorithms is the PIM-algorithm (Parallel Iterative Matching) [Anderson et al, 1993]. One of the research directions is working on modifications to PIM-algorithm, relying on input buffering with virtual output queuing (VOQ) [Guannan Qu et al., 2010]. Other studies are directed to the use of inputs and intermediate buffering (CICQ) [Shunyuan Ye et al., 2010].

Cellular automata, neural networks, etc. are used as formal means to describe and study the characteristics of crossbar switch nodes. In this investigation the apparatus of Generalized Nets (GN) are used as a powerful modern tool for formal modeling of parallel processes. Generalized nets (GN) [Atanassov, 1991, Atanassov, 1997] are a contemporary formal tool created to make detailed representation of connections between the structure and temporal dependencies in parallel processes. They are used in different fields of application, telecommunication is one of them [Gochev, 2008], [Tashev, 2010]. The apparatus of GN in this research is applied to synthesize a model of one algorithm for computing of non-conflict schedule in the crossbar switch node.

In this paper we presented the investigations on the time execution of PIM-algorithm for crossbar switch. By computer simulation of switching and using synthesized GN-model of the PIM-algorithm the execution time is obtained. Its assessment is based on the modeling of the throughput in the presence of uniform distributed incoming traffic. For this purpose, two templates are used to simulate uniform traffic.

Generalized Net Model of PIM-Algorithm

The requests for transmission through switching *n* x *n* line switch node is presented by an $n \times n$ matrix *T*, named traffic matrix (*n* is integer). Every element t_{ij} ($t_{ij} \in$ [0, 1, 2, …]) of the traffic matrix represents a request for packet from input *i* to output *j*. For example $t_{ij} = 4$ means that four packets from the i^{th} input line have to be send to j^{th} output line of the switch node, etc.

It is assumed that a conflict situation is formed when in any row of the *T* matrix the number of requests is more than 1 – this corresponds to the case when one source declares connection with more than one receiver. If a column of the matrix *T* hosts more than one digit 1, it indicates a conflict situation. Avoiding conflicts is related to the switch node efficiency [Elhanany, 2007].

The PIM-algorithm is based on the principle of distributed-random choice. Its informal description has three phases. 1) **Request**: Every input sends request to every output for which it has a packet for transmission; 2) **Grant**: Every output chooses randomly one of the received requests and grants permission for sending to the corresponding input; 3) **Accept**: Every input received grants chooses randomly one of them. This packet will be accepted for commutation.

Inputs execute in parallel the first phase. Outputs execute in parallel second phase. Inputs are working in parallel in the third phase [Anderson et al, 1993]. This parallelism is suitable for applying of GN

The PIM-algorithm can be described formally by the means of Generalized Nets. Based on a previous work [Tashev, 2010], here, we give an explicit form of the VOQ The model is developed for switch node with *n* inputs and *n* outputs. Its graphic form is shown on Figure 1.

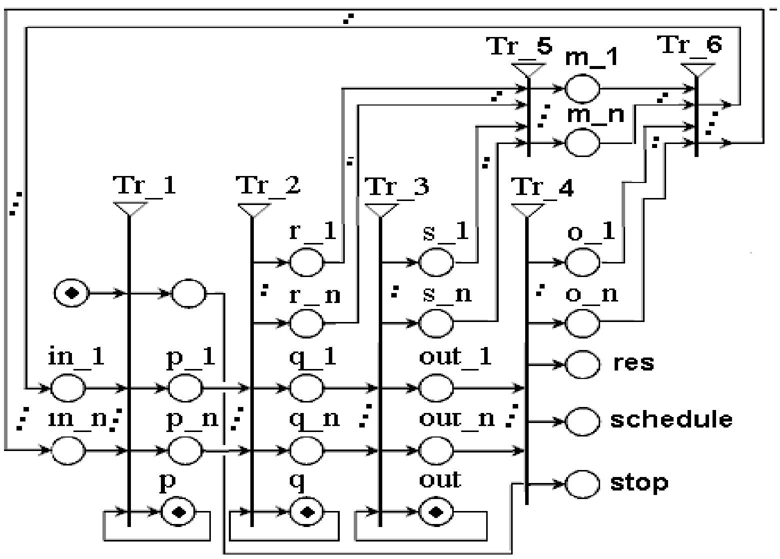


Figure 1: Graphical form of GN-model of PIM-algorithm.

The model has possibilities to provide information about the number of switching in crossbar matrix, as well as about the average number of packets transmitted by one switch. Analysis of the model proves receiving a non-conflict schedule. Calculation complexity of the solution depends on the power of three of the dimension *n* of the matrix $T\ (O(n^2))$.

Computer Simulation

The transition from GN-model to executive program is performed as in [Tashev and Vorobiov, 2007]. The program package Vfort of Institute of mathematical modeling of Russian Academy of Sciences is used [Vfort]. The source code has been tested by the IBM PC-compatible computer and then compiled by the means of the grid-structure of CERN (lxplus.cern.ch). The resulting executive code is executed in the grid under Scientific Linux SLC release 5.7. Main restriction for the choice of parameters in simulation (dimension *n* and type of load traffic) is the time for execution of the program.

Achieving maximal throughput of crossbar switch node depends on creation of non-conflict schedule for packet commutation. The first step while checking their efficiency is throughput modeling of the switch by uniform demand traffic. The matrix *T* defines a uniform traffic demand matrix if the total number of packets in each element in rows and columns are equal [Gupta and McKeown, 1999]. The uniform demand traffic matrix is called in the investigation as $Pattern_i$. The index *i* shows values of element in the traffic matrix. All elements in the traffic matrix are equal and in this case an optimal solution is known. The throughput is computed by dividing the result of optimal solution on the result of the simulated solution. The result of algorithm is a number of non-conflict matrices. Their sum is equal to *T*, as number of matrices shows number of commutations.

Figure 2 presents the used input data – *uniform matrix T*, defined by us. The first type of the matrix is called $Pattern_1$. Its specification is shown on the left of the figure 2. The optimal schedule requires *n* switching of crossbar matrix for *n* x *n* switch. The second type of the matrix is called $Pattern_i$. Its specification is shown on figure 2 (right). The optimal schedule requires (*i* . *n*) switching of crossbar matrix for *n* x *n* switch.

$$T=\underset{2\times 2}{\begin{bmatrix}1&1\\1&1\end{bmatrix}}\ \underset{3\times 3}{\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}}\cdots\underset{k\times k}{\begin{bmatrix}1&\cdots&1\\\vdots&\ddots&\vdots\\1&\cdots&1\end{bmatrix}}\cdots\qquad T=\underset{2\times 2}{\begin{bmatrix}i&i\\i&i\end{bmatrix}}\ \underset{3\times 3}{\begin{bmatrix}i&i&i\\i&i&i\\i&i&i\end{bmatrix}}\cdots\underset{k\times k}{\begin{bmatrix}i&\cdots&i\\\vdots&\ddots&\vdots\\i&\cdots&i\end{bmatrix}}\cdots$$

Figure 2: Types of the uniform traffic matrix T

The results from the computer simulation of the PIM-algorithm with input data $Pattern_1$ and $Pattern_{50}$ are displayed on figure 3 and 4.

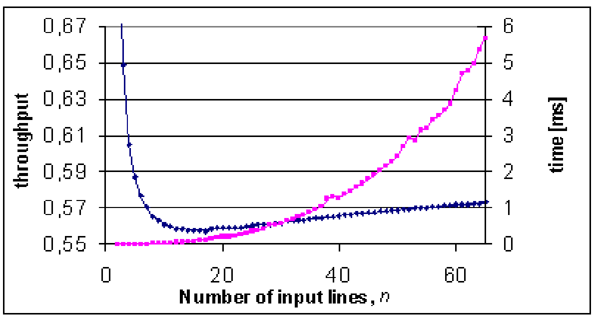


Figure 3: Throughput and time with $Pattern_1$

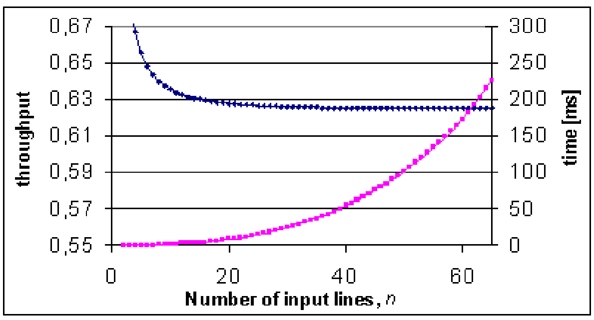
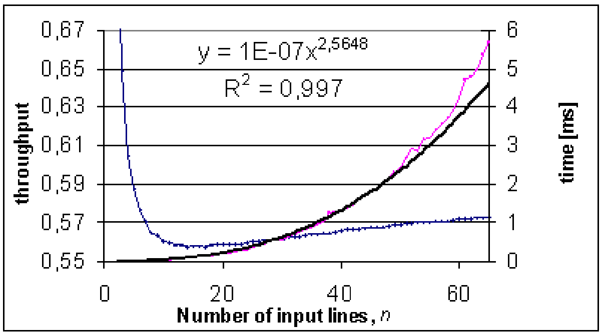


Figure 4: Throughput and time with $Pattern_{50}$

The crossbar matrixes of the size 2x2 up to 65x65 are simulated. It can be seen that when the size of *Pattern* and dimension of the switch field increases, the throughput asymptotically tends to the known boundary (~63,2 % [Gupta and McKeown, 1999]). Therefore the simulation is correct. Evaluation of the simulation results illustrates that PIM algorithm has high sensitivity to the increasing of input buffer.

The results of the approximated time with input data $Pattern_1$ and $Pattern_{50}$ are demonstrated on figure 5 and 6. We expect that the time coefficient tend to 3 since the simulation execution is not parallel.



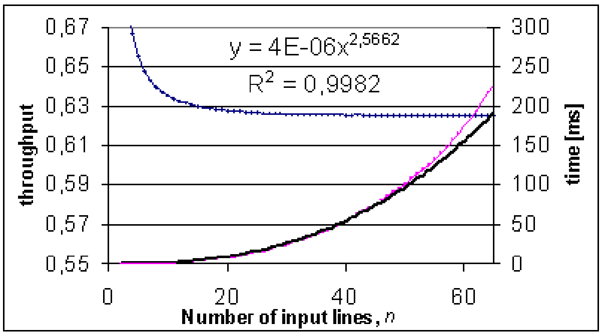
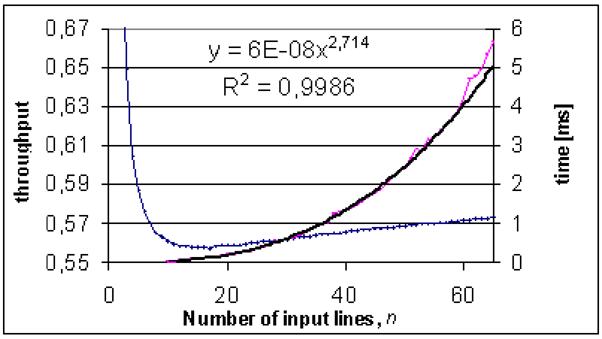


Figure 5: Approximation for time with $Pattern_1$

Figure 6: Approximation for time with $Pattern_{50}$

The figures give evidence of a difference between throughput and time in cases of $Pattern_1$ and $Pattern_{50}$ – the input buffer increases 50 times. The difference in time in the cases of $Pattern_{50}$ and $Pattern_1$ is increasing 40 times (from 1.10^{-7} sec to 4.10^{-6} sec) as opposed to the expected 50 times. The time coefficient is ~2.6 as opposed to the expected 3. The approximation is not very good.

If we reject the results for n = 2,..., 9, the difference between time for $Pattern_{50}$ and $Pattern_1$ is increasing 50 times (from 6.10^{-8} sec to 3.10^{-6} sec) - exactly as it should. The figures 7 and 8 shows the time approximation for this case. The time coefficient is increasing to ~2.7.



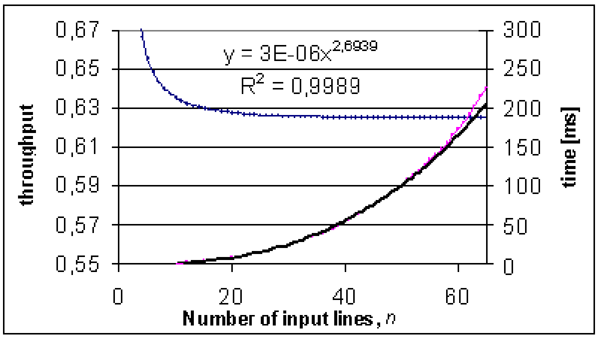


Figure 7: Correction for approximation of P_1

Figure 8: Correction for approximation of P_{50}

Let us increase the dimensionality of the simulation to 130. The results from the computer simulation of the PIM-algorithm with input data $Pattern_1$ for size *n*=2x2 up to 130x130 are displayed on figure 9.

The time coefficient is increasing to ~2.8. But the real data for time execution are still up from approximated data.

Let us reject the results for n = 2,..., 19. In this case y=3E-08x 2.8911. The time coefficient is ~2.9. Let us reject the results for n = 2,..., 29. In this case y=3E-08x 2.9343. The time coefficient is ~2.93.

It is shown that direct receipt of the characteristics of simulation time with the required accuracy would require the introduction of strictly defined intervals of size of simulation.

The promising results from the simulation on the PIM algorithm lead us to an idea of conducting of large-scale simulations for non-uniform demand traffic that can be direction for the future work.

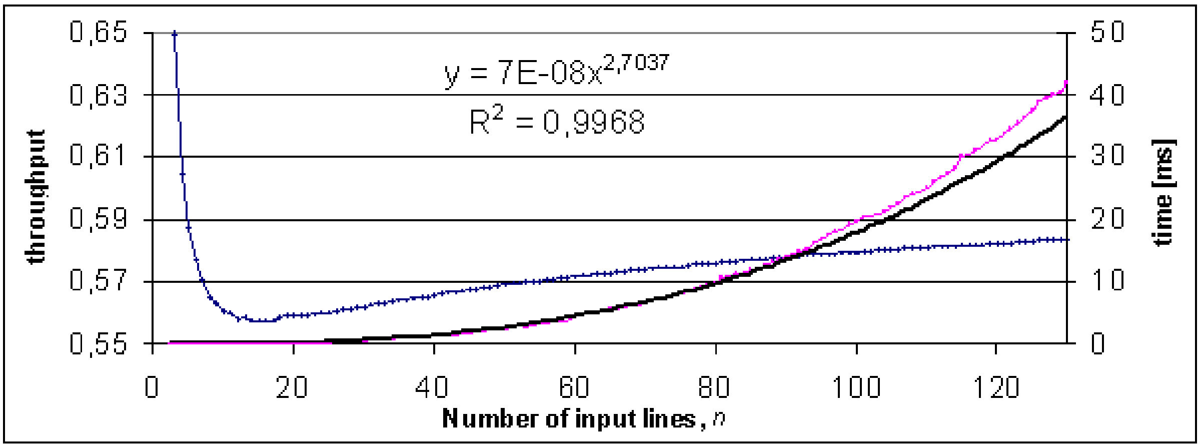


Figure 9: Throughput and time approximation for n=130x130 with Pattern₁

Let us reject the results for n = 2,..., 9. Figure 10 show the time approximation for this case.

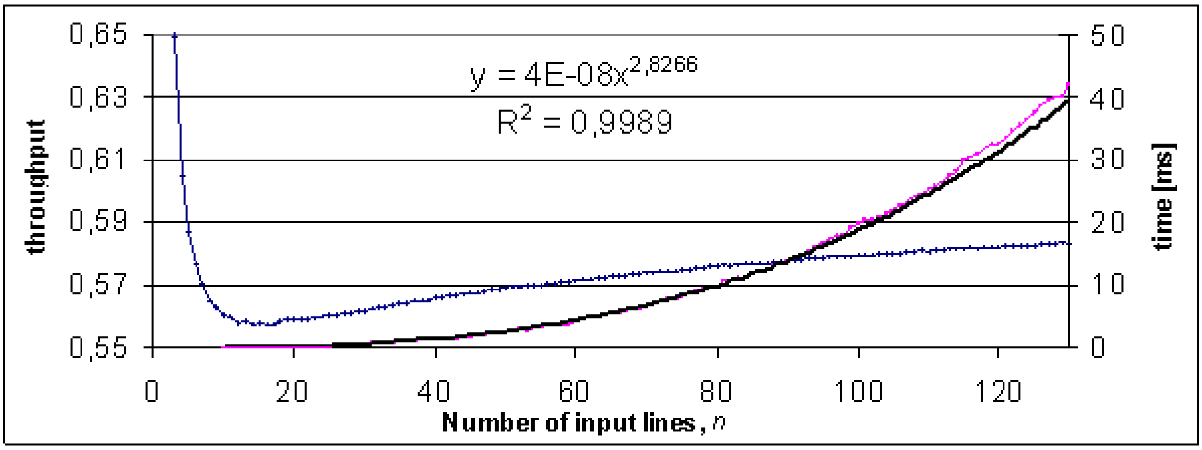


Figure 10: Coorection for approximation for time n=130x130 with $Pattern_1$

Conclusion

In this paper the investigations on PIM-algorithm for calculating a non-conflict schedule for crossbar switch node are presented. Computer simulations of a Generalized Nets-based model of PIM-algorithm performing uniform load traffic have been carried out. The results of simulation such as throughput and execution time are evaluated. It is shown that direct receipt of the characteristics of simulation time with the required accuracy would require the introduction of strictly defined control points.

Future work should be directed towards carrying out large-scaled computer simulation to study the throughput and execution time for a wide range of incoming demand traffic.

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MAUGRY: AUGMENTED REALITY GUIDE FOR MUSEUMS. FROM PROOF OF CONCEPT TO MUSEUM AS A SERVICE

Kirill Yurkov

Abstract: *Augmented reality solution development for mobile devices is a rather young domain. There are very few guidelines and practically no patterns or mature frameworks for application developers. In this paper we present an evolution of an augmented reality guide for museums, we demonstrate possible solutions for major problems that were encountered. We discuss possible uses of augmented reality for mobile guide development and propose a possible alternative for augmented reality: a technique we call Smooth Transition. We demonstrate that for mobile guide a blend of Smooth Transition and Augmented Reality is the best solution. We analyze several approaches to exhibit recognition including: barcode recognition, special marker recognition and image of exhibit recognition. We analyze several major augmented reality frameworks based on practical experience of mobile guide development. Also we argue that a mobile guide must have user navigation capabilities, which allow users to find their route in an exhibition. We propose two different approaches to user navigation: spatial and semantical: first allows user to see a general layout of exhibition, while second helps user to navigate between thematically close exhibits. We also outline the basic components of a service-oriented architecture we call museum as a service. Museum as a service is a system which will allow any museum to promptly and with minimal expenses deploy a mobile guide application based on augmented reality and smooth transition.*

Keywords: *Augmented Reality; Museums; Mobile application development.*

ACM Classification Keywords: *H.5 Information Interfaces and Presentation: H.5.1 Multimedia Information Systems – Artificial, augmented, and virtual realities.*

Introduction

Rapid evolution of mobile devices has already significantly changed ways people solve problems. State-of-the art mobile device is often an irreplaceable tool for business operations, an always-present means of communication and recreation. One of many ways in which this evolution impacted computer science is the appearance of a new and still widely unclaimed market for augmented reality solutions. Contemporary mobile device is capable of real-time video processing and analysis and usually carries a number of sensors including video camera, accelerometer, gyroscope, geolocation sensor, making it a perfect platform for augmented reality applications.

Although augmented reality (AR) is a known scientific/application area there are still a lot of diffent problems and types of problems (including fundamental, project management, computer vision and technological) that need to be addressed in order to develop new applications. This paper presents some of these problems and solutions which were found while developing an Augmented Reality Guide for Museums application called Maugry.

Providing multimedia information for museum and exhibitions visitors is a natural domain for AR solutions. Nowadays museum attendee often is an individual less interested in group excursion who still wants to get a high level of service and personalized experience. Mobile device is a perfect medium for providing such service and experience.

In order to illustrate AR solution development problems and proposed solutions for them we are going to follow evolution of Maugry through 3 phases:

1. Demonstration prototype developed as a proof of concept.
2. Working prototype developed for Perm State Gallery.
3. Museum as a service. A work in progress to create an Internet portal which will allow any museum, exhibition or unaffiliated user to create an augmented reality guide.

Term definitions

Real space – real world space. Users move in real world space. Real space is divided in separate locations.

Scene space – background and all objects which form the scene (image that is displayed to user).

Augmentation point – place (point) in real space where augmentation object should be located.

Scene in augmented reality application is formed by displaying real world image and augmentation objects. Hence real space is called augmented space and collection of all augmenting objects is called augmenting space.

Maugry demonstration prototype

One of fundamental questions of AR solutions is "When should AR be used?" Demonstration prototype of Maugry (Maugry 0.1) was developed to answer this question for museum excursion domain (museum domain). The major capability of AR is that it allows to make content:

– Adaptive/Personalized. Displayed content can be modified to better address interests of a particular user, can be based upon his profile including his language preferences.

– Interactive. Content can react to user actions, interact with user.

– Multimedia enabled. AR allows presenting audio, video, cartographic information.

– Three dimensional. AR allows displaying 3d objects.

One of the alternatives for augmented reality is a technology we call smooth transition (ST). Upon augmentation point recognition ST replaces (instead of augmenting) whole real world scene (video stream) with content corresponding to augmentation point. One of major requirement for ST solution is to provide seamless transition from real world scene to content and back.

Major advantage of AR applications over ST applications is their ability to present augmented content side-by-side (in context) with real objects, allow real objects to interact with augmented objects without need for any transitions.

General algorithm of major component of AR and ST application is practically the same

1. Get video stream from camera and if necessary data from other mobile device sensors.

2. Analyze video and sensor data. Find first (all) augmentation point.

3. Construct the scene.

AR and ST solutions differ in way they construct the scene that is presented to user. Further analysis demonstrates that AR usually demands more sophisticated and computationally intensive algorithms for image analysis.

Maugry 0.1 heavily uses OpenCV library (a de facto standard library for computer vision applications) [OpenCV, 2012]. Maugry 0.1 is capable of recognizing three different exhibits and displaying corresponding content through a smooth transition to this content. Content is presented via interactive HTML 5 pages with audio fragments. Additionally this prototype is capable of presenting short text messages which appear near specific parts of a different exhibit and basic 3d objects which are displayed side-by-side with real exhibits.

Maugry 0.1 was presented to potential users. Upon receiving feedback from them several important conclusions were drawn.

1. It is hard and often impossible to use AR for displaying large amount of multimedia information. But AR allows creating unique and engaging applications where small chunks (separate objects, sentences, small video fragments) of data are sufficient to present the necessary material. One possible exception to the first conclusion is audio content. But in order to make application truly interactive we still recommend using short audio records (less than 30 seconds long).

2. AR ability to present 3d objects is a major advantage of this technology that should be used extensively. AR with 3d content can be used to demonstrate exhibits from different museums or even destroyed or non-existent exhibits side-by-side with real ones.

3. ST is a more capable technology for presenting large amounts of multimedia information.

4. Same computer vision components can be used for AR and ST application.

For domain of museum excursion we recommend to develop solutions which combine AR and ST components and allow to present complex multimedia information. To make porting (from one mobile platform from another) mobile applications simple we recommend using C++ based components for computationally intense tasks like video analysis. Content can be stored and viewed as HTML 5 pages for ST. In our application we used 3ds files to describe 3d models displayed through AR. 3ds format model can be imported/exported in/from most of major 3d computer graphics packages.

Maugry Industrial Prototype

Industrial prototype (Maugry 1.0) was developed for Perm State Art Gallery wooden sculpture exhibition.

One of major problems of AR and ST applications is augmentation point recognition. Following three methods are the most popular approaches to solving these problems:

1. 2D barcode recognition and QR-code recognition in particular.
2. Special Maker recognition (Marker-based AR).
3. Image recognition (Markerless AR).

The first approach based on 2d barcode recognition can primarily be used for ST applications, because they do not need to compute transformation matrix for content modification. Furthermore usage of 2D barcodes allows to embed information about content (for example its URL) directly into the code which simplifies development of ST application for expanding domains. However QR codes are hard to call esthetically appealing and in museum domain where composition of exhibition very often requires sustaining a certain style even in markers this disadvantage can be very important.

Alternatively markers specifically designed for AR can be used. They inherently allow reliable transformation matrix computation and several types of them allow markers to contain arbitrary images (which can be chosen to fit the style of a particular exhibition).

The third most common approach in AR is to recognize objects or images of objects. This approach is usually referred to as markerless AR [Ferrari, 2001]. According to feedback we got from potential users of augmented reality in museums this approach is the most suitable for museum domain, but it is also the most computationally intensive approach

We analyzed existing libraries and frameworks for AR solution development. For our purposes we analyzed and tested ARToolkir [Kato, 2000], ARTag [Fiala, 2005], Vuforia [Vuforia, 2012] and Layar [Layar, 2012]. Thorough testing result analysis is beyond the scope of this paper, but according to out result Vuforia demonstrates most stable and effective behavior on mobile devices and practically does not constrict developers in choosing ways of delivering their AR solution. Vuforia can also be used as the image recognition component for ST solution.

We used Phonegap framework [Phonegap, 2012] to develop parts of applications that are not computationally intensive. This allowed us to create easily portable solution.

Content for ST is stored on server in HTML 5 pages and retrieved by mobile client when exhibit is recognized. HTML 5 page can contain text, image, audio, video and interactive content. Also usage of HTML 5 pages allowed us to use standard web server (IIS 7.0) as a server side component minimizing complexity of server side development. Content for AR is stored in 3ds files and is similarly retrieved from server on demand.

Museum as a service

We are developing museum as a service portal which main goal is to allow different museums all around the world to use our mobile augmented reality guide.

Museum representative will be able to register on the portal and create an exhibition (a collection of exhibits). Then representative will provide means of recognition for each exhibit, which will constitute either photographs of the exhibit to be recognized or an image which will be used in special marker or representative may choose to use QR code. Also representative will provide additional content which should be displayed when exhibit is recognized. At first we plan to introduce only ST capabilities in our application because it is much easier for users to understand how to prepare content for such application. As a separate service we are planning to provide capabilities to introduce AR elements designed either by user or by our company.

Mobile application on museum visitors’ device will be able to get data necessary for exhibit recognition from our portal. When exhibit is recognized museum visitor will be presented with multimedia content provided by museum.

However AR and ST alone are not enough to allow user to get maximum information about exhibition. Museum guide should also be able to assist visitor in navigation. In order to facilitate navigation trough exhibition we show user two lists of exhibits that are close to the currently recognized one:

1. Exhibits which are spatially close.
2. Exhibits which are semantically close.

In order to find semantic distance from one exhibit to another we use a special metric on concept lattice. Concept lattice is constructed via a Gartner algorithm [Ganter, 2005]. Exhibits are considered objects, attributes are taken from attributes created by museum representative and extracted from text (using a keyword search algorithm).

Museum as a service is in many way architecturally more complex solution than a stand-alone application used in Maugry 0.1. In our Museum as a service solution we use MongoDb as a primary DBMS. Every museum can describe its exhibits differently; furthermore different exhibits in one collection can have very different sets of attributes. Choice of non-relational DBMS to store data about exhibits and exhibitions proved to be a more adequate solution (previously we were using MySQL DBMS and we found its capabilities ill-suited for museum domain). To allow full-text search and text mining algorithms implementation we also use Lucene [Lucene, 2012] indexing capabilities.

Server-side application is a .Net web-service which implements standard create, read, update, delete capabilities, and specifically designed query language to allow for schema ignorant querying. This approach allows us to abstract data layer specifics from service clients and change data-storage mechanics without affecting client applications.

We use Phonegap framework to develop parts of mobile applications that are not computationally intensive. Mobile client also implements a special cache level to minimize number of round-trips between client and server. It also features a "micro-query language" to allow mobile client to work with structurally different exhibits after they have been fetched from server without having to rely on server-side implementation of querying.

Conclusion

This paper has presented the evolution of Augmented reality museum guide application called Maugry. Each step of evolution was used to demonstrate solutions for different problems that typically arise when creating an augmented reality application. Advantages of AR usages were examined and ST alternative proposed. Fundamental architectural principals for AR solution development were demonstrated by example. Several questions of general architecture for museum as a service solution were discussed.

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RISK IDENTIFICATION ANALYSIS OF STATISTIC DATA FOR BUILDING THE INVESTMENT FORECAST WITH THE HELP OF BROWNIAN MOTION MODEL

Kyzemin Oleksandr, Irina Gurina

Abstract: *Shocks and jumps of different funds' functions bring extreme negative values of great consequences to investors. There is always a factor of uncertainty in any economic situation, and in order to make the right investment decisions, or to choose the right business strategy, we require some form of workable hypothesis (that takes into account uncertainty and randomness) to base our decisions upon. Although both risk and upward potential are related to uncertainty of future events, risks usually play a more dominant role in investment decisions since investors are risk averse. At most cases detection of risk is one of the most important parts of a financial analysis.*

This article will examine ways to measure and manage risk in making investment decisions. Here we determine Brownian motion as the estimation method of the investment risks and show the specific features of the given method during the statistic data analyses.

Keywords*: Brownian motion, risk, function, financial analysis, investment market, non-recurrent cycles, deviations, noises, inaccuracies, strategy, knowledge, the Hurst analyses, correlation, entropy.*

ACM Classification Keywords: *G.3 Probability and statistics - Stochastic processes*

Introduction

Every risk strategy of investment business has the probability of heavy material losses. Misinformation, a lack of knowledge about the investment, or market pressures are influencing investors thinking in some way and leading them to wrong decisions. Successful implementation of the risk strategy involves overcoming these factors and rationally examining the proposed investment. The main strategy for reducing investment risk is diversification [Granot, Soši´, 2003]. By spreading investments among several asset classes such as stocks, bonds and cash, the firm effectively reduces its overall investment risk because there is almost always at least one asset class that is doing well [Plambeck, Taylor, 2003]. For example, if stocks are down, then interest rates may be up, which means that bonds could be a good investment. Another way to lower investment risk is by using derivatives such as options and futures. Derivatives allow the firm to hedge its investments and increase its overall return with limited risk and can protect firm's portfolio from possible downside exposure. One of the easiest ways to lower equity investment risk is to simply give them time to grow. Long-term investors are much more likely to see their investments grow over time than market timers or those who invest for five years or less. However, all these metods need qualitative mathematical analysis to choose the right strategy [Salvatore, 2003].

The building of the classical lineal models cannot describe the saturation, resonance jumps and vibrations. The exceptions to this rule are only steady growth and equally steady decrease [Kronover, 2000]. The Hurst analyses showed that the market had the long term memory of the long term investment horizons. We can present the behavior of the market function as the filter of the informational materials, which are shown in its structure of performance [Guasoni, 2006].

According to the theory of chaos errors, deviations, noises, inaccuracies are more fundamental and ontological, rather than the processes described by classical science.

According to the sinergetic point of view, we can talk about the investment market as an open dynamic, dissipative system, the system that has the possibility of self-development, self-sustaining and self-control [Markov, 2009].

The behavior of the sale value of certain goods or funds in the time interval is characterized by uncertainty, which is caused by entropy effects of independent market participants. The investment market has non-lineal development because its structures are in a constant state of struggle with arising fluctuations – deviations from some of the averages indicators. For example, the beginning of new centers of attraction is nothing like a strong fluctuation, which arose under the influence of environment (creation of new businesses, economic crisis, etc.) [Markov, 2008]. This behavior of the function can be described as the Brownian motion of the elements, where the change of the point's parameters is caused by other points' functions. At each time this function experiences unbalanced influence from other functions and as the result the movement of the point during the time interval has the stochastic behavior [Peters, 2000]. The fractal methods such as Brownian motion method are used in case if a real object cannot be presented in the classical view. It means that we work with nonlinear constraints and nondeterministic (random) kind of data. Nonlinearity at the worldview sense means multiversion of routes development, a choice of alternative routes and certain rate of evolution and the irreversibility of evolutionary processes [Peters, 2000].

Brownian motion (named after Robert Brown, who first observed the motion in 1827, when he examined pollen grains in water), or pedesis (from Greek: πήδησις "leaping") is the assumably random movement of particles suspended in a fluid (i.e., a liquid such as water or a gas such as air) or the mathematical model used to describe such random movements, often called a particle theory.

Brownian motion has desirable mathematical characteristics, where statistics can be estimated with great precision, probabilities can be calculated, and hence scientists and analysts often turn to such an independent process when faced with the analysis of a multidimensional process of unknown origin (i.e. the stock market). The mathematical model of Brownian motion has several real-world applications. Brownian motion is among the simplest of the continuous-time stochastic (or probabilistic) processes, and it is a limit of both simpler and more complicated stochastic processes. One of the main distinctive features of the Brownian motion is that it has non-recurrent cycles and these cycles are the main subject of analysis [Peters, 2000].

The essence of work

Goals and objectives of our work:

For many years investors, economists, statisticians, and stock market players have been interested in developing and testing models of stock price behavior. One important model that needs attention and more thorough investigation is the Brownian motion method.

The aim is to analyze (like examlpe) the value function of the sold shares of the open joint stock company "State Energy Generating Company "Centrenergo" [Ukrainskaja birzha]. In this module we use collected primary data and processed secondary to calculate various parameters and uncertainty modeling required for running the model.

In this document, we do not present in detail all the parameter calculations that are necessary for project's economic and financial evaluation [Gabidulin, 2007]. Rather, we only present the calculations and modeling of several key parameters, including the function of the values; the correlation integral; the correlation entropy; the auto correlation function; the Hurst value.

Scientific novelty:

Great theoretical and practical interest presents the study, that allows according to the result of complex fluctuations in an example of a separate company, give an answer about the nature of modes of operation of the entire dynamic of the market as a whole, from the standpoint of modern concepts of deterministic chaos, where the role of the traditional linear approaches to the study of these patterns is strongly limited.

When making capacity, inventory, and production decisions, firms are typically uncertain about future market conditions such as demand, prices, and exchange rates. Within the framework of the investment market the Brownian motion is one of the first attempts to take into account the fluctuations of the financial market. The firms always take a certain risk. The use of stochastic methods would help to perform the high accuracy analyses of different data and to study the main driving forces of investment market. All that would help to create a well-established and empirically tested forecast updating model in which the forecast evolution process follows a geometric Brownian motion.

Practical value:

The actuality of research is caused by high practical significance and poor study of the problem of the investment risks at the market, submitted in shocks and jumps. It involves the need of the researchers and investors to create an effective instrument for adequate assessment of investment risks. With the help of Brownian motion method and other fractal methods we can get useful recommendations necessary for more accurate assessment of the market risks. And it can improve the work both of private and governmental establishments.

Applied methods of the investment risks today:

The main methods of the investment risk assessment can be divided into the following groups: building confidence intervals; finding out indexes; expert methods; historical methods; discounting methods; structure methods; defining the level of the project's stability; sensitivity analysis of the project; scenario analysis of the project development.

However, these methods are not steady to shocks and don't show enough impact of the initial conditions and noise. Meta heuristics, fractal methods, and stochastic methods are more flexible and show high accuracy of the calculations.

The most popular and traditional measure of risk is volatility. The main problem with volatility, however, is that it does not care about the direction of an investment's movement: a stock can be volatile because it suddenly jumps higher.

The proposed method of analyses:

We use the time row to assess the value of a statistical data. We located the row at the time sequence, and with the help of that we can identify the level's rate of change, determine the trends, and follow certain patterns of variable to identify the factors influencing the change process in the future [Orlov, 2004].

We analyzed the value function of the sold shares of the open joint stock company "State Energy Generating Company "Centrenergo"", which has 15% of the of all electric power in Ukraine and plays a significant role in supporting and regulating energy balance in the whole country. This analysis could be useful for investors and researches who work in the sphere of the energy (for example in the field of the renewable energy). For the sample data, we took an interval of one minute and 8521 values of the sold shares (UAH) [Anupindi, Bassok, Zemel, 2001]. The following figure (1) illustrates the model of the sold shares; the values of the function have the high wide variation, from which we can conclude that this function is stochastic [Peters, 2000].

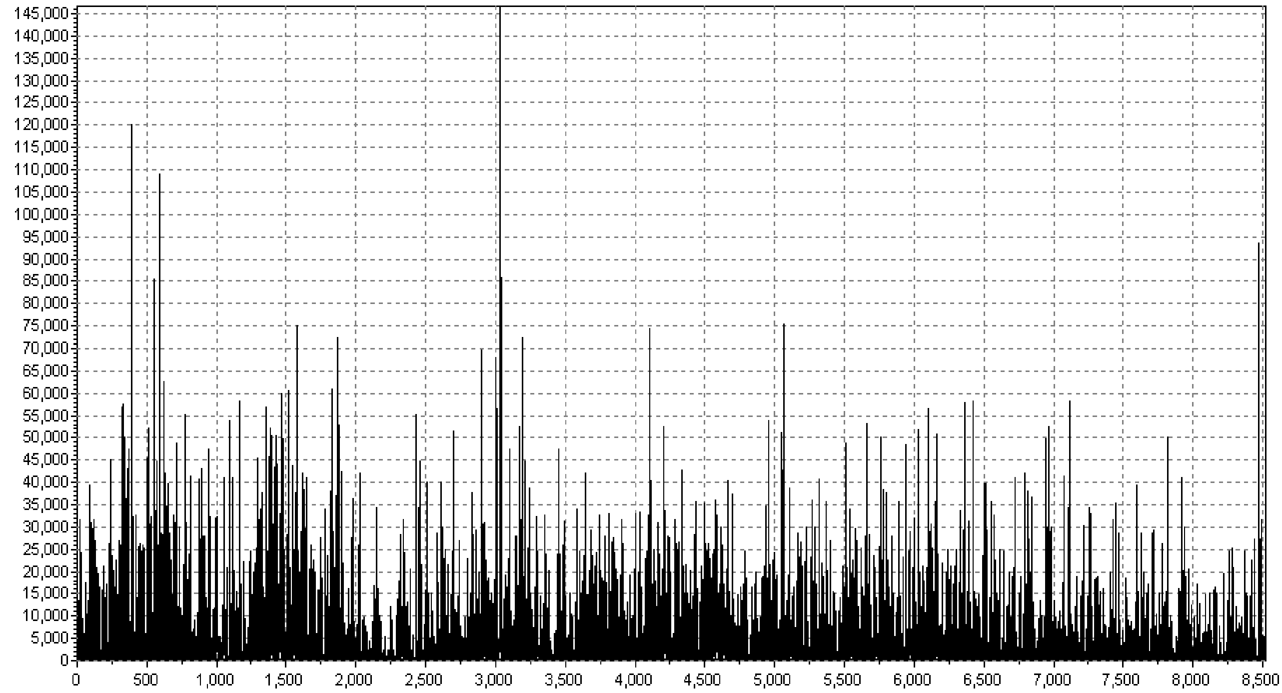

Figure 1 - The model of sold shares

Correlation dimension:

Correlation coefficient for short is a measure of the degree of linear relationship between two variables. We calculated the correlation size of this time sequence, which includes the minimum number of space dimensions that includes the trajectories[Markov, 2009].

With increasing embedding dimension, correlation dimension increases. However, for a deterministic system, no matter how chaotic it seems the correlation dimension sequence stops growing after reaching a certain dimension. If we observe the saturation at the sertain level, we can take this dimension as the estimate of the correlation dimension of attractor. For random data such saturation is not observed and the correlation dimension increases monotone [Kantz, Schreiber]. Correlation dimension $C(\varepsilon)$ is calculated using the following formula (1):

$$C(\varepsilon) = Lim_{n \longrightarrow \infty} \frac{1}{N^2} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} \theta(\varepsilon - \left\| x(i) - x(j) \right\|), x(i) \in R^m \quad (1)$$

where ε is the threshold distance, $\|x(i) - x(j)\|$ is a norm (Euclid norm), θ is the function of Heaviside, R^m is Euclid multiplicity, N is the number of the observations, n is set of points in an m-dimensional space. The correlation integral helps to calculate the correlation dimension. In chaos theory, the correlation integral means the probability that two variables at different time intervals would have similar values (2):

$$C(\varepsilon) = Lim \frac{1}{N^2} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} \theta(\varepsilon - \| x(i) - x(j) \|), x(i) \in R^m \tag{2}$$

In this sample it has the value 4.19. According to the figure (2), at the last iteration the correlation size starts to decrease and it means that the behavior of the function isn't occasional and is subordinated by certain parameters' principles.

It can show the change of the sold activity during the day, month or season. Depending on the size of the resulting values of the correlation dimension, all graphics can be divided into two types, reflecting the degree of presence of deterministic chaos in the term structure: the cycles of the chaotic dynamics of the average dimension (C ≤ 6); the cycles of the chaotic dynamics of high dimension (P> 6).

For the sales of "Centrenergo" correlation size is in the middle dimension [Kuusela, Jartti, Tahvanainen].

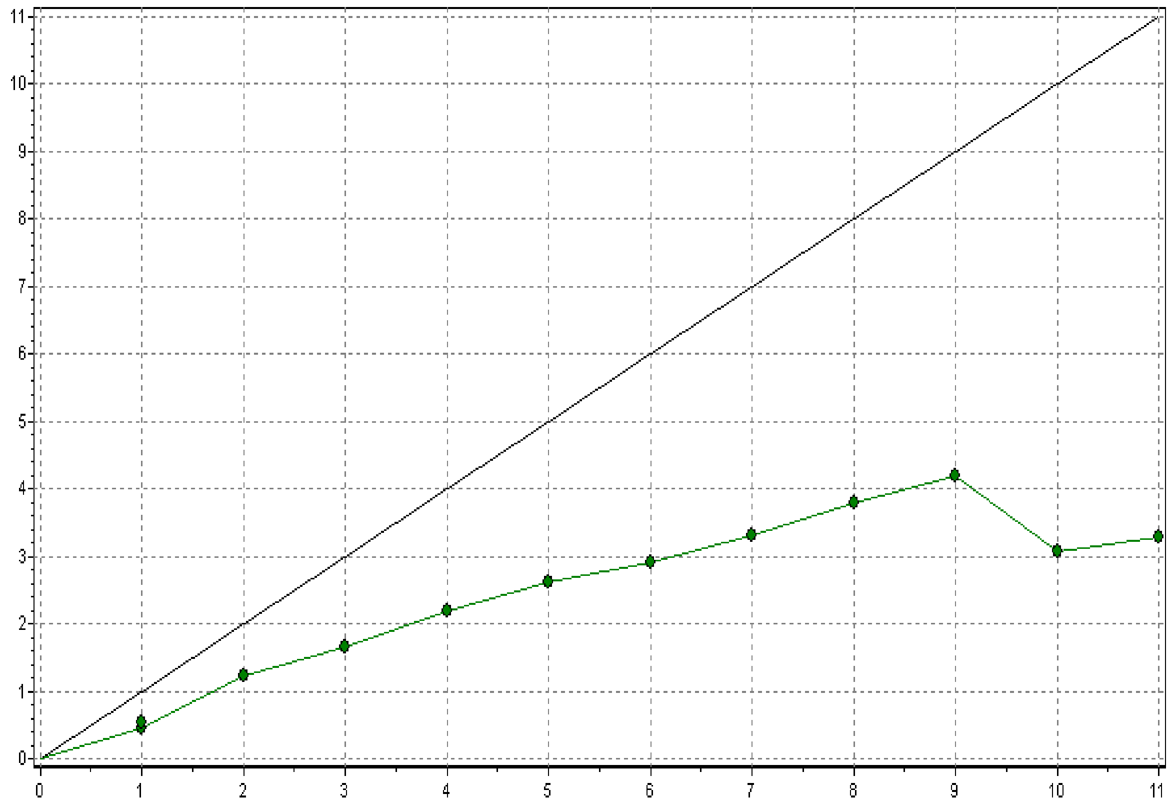

Figure 2 – The correlation size behavior

Correlation dimension can be used to assign a sample to a specific group depending on the presence of random processes, or to evaluate possible changes in the structure of sales of the company as it develops.

Correlation entropy:

We found out the correlation entropy that showed the degree of the recession of the near phase trajectories and allows measuring the amount of information necessary to forecast the behavior of this function in the future [Markov, 2009]. The correlation entropy $H(x)$ can be calculated by the following formula (3):

$$H(x) = -\sum_{k=1}^{m} w(x_k)\Delta x Log\{w(x_k)\Delta x\} \quad (3)$$

where $w(x_k)$ is probability density of the quantized continuous quantity, $\Delta(x)$ is chosen interval. According to the following figure (3) we found out the minimal value of the line, thus, for this research the correlation entropy is 3.8 and it means that the optimal time of function's stability is 3.8 minutes:

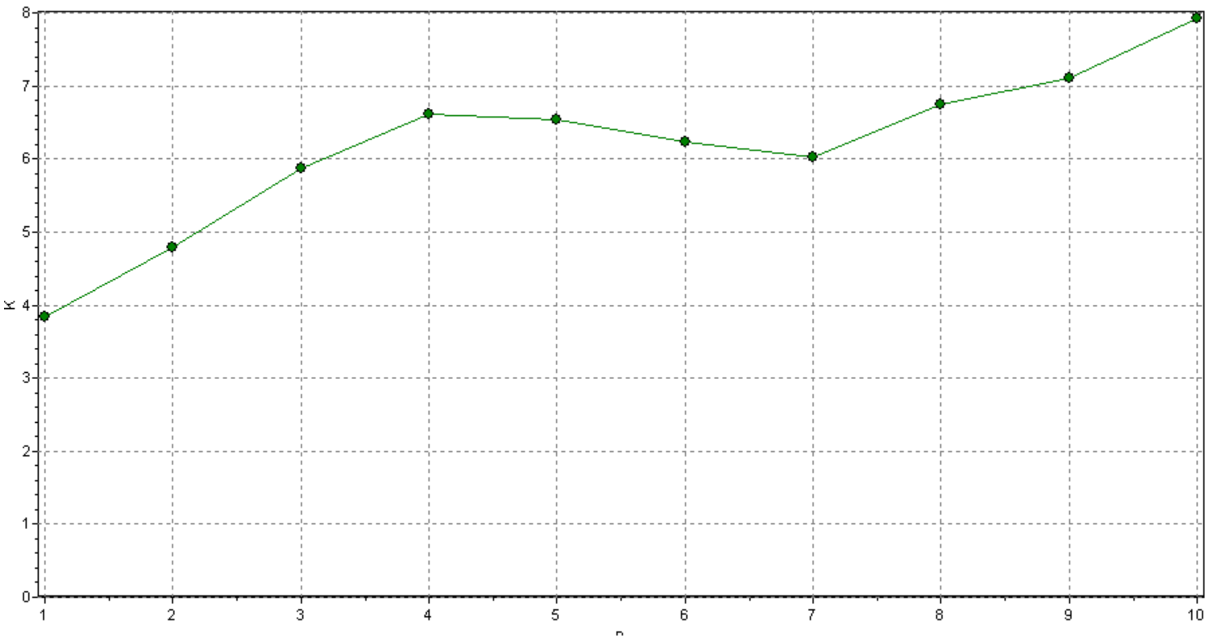

Figure 3 - Correlation entropy

The auto correlation function:

In statistics the auto correlation function shows the correlation dependence between the volumes of sales of the series with different time lag [Markov, 2008].

The autocorrelation function $R(t,s)$ can be calculated by the following formula (4):

$$R(t,s) = \frac{E[(x_t - \mu_t)(x_s - \mu_s)]}{\sigma_t \sigma_s} \quad (4)$$

where E is the expected value operator; X is the value produced by a given run of this function at time t or S; μ is correlation and σ is dispersion [Markov, 2008]. According to the received result, the largest point of the auto correlation function is achieved at the three-four values, and it tells that the inertness of the current sales time is saved for three-four minutes.

The Hurst value:

It shows the trendiness or persistence of row numeric incomes. Basically, this method is used to identify when a value is persistence i.e. the tendency of the value to continue its current direction and also antipersistence i.e. the tendency of the value to reverse itself rather than to continue its current direction. Or it is random and unpredictable. The statistic graphic can be used to estimate the cycle length. With the help of these calculations we can find out how many cycles has the value for a definite period. The Hurst calculations were made according to the formula from the work of Albert Einstein about Brownian motion of particles. According to these calculations

Brownian particle moves a distance equal to the square root of time spent on this promotion. If H=0.5 the system passes the same distance as the Brownian particle, during the time T. If T has the value more than 0.5, the system passes over a greater distance during the same period T as a Brownian particle. The calculation of the Hurst value H could be done according to the next formula (5):

$$H = \frac{Log(R/S)}{Log(aN)} \tag{5}$$

where H - the Hurst exponent; S - standard deviation of a set of observations; R - amplitude of the accumulated deviation; N - number of observation periods; a - a given constant, positive number (Hurst calculated this exponent constant empirically for a relatively short time series of natural phenomena as 0.5).

The following picture shows time dependence of the normalized value in a double logarithmic scale and its linear approximation. The slope coefficient of the approximating line at this picture is the Hurst value [Markov, 2008].

The Hurst value of this interval is 0.71 and it lies at the (0.5, 1] interval. It means that this row is trendiness and it means that the next value would have the same sign as the previous (figure 5).

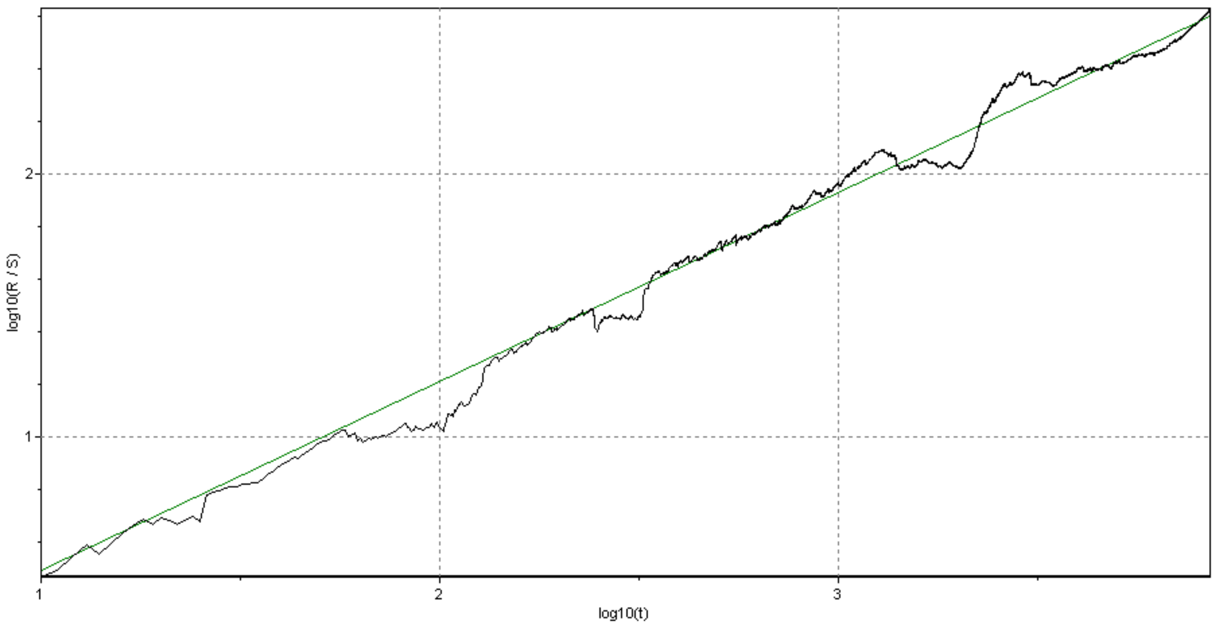

Figure 5 - The Hurst value

Investment planning starts at the top of the organization with strategic planning, which includes the analyses of the different goods and stocks. In order to assess the situation, we can look at past histories of the similar operations or projects and various factors that influence the future situation. The analyses of the data of company "Centrenergo" helped to identify useful information.

We found out the correlation dimension and with the help of that we found the probability that two variables at different time intervals would have similar values. This function of sold shares has the cycles of the chaotic dynamics of the average dimension (C ≤ 6). Thus, we found out the information that would help to build the investment forecast with the help of cycles. The correlation entropy of our function is 3.8 and it means that the optimal time of function’s stability is 3.8 minutes. It would help to consider the risks, during the market analysis that takes into account the function of sales of company”Centrenergo".

We found out the the inertness of the current sales time and it can be used to build some kind of forecast for this function with certain probability. As distancing from the inertness time, the risk of deviation from the real function increases. With the help of the auto correlation function we could compare many pairs of cycles and models and search the interdependence. Comparison of models, finding out the interdependence and identification of the similar or reverse regions on the graphics of models constitute some important aspects of model validation that deserve serious study.

The Hurst value is the global characteristic, which shows the connection between the next increment and the previous increments, consisting in the fact that if the value of the function increased, the density distribution of the next increment is biased towards growth. These values also help to consider the risk.

With the help of all these characteristics we can make the recognition of the graphic view of the model and carry them for the sample comparison. It can be done by scaling of the image and splitting the image into pieces with different coefficients. But during the modification process of the of the sample model, its inner part should remain changeless.

With the help of Brownian motion method we can create a unique trade system, which would handle the data from different data bases and recourses and it would help to minimize risks and make reasonable decisions.

Conclusion

Every investment involves some degree of risk, but a solid understanding of risk in its different forms can help investors to understand better the opportunities, trade-offs and costs involved with different investment approaches. Described in this work the analysis method of statistic data for building the investment forecast with the help of Brownian motion model can be used to measure the risk during the planning of the investment activities, at the market alone or with complex of other methods, and can be faster and more accurate than the traditional existing ones. With the features described above, the model allows one to determine risk and quantify and optimize investment opportunities in different manners and categories. The cognitive power of these calculations is that they help to order and divide the analysed investment proccesses by their chaotic values and complexity, and, thus, classify and systematize them. It would help to determine, more accurately, the investment horizons, to develop the action strategy with the risk minimization and identify some features of the market as a whole.

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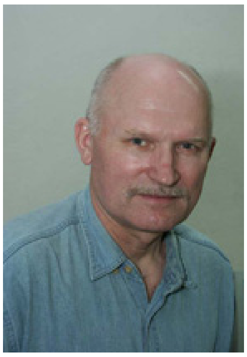

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APPLICATION OF THE UNIVERSE THEORY: MODERN GLOBALIZATION IS PROGRESSIVE BUT UNFAIR AND PROBLEM WORLD SYSTEM THE MANIFESTO OF THE NEW WORLD ORDER

Alexander V. Sosnitsky

Abstract: *For the first time the properties of World human Globalization are deduced in the paper from the most general concepts of our Universe and they are presented in the form of the Universal Model. It is shown in a formal way that modern Globalization is a progressive, but unfair and problematic, world system that naturally leads to local and global cataclysms, which take place in the modern World. The approach is offered to a formal solution of problems of Civilization by means of absolutization of human activity by application of absolutizings methods which can be well created by further development of the Universe Theory. This paper is a formal ground for the World Globalism/Antiglobalism in correlation of the existing Harmony/disHarmony of the modern Humanity and, in fact, offers a new World Order of organization of our Civilizations.*

Keywords: *the World Globalization, the Universe Model, the Absolute Model, the SuperLow of Harmony, the new World Order.*

ACM Classification Keywords*: H.0 Information systems – General*

Global Worning

World Globalization is the most important harmonizing historical phenomenon that consistently improves Mankind and, therefore, on the whole is approved and supported by it. Today Globalization has reached a planetary scale.

However, it is known in exact Sciences that any basic change (the so-called phase transition) in any system always generates new qualities which are often unforeseen and do not fully correspond to initial expectations because more adequate theories of such transitions are created much later, especially for the systems of unprecedented size and complexity, which is modern Mankind. Therefore, subjective estimate of various kinds of experts are usually applied instead of them.

As a result of that, big public events are often far from being "locomotives of history" according to K. Marx, and more often lead to World shocks and sufferings of the great mass of people, throwing Mankind further back from even the noblest goals.

If the past history still tolerated that somehow, the modern society is becoming increasingly similar to a "crystal castle", a kind of fine craftsmanship that is poorly protected from any even unconscious damage and exists mainly with good intentions of all its inhabitants. It especially concerns non-material, spiritual and intellectual values that make the basis of civilization and can be easily destroyed by any rough influence with disastrous consequences.

In fact, the history of Mankind is a sequence of 1) local Globalizations in the form of states and 2) continental Globalizations in the form of empires accompanied by continuous military, political, economic, cultural, ideological and other conflicts. Today it finishes 3) with World Globalization and we can only guess where it will actually lead.

The last such conflicts are:

- social disaster of the post-Soviet East European peoples integrated into the World system who are quite reasonably suspicious of further integration offers;
- the EU crisis with threatening default of constantly growing well-known number of its members;
- growing crisis of a leading World superpower, the USA;
- continuous illegal wars of the strong states against the weak ones;
- World terrorism;
- World opposition of states with the threat of mass destruction;
- dangerous spread of obsolete destabilizing ideologies of World leaders and many other things.

As a result of that, together with the general accelerating progress, the World history usually contains temporary falls of its members in the form of cyclic sawtooth processes, during which the intervals of consecutive growth are naturally changed into a sharp decline (slowdown – in the best case) in the level of processes, which generates multiple complex secondary internal uncontrollable conflicts (Fig. 1). It concerns both global system and its each member. At the same time, on the whole Globalization plays a useful role of the stabilizing environment for all the participants, allowing and stimulating restoration of temporary fallen participants per sample of successful members.

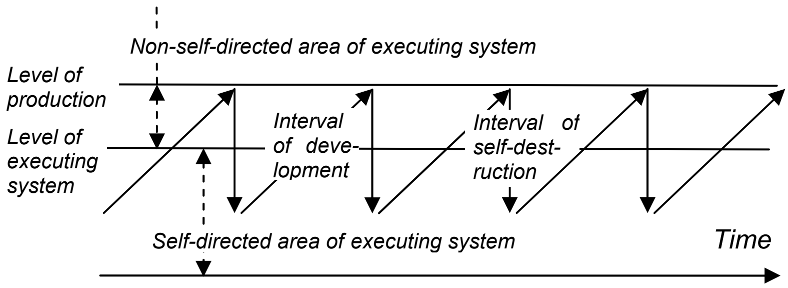

Figure 1. General Scheme of disHarmonization of a Historical Process Participant

Exceeding the level of production activity over the level of the manufacturer (a participant of the global system) is the basic mechanism of fall, which we are going to explain in the following way. Every entity is, in fact, the system of concepts. Manufacturers always have to improve their product, and consequently forcedly develop themselves. But as long as their aim is mainly directed at a product, the system of concepts of the product usually exceeds the system of concepts of the manufacturer, and the difference between them becomes invisible to the executor because of the subsystem of higher stealth concepts (phantom concepts) that turn out to be uncontrollable and destroy the executor, returning it down to the self-directed level, from which the development begins again.

It is under such a scheme of internal dogmatism that the map of the states was redrawn, all the greatest empires up to the USSR have fallen to pieces and the modern empires have been unsteady for the main reason of self-insufficiency. The time has come to admit with all the responsibility that all the past and modern problems are not just simple side effects of history, accidental coincidence of reparable factors or results of skilful game of certain secret forces, but the display of the latent real unknown powerful uncontrollable laws in force.

Mankind is obliged to cognize its laws and take new global measures similar to the decisions after the Second World War and to establish a new World order corresponding to the global phase of Mankind development. And uncontrollable global "games" inside the "crystal castle" do not bring anything good to all its participants similar to criminal thoughtless experiments with the Chernobyl nuclear reactor.

What to Do?

A well-known remark of fairy-tale baron Munchausen goes that the silliest things in the World are done with a serious expression on the face. It clearly defines the insufficient condition of modern political Science. With all due respect, it should be noted that as a result of the unacceptable high price of political imperfection of outstanding historical persons, the modern epoch demands more exact formal global estimates and calculations that are unattainable by a manual political method.

The problem is that modern Science is unable to provide such an accuracy as it is focused on inanimate Nature and, in fact, is not capable of processing infinitely more complex animate Nature, to which Mankind belongs.

However, some essentially new scientific works appeared recently, allowing to estimate and calculate complex World phenomena on the basis of the Universal Theory that claim to be a new scientific standard, and for the first time this Theory allows to investigate many actual problems [Sosnitsky, 2008 - 2011]. In the given paper this Theory is applied to the phenomena of Globalization, and the results are published for the wide range of experts common people.

Initial Concepts

Our Universe is a full set of entities that are related, directly or indirectly. It has an initial structure in the form of the observable Real World (RW) that is ruled by the invisible Abstract World (AW) (Fig. 2). The entities of the Real World are phenomena. The entities of the Abstract World are abstracts (concepts, categories) built in the phenomena of the Real World. They are invisible but effective, and they are widely applied in thinking as words, sentences, texts, formulas, laws, models, theories, etc. At first all problems are abstracted, and then they are realized.

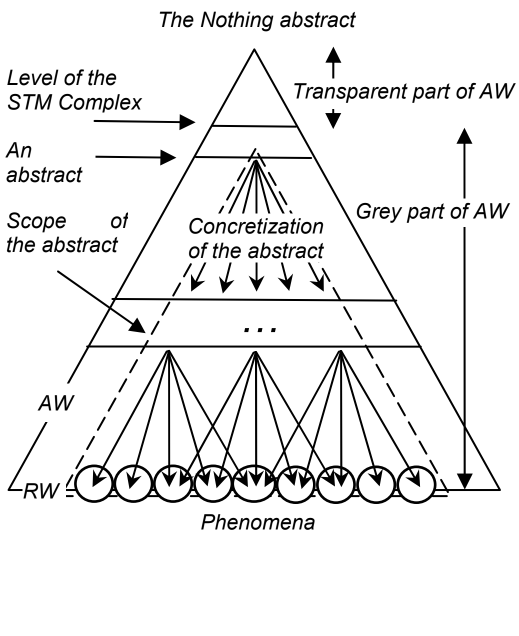

Figure 2. The General Scheme of the Universe

The Abstract World divides into layers (subWorlds) so each subWorld comes from the previous one beginning with the initial Nothing abstract, consideration of which lies beyond the scope of our investigation. At a certain abstract level there arise three common abstracts (Complexes) that are present in each derivative entity (Fig. 3): Space, Time and Matter (together – the STM Complex). Space is a regular constant, Time – a regular variable, and Matter – an irregular part of the Universe. Space and Matter are infinite, and Time is finite having the Beginning and the End and it is divided into the Past, Present and Future. Entities change only in the point of the Present, moving from the Past into the Future.

Entities below the STM Complex have the form of a time process which 1) begins from the definition (initial concept) of an entity, 2) continues with the cone of development, 3) comes to an end with the cone of degradation and 4) disintegrates (the definition is destroyed) with the generation of derivative more harmonious processes (Fig. 3).

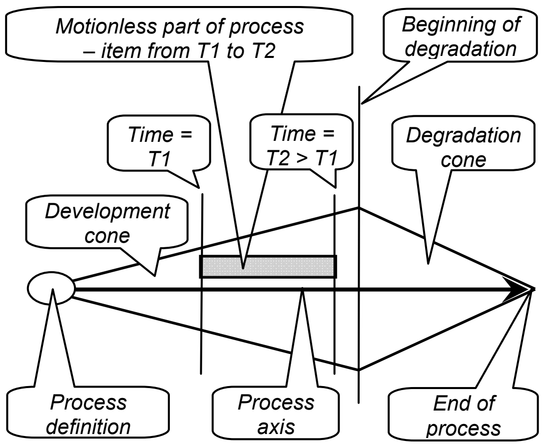

Figure 3. The General Scheme of a Process

Connectivity of the Universe

All the entities (abstract and real) are directly or indirectly interrelated and come from one another. Each entity has an origin, current condition and continuation. An entity is a certain set of relations that is singled out by a certain relation as a coherent whole. Relation (existence) is a copy of one entity (object) in the other entity (subject). Property (quality) is a structure of relations of entities. In general, entities participate in many incoming and outgoing external relations (Fig. 4). We should note that all the components (including their subjective copies) have their own abstract superstructures.

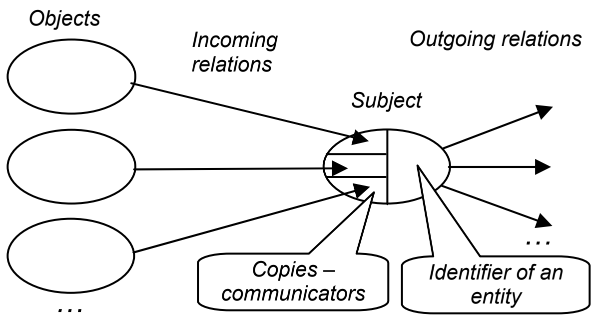

Figure 4. The External Scheme of an Entity

Entities have an internal structure. Below the STM Complex (up to the phenomena) they contain eight classes of components (Fig. 5): 1 – 3) the STM Complex, 4) enclosed entities, 5) internal relations, 6) movement, 7) laws and 8) the purpose.

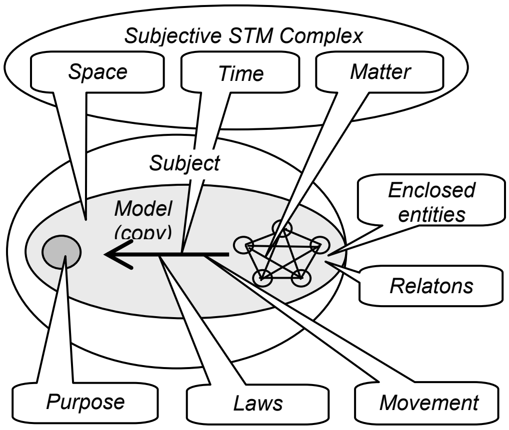

Figure 5. The Internal Scheme of an Entity

Harmony of the Universe

Harmonicity is an ability of each entity to form and develop every possible relation (copies of other entities) according to the supreme SuperLaw of the Universe: each entity represented by itself desires to reach the condition of maximum Harmony, which is approximately understood as the quantity of constant relations of an entity. This condition is determined by the purpose of an entity, which is (in general case a deformed and inexact) projection of the SuperLaw on the level of an entity through some other indirect entities.

As in general case relations are mobile, Harmony also moves together with them as a certain Universe property having qualitative and quantitative measurements and capable of formalization.

According to the SuperLaw the Universe has a divided Time with an admissible (that is real) movement, and consequently (also real) harmonization only in the point of the Present. However, it is possible to expand harmonization area at the expense of bilateral virtual relations of the Present with the Past and Future under the scheme in Fig. 6.

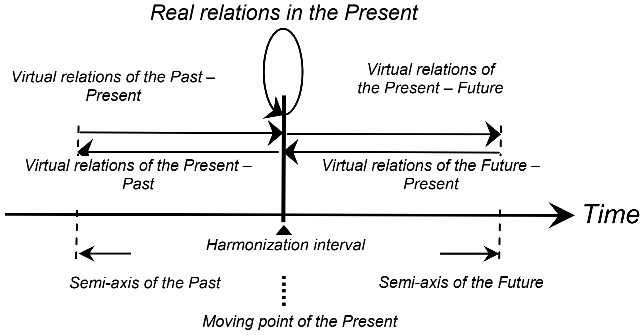

Figure 6. The Scheme of Time Virtualization

Virtual copies are the copies of real relations in the moving Present 1) before their leaving for the Past and 2) while forecasting the Future with 3) the subsequent realization again in the current Present. By means of virtualization it becomes possible to harmonize a greater volume of relations (on an interval of Time instead of one point of the Present), by which the advantage of animate entities over inanimate ones is conditioned.

Depending on the degree of virtualization of the Time axis there appear the following first three classes of entities (five in total) (Fig. 7).

1. Thermodynamic entities. The internal structure does not participate in the movement. The mutual relations of entities are only real in a moving point of the Present.
2. Mechanical entities. The internal structure simply participates in the movement. In addition to item 1, these virtual mutual relations of the Past − Present and the Present – Past are added.
3. Animate entities. The internal structure contains a subjective analogue (copy) of the STM Complex. In addition to item 2, these virtual mutual relations of the Present − Future and the Future − Present are added.

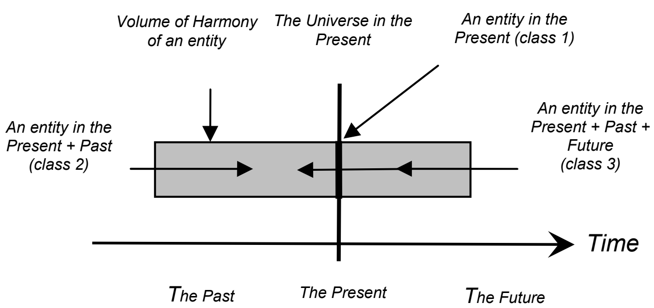

Figure 7. The Scheme of Harmonious Classification of Entities in Time

Animate entities as the most developed in this classification possess a larger volume, quality and accuracy of copying of external entities and, as a consequence, the highest harmonizing ability. The Harmony of inanimate entities (classes 1 − 2) has 1) a limited form of a 2) thermal and 3) mechanical movement, 4) self-destructing such entities and 5) moves from the entities with bigger harmonious potential to the entities with smaller one. The Harmony of class 3 has 6) a full-fledged form 7) developing animate beings. Figuratively speaking, if in primitive entities the harmonious potential moves from more harmonious (warm) to less harmonious (cold) entities, then in the higher entities Harmony it actively moves back to a more harmonious side from less harmonious to more harmonious entities (or rather in the direction of its subjective purpose).

Absoluteness of the Universe

The Universe is a certain uniform and unique Absolute (original) generating multiple partial copies in the form of entities and forming all the variety of the Universe (Fig. 8). The closer entities are to the Absolute, the higher its degree of Harmony is, and their existence is greater and vice versa. Thus, the Absolute is the superior truth of all the things.

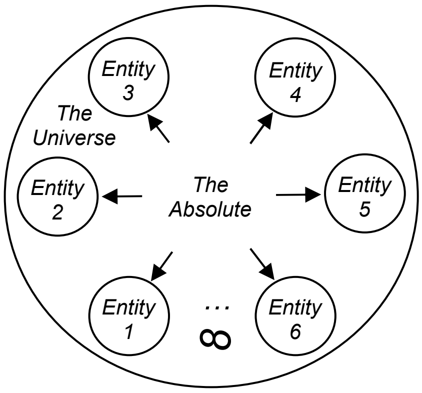

Figure 7. The Scheme of the Absolute

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The abstracts above the STM Complex are motionless and absolute, but abstracts below up to the phenomena of the Real World are mobile and diverge from the Absolute. The purpose of all the entities is the movement to the Absolute that possesses the greatest Harmony. The always non-negative difference between them (Relative disHarmony) is the source of disHarmony of an entity, and the disHarmony takes multiple forms (Fig. 8):

Relative disHarmony (Entity) = Absolute Harmony (Entity) – Real Harmony (Entity) ≥ 0

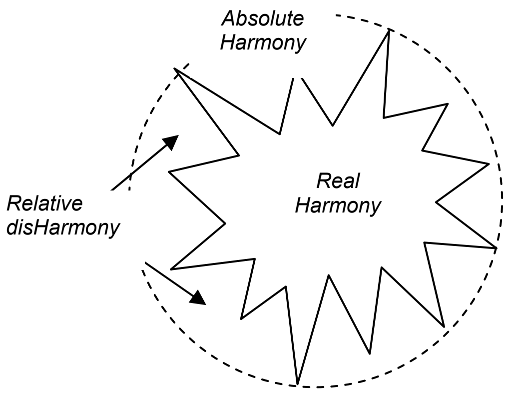

Figure 8. The Scheme of Relative disHarmony of an Entity

Absolute Harmony is a maximum Harmony that always exists for each entity in each situation. Hypothetically it always ensures unproblematic development of any entity. But current Harmony of phenomena is real, non-absolute and it changes in Time. Having achieved in Time the state of absolute Harmony, any disHarmony disappears. And, on the contrary, any incomplete use of Harmony leads to disharmonic phenomena up to the self-destruction of entities.

The Globalization Phenomenon

Globalization is a process of joint harmonization of external relations of several entities. Globalization strengthens (both external and internal) the existence of a global entity (system, network, net) that is being formed, which is, according to the SuperLaw, a natural progressive phenomenon (Fig. 9).

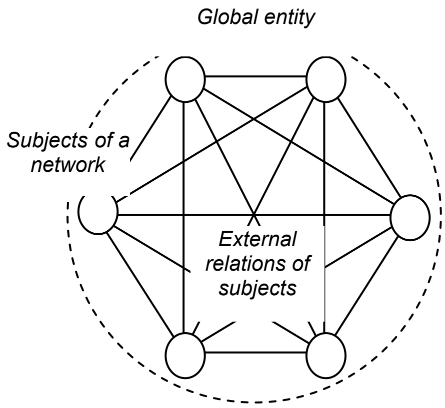

Figure 9. The Scheme of Globalization of Entities

Globalization develops in two directions: 1) the increase in number of network members (dimension increase) and 2) the increase in number of relations among them (increase in network complexity).

The first tendency gets involved in Globalization the largest number of members within the limits of natural obstacles (a family, a team, a state, a continent, a planet, etc.) that consistently reduces the number of alternative members and sterilizes the network developing only the (compatible) properties that are harmonized.

The second tendency increases availability and strengthens sterilization even more through the acceleration of movement of copies (abstract and real), for example, raw materials, goods, money, people, ideas, information, etc.

Harmony moves with copies. In case of inanimate movement Harmony spreads from more organized to less organized entities, and in case of animate – to the opposite direction together with disharmonization of lower entities of the network. Competing counter flows of Harmony arise in this way. Animate Harmony is more active and suppresses inanimate Harmony by the actual replacement of lower entities for higher ones. For example, this is the reason for domination of Mankind on Earth.

It is possible to show that every entity is combinatorially formed from orthogonal (polar) qualities and the loss of each of them owing to sterilization stops further development and blocks the transition from local to global harmonization. It contradicts the SuperLaw and has disastrous consequences for Globalization, which is one of the reasons for destruction of the Universe processes.

Thus, for example, 1) some peoples, that seemed to have "hidden" from shocks of Civilization, have disappeared, 2) the other peoples have unusually blossomed having apparently suffered fatal blows, 3) and the later have gone through the stage of stagnation in the process of exhaustion of their polar variety, and 4) the peoples with a heavy genetic burden of seemingly unnecessary orthodox qualities paid by the additional expenses of Harmony turned out to be viable.

And one more example. Let us assume that someone in a certain network has launched a certain top product. Thanks to Globalization the product quickly spreads over a network and supersedes other products of this kind, which makes their manufacturers bankrupt, though their backlog is temporary and they can make even a better product in the future. The reduction of variety in the network stops mutations and synthesis of new products. The network stagnates and is destroyed by the external competing networks taking its field of action. The quality of a global competition decreases.

Subject Purpose Classification

But the Universe is thus arranged that giving rise to a problem it always has ways of its solving. The only thing to do is to find and apply them. The highest Methodology of solution is the SuperLaw revealing and activating latent resources of problem harmonization, and then it is naturally solved. Harmonization of purposes of subjects of Globalization defining the properties of a network in general is such an important resource.

The forms of the purpose of subjects are naturally classified (from simple to complex) as follows.

1. Egoism. The purpose of the subject is inside it (harmonization of itself) (Fig. 10). Subjects interact with all the partners, but for their own benefit. Properties of the network: leaders exploit, monopolize and sterilize the network with subsequent stagnation and degradation up to the destruction from the outside.
2. Altruism. The purpose of the subject is outside it (harmonization of other (one, several, all) subjects) (Fig. 11). Properties of the network: altruists harmonize other subjects who they know worse than themselves owing to their divided nature. Direct harmonization is replaced by a less steady indirect collective harmonization. There arises multiple duplication of harmonious functions.

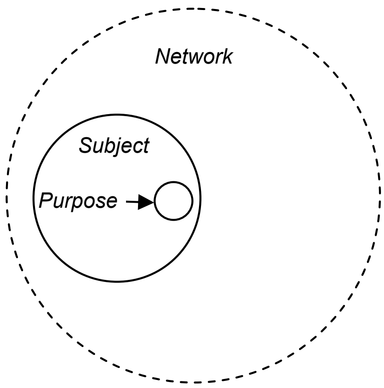

Figure 10. The Scheme of Egoism

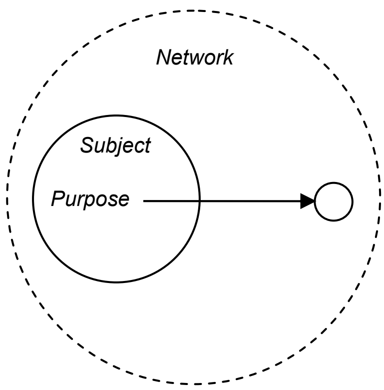

Figure 11. The Scheme of Altruism3.

3. Collectivism. The purpose of the subject is the entire network, including itself (Fig. 12). Properties of the network: joint direct and indirect harmonization of subjects is supported, the degree of harmonization and internal stability of the network increases. Collectivists duplicate functions of harmonization of other subjects.

4. Centralism. The purpose of the subject is the entire network, including itself with the elimination of duplication of functions by the appointment of central subjects (Fig. 13). Properties of the network: compactness, but high requirements of reliability of central subjects.

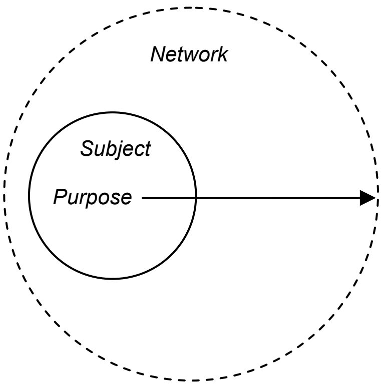

Figure 12. The Scheme of Collectivism

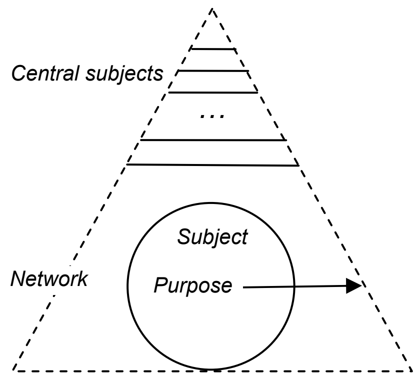

Figure 13. The Scheme of Centralism

Each class has subclasses of gradation of purposes which we are going to consider for the form of Egoism:

1.1. Aggression. The purpose of the subject is directed at degradation of other subjects. Properties of the network: the network self-destructs.

1.2. Exploitation. The purpose of the subject is directed at appropriation of a part of Harmony of other subjects under conditions of limited harmonious resources. Properties of the network: the network stagnates.

1.3. Greed. The purpose of the subject is directed at appropriation of a part of Harmony of other subjects under conditions of unlimited harmonious resources. Properties of the network: the network develops.

Real networks usually have complex combinations of all the polar forms of purposes.

The World Globalization

For the first time the universal analysis allows to deduce formally basic properties of the World human Globalization.

World Globalization is the most complicated historical, ethnic and geographical formation coming from many cultural centers, including West European ones and deeper from Scandinavian and Mediterranean roots going through the Roman, Greek, Trojan and Judaic branches to Mesopotamia and the sources of a human Civilization.

Taking the wild origin of Mankind, continuous wars and conflicts in the course of its development up to the present day into consideration, we come to a well-substantiated conclusion on an inborn combination of two competing beginnings in modern Civilization – the Universe Harmony and Humanity Egoism in aggressive forms. If someone does not like any historical sources and facts, it is quite possible to take many others confirming the same.

The origin from Egoism remains the main problem of modern World Globalization which with all good intentions is objectively estimated as progressive, but it is mainly unfair, thievish, dangerous, totalitarian and problem system, in which some well-known groups of states with different properties of purposes that are developed from the above-mentioned forms. Inside and outside of these groups some harmonious leading states have distinctly singled out, egoistically exploiting and sterilizing other less developed states.

Owing to the SuperLaw operation, the World system is successfully developing and backward states and groups are gradually catching up with the leaders, but it does not guarantee achievement of full parity and happens with considerable misunderstanding, with which not many of the participants agree, which generates various interstate and domestic problems and cataclysms.

Moreover, World injustice is quite consciously and even officially, in fact, fixed in modern political, economic and social culture and is a hidden task of human Globalization. Such a conclusion is reached not for first time under the well-established World system, but it is drawn for the first time by a formal way from the Universe Theory, which is very important.

At the same time, all the participants of World Globalization have their own inherent injustice, and maybe the leaders have it to a lesser degree as they are more harmonized and closer to absoluteness, and backward states have it to a greater degree as they are less harmonized and distant from absoluteness. For example, the latter use mostly free of charge and do not completely compensate leaders for their progressive technological advances, which is disputable to provide, owing to the usual abstract non-material nature of values, which are the most important, invisible, difficult to estimate and obtain and easily copied. In answer the leaders by the right of the strong return their fair (as it seems to them) share (usually larger) in the material form and strengthen Egoism even more.

The number of such problems is infinite, and they are both obvious and latent inside our Civilization changing one another as far as Civilization develops. According to the SuperLaw, all these problems should be gradually solved, but it is difficult and dangerous in our constantly becoming more and more complex "crystal" time with badly predicted risks, hampering Civilization.

It is obvious that the global solving of the problem of World Globalization consists in the creation of specifying techniques of absolutization of development trajectories of all its participants which undoubtedly exist within the framework of the harmonious Theory of the Universe, and realization of these trajectories by means of a specialized World Service, which, in fact, means a new World Order of our Civilization, to which there is no alternative. Such methodologies can be well created by further development of the Universe Theory.

This paper is a formal ground for the World Globalism/Antiglobalism in correlation of the existing Harmony/disHarmony of modern Humanity.

Conclusion

1. For the first time the properties of World human Globalization are deduced in the paper from the most general concepts of our Universe and they are presented in the form of the Universal Model.
2. It is shown in a formal way that modern Globalization is a progressive, but unfair and problematic, World system that naturally leads to local and global cataclysms, which take place in the modern World.

3. The approach is offered to a formal solution of problems of Civilization by means of absolutization of human activity by application of absolutizings methods which can be well created by further development of the Universe Theory.

4. This paper is a formal ground for the World Globalism/Antiglobalism in correlation of the existing Harmony/disHarmony of the modern Humanity. In fact, it offers a new World Order of organization of our Civilizations.

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Major Fields of Scientific Research: Absolute Theories of the Universe, Reform of Science, Scientific Methodologies and Education, Artificial Intelligence

TREND, DECOMPOSITION AND COMBINED APPROACHES OF TIME SERIES FORECASTING BASED ON THE “CATERPILLAR”-SSA METHOD

Vitalii Shchelkalin

***Abstract**: In presented paper mathematical models and methods based on joint applying ideas of the “Caterpillar”-SSA and Box-Jenkins methods are produced. This combination of models lead to a synergy and mutually compensate the opposite by nature shortcomings of each models separately and increases the accuracy and stability of the model. The further development of technique for models constructing, technique of Box-Jenkins, and improvement of themselves autoregressive integrated moving average (ARIMA) models, designed about forty years ago and remaining in present time as one of the most efficient models for modeling, forecasting and control exceeding their own rivals on whole row of criterions such as: economy on parameters quantity, labour content of models building algorithm and resource-density of their realization, on formalization and automation of models construction is produced. A novel autoregressive spectrally integrated moving average (ARSIMA) model which describes a wider class of processes in contrast to the Box-Jenkins models is developed. Decomposition and combined forecasting methods based on “Caterpillar”-SSA method for modeling and forecasting of time series is developed. The essence of the proposed decomposition forecasting method and combined forecasting method consist in decomposing of time series (exogenous and predicted) by the “Caterpillar”-SSA method on the components, which in turn can be decomposed into components with a more simpler structure for identification, in selection from any of these components of constructive and dropping the destructive components, and in identification of those constructive components that are proactive on the propagated time series, or vice versa if its delay interval is less than the required preemption interval of forecasting, mathematical models with the most appropriate structure (in the combined approach) or its ARIMAX models (in decomposition approach) models and calculation of their predictions to the required lead time, to use the obtained models, or as a comb filter (in the case of signals modeling), or as an ensemble of models, setting the inputs of MISO model or used as a component of the combined mathematical model whose parameters are adjusted to further cooptimization method. In such models as inputs can be also include the instantaneous amplitudes, obtained after applying the Hilbert transform to the components of the expansions. The advantages of the proposed methods for models of the processes constructing is its rigorous formalization and, therefore, the possibility of complete automation of all stages of construction and usage of the models.*

***Keywords**: modeling, filtering, forecasting, control, "Caterpillar"-SSA method, ARIMA model, "Caterpillar"-SSA – ARIMA – SIGARCH method, ARSIMA model, ARSIMA – SIGARCH model, heteroskedasticity, Levenberg-Marquardt method, Davidon–Fletcher–Powell method, decomposition forecasting method, combined forecasting methods, Hilbert transform.*

Introduction

To this time a large amount of mathematical models and methods of time series analysis and forecasting is created and it is trend to combining mathematical models in order to obtain the best characteristics of the final models in the sense of formation and the translation of some of the theoretical developments of some methods to other methods where it is can be possible and appropriate. In this paper the synthesis of mathematical models based on the joint usage of ideas of two methods, to each of which individually skeptically pertain many specialists from area of forecasting, but sufficiently well grounded in theory is produced. The first method - a deterministic method for different types of analysis and forecasting has not been entered yet into the standard mathematical packages – a "Caterpillar"-SSA method. The second – a statistical method – a Box Jenkins method. The proposed models realize trended approach, which is concluded in modeling of the process as deflections of actual values relatively to the trend component and lead to synergies, mutually compensating of opposite in nature shortcomings of models which their forming.

The development of the methods of mathematical modeling, forecast and control is determined by the degree of mathematical description of processes, phenomena and objects taking place in various branches of science and technology, taking into account both the mathematical and technical advantages and achievements and shortcomings and limitations, as well as the quality and volume of the sample data and resource constraints, including the temporal of formation an adequate mathematical model of the process.

A general class of multivariate polynomial multiply stochastic models

Polynomial models can adequately describe an extremely wide class of multidimensional multiply stochastic systems and processes and to solve on their basis the tasks of modeling, forecasting and control. A general class of multivariate polynomial multiply stochastic models is presented below.

A general class of multivariate polynomial multiply stochastic models for the system having r exogenous variables, m outputs and m noises can be represented as:

$$F(q)\cdot Y(k)=\sum_{i=1}^{N}\frac{B_i(q)}{A_i(q)}\cdot\Theta_{X_i}\cdot X_i(k)+\frac{C'(q)}{D'(q)}\cdot W(k) \tag{1}$$

or

$$Y(k)=\sum_{i=1}^{N}P_i(q)\cdot X_i(k)+R(q)\cdot W(k),$$

where q - or backshift operator such that $q^i X(k)=X(k-i)$, here the time in parentheses; $Y(k)$, $X(k)$, $k=\overline{0,n-1}$ - centered multivariate time series; $P_i(q)=\frac{B_i(q)}{A_i(q)}\cdot\Theta_{X_i}$ – the models of transfer functions; $R(q)=\frac{C'(q)}{F(q)\cdot D'(q)}$, $R(q)\cdot W(q)$ – additive noise model in the form of moving average; $C'(q)=C^1_{q_1}\left(q^{s_1}\right)\cdot C^2_{q_2}\left(q^{s_2}\right)\cdot\ldots\cdot C^1_{q_n}\left(q^{s_n}\right)=\prod_{i=1}^{n}C^i_{q_i}\left(q^{s_i}\right)$, $C'(q)$ – a generalized moving average operator; $D'(q)=D^1_{p_1}\left(q^{s_1}\right)\cdot D^2_{p_2}\left(q^{s_2}\right)\cdot\ldots\cdot D^1_{p_n}\left(q^{s_n}\right)=\prod_{i=1}^{n}D^i_{p_i}\left(q^{s_i}\right)$, $D'(q)$ – generalized autoregressive operator; $C^k_{n^k_c}\left(q^{s_k}\right)=I+\sum_{j=1}^{n^k_c}C^k_j q^{j\cdot s_k}$ – matrix polynomial from q^{s_k} of order n^k_c, defining moving average component of the periodic component with period s_k ; $D^k_{n^k_d}\left(q^{s_k}\right)=I+\sum_{j=1}^{n^k_d} D^k_j q^{j\cdot s_k}$ – the matrix polynomial from q^{s_k} of order n^k_d, defining autoregressive component of the periodic component with period s_k ; $A_i(q)$, $B_i(q)$, $C(q)$, $D(q)$, $F(q)$, $G(q)$, $H(q)$ – matrix polynomials $A_i(q)=I+\sum_{j=1}^{n_a} A^i_j q^j$, $B_i(q)=\sum_{j=0}^{n_b} B^i_j q^j$, $F(q)=I+\sum_{j=1}^{n_f} F_j q^j$ of orders n_a, n_b, n_h, n_g and n_f respectively; Θ_{X_i} – delay matrix of exogenous variables with respect to the outputs of the system, which has the form $\Theta_{X_i}=\begin{bmatrix} q^{c^{11}_{X_i}} & q^{c^{12}_{X_i}} & \vdots & q^{c^{1r}_{X_i}} \\ q^{c^{21}_{X_i}} & q^{c^{22}_{X_i}} & \vdots & q^{c^{2r}_{X_i}} \\ \cdots & \cdots & \ddots & \cdots \\ q^{c^{m1}_{X_i}} & q^{c^{m2}_{X_i}} & \vdots & q^{c^{mr}_{X_i}} \end{bmatrix}$; $c^{kj}_{X_i}$ – time delay of j th exogenous variable relative to output; $X(k)=\left(x_1(k) \quad x_2(k) \quad \ldots \quad x_r(k)\right)^T$, $Y(k)=\left(y_1(k) \quad y_2(k) \quad \ldots \quad y_m(k)\right)^T$, $W(k)=\left(w_1(k) \quad w_2(k) \quad \ldots \quad w_m(k)\right)^T$ – vectors of inputs, outputs and noise, respectively, for the k th time moment. And as for the model with a scalar output value, a rough preliminary structural and parametric identification of the matrix polynomial $F(q)$ is supposed to find by the "Caterpillar"-SSA method.

If in the model (1) $A_i(q)=I$, $i=\overline{1,N}$ and $D'(q)=I$ then we obtain seasonal VARMAX model:

$$F(q)\cdot Y(k)=\sum_{\mathrm{i}=1}^{N} B_i(q)\cdot \Theta_X \cdot X(k)+C'(q)\cdot W(k) \tag{2}$$

and if $F(q)=I$ - the Box-Jenkins model:

$$Y(k)=\sum_{i=1}^{N}\frac{B_i(q)}{A_i(q)}\cdot \Theta_{X_i}\cdot X_i(k)+\frac{C'(q)}{D'(q)}\cdot W(k) \tag{3}$$

Let’s write models (2), (3) and (1) in difference form.

Box-Jenkins model:

$$\prod_{i=1}^{N} A_i(q)D'(q)Y(k)=D'(q)\sum_{i=1}^{N} B_i(q)\cdot \Theta_{X_i}\cdot X_i(k)+\prod_{i=1}^{N} A_i(q)C'(q)W(k)$$

or

$$A'(q)Y(k)=\sum_{i=1}^{N} B'_i(q)X_i(k)+C''(q)W(k),$$

where $A'(q)=\prod_{i=1}^{N} A_i(q)D'(q)$, $B'_i(q)=D'(q)B_i(q)\cdot \Theta_{X_i}$, $i=\overline{1,N}$, $C''(q)=\prod_{i=1}^{N} A_i(q)C'(q)$.

The general polynomial model (1):

$$\prod_{i=1}^{N} A_i(q)D'(q)F(q)Y(k)=D'(q)\sum_{\mathrm{i}=1}^{N} B_i(q)\cdot \Theta_{X_i}\cdot X_i(k)+\prod_{i=1}^{N} A_i(q)C'(q)W(k)$$

or

$$A''(q)Y(k) = \sum_{i=1}^{N} B_i''(q)X_i(k) + C''(q)W(k),$$

where $A''(q) = \prod_{\mathrm{i=1}}^{N} A_i(q)D'(q)F(q)$, $B_i''(q) = D'(q)\sum_{i=1}^{N} B_i(q)\cdot \Theta_{X_i}$, $C''(q) = \prod_{\mathrm{i=1}}^{N} A_i(q)C'(q)$.

ARIMA model

A mathematical model of the processes that depend from several exogenous factors in the operator form can be presented as a model of the seasonal autoregressive integrated moving average (SARIMA) [Бокс, Дженкинс, 1974], [Евдокимов, Тевяшев, 1980]:

$$y_t = \sum_{i=1}^{N} \frac{\omega_{c_i}^i(B)}{\delta_{r_i}^i(B)} x_{t-b_i}^i + \frac{\theta_{q^*}^*(B)}{\Phi_{p^+}^+(B)} e_t \qquad (4)$$

where

y_t, $t = \overline{1,n}$ – initial or transformed (normalized or logarithm) centered time series of the predicted values;

n – volume of time series;

x_t^i, $t = \overline{1,n}$, $i = \overline{1,N}$ – initial or transformed (normalized or logarithm) centered time series of the external (exogenous) factors;

N – the number of exogenous factors;

B – the lag operator or backshift operator which operates on an element of a time series x_t to produce the previous element such that $B^i x_t = x_{t-i}$;

b_i – the time delay of i th exogenous time series x_t^i relative to predicted time series y_t;

$\delta_{r_i}^i(B)$ and $\omega_{c_i}^i(B)$ – polynomials of the transfer functions form B of r_i and c_i degrees respectively;

$\delta_{r_i}^i(B) = 1 - \delta_1^i B - \delta_2^i B^2 - \ldots - \delta_{r_i}^i B^{r_i}$;

$\omega_{c_i}^i(B) = \omega_0^i - \omega_1^i B - \omega_2^i B^2 - \ldots - \omega_{c_i}^i B^{c_i}$;

$\Phi_{p^+}^+(B)$ – the generalized autoregressive operator of the order $p^+ = p^* + \sum_{i=1}^{n_s} D_i S_i$, $p^* = \sum_{i=1}^{n_s} p_i S_i$;

$\Phi_{p^+}^+(B) = \Phi_{p^*}^*(B)\nabla_{S_1}^{D_1}\nabla_{S_2}^{D_2}\ldots\nabla_{S_{n_s}}^{D_{n_s}}$;

D_i, $i = \overline{1,n_s}$ – the order of difference capture S_i;

S_i, $i = \overline{1,n_s}$ – the period the i th periodic component and S_1 = 1;

n_s – the amount of periodic components;

∇_{S_i} and B^{S_i} – simplify operators such that $\nabla_{S_i} x_t = \left(1 - B^{S_i}\right)\cdot x_t = x_t - x_{t-S_i}$.

$\Phi^*_{p^*}(B)$ – the generalized autoregressive operator of the order p^* of form $\Phi^*_{p^*}(B) = \prod_{i=1}^{n_s} \Phi^i_{p_i}\left(B^{S_i}\right)$;

$\Phi^i_{p_i}\left(B^{S_i}\right)$, $i = \overline{1,n_s}$ – polynomials from B^{S_i} of orders p_i respectively that define the components of autoregression of the periodic components with periods s_i respectively;

$\theta^*_{q^*}(B)$ – the generalized moving average operator of order $q^* = \sum_{i=1}^{n_s} q_i S_i$ of form $\theta^*_{q^*}(B) = \prod_{i=0}^{n_s} \theta^i_{q_i}\left(B^{S_i}\right)$;

$\theta^i_{q_i}\left(B^{S_i}\right)$, $i = \overline{1,n_s}$ – polynomials from B^{S_i} of orders q_i respectively that define the moving average components of the periodic components with periods S_i respectively;

e_t – error terms of the model that are generally assumed to be independent, identically distributed variables sampled from a normal distribution with zero mean.

The solution of task of structural identification of the parameters c_i, r_i, b_i $i = \overline{1,N}$ is performed automatically by the analysis of the response function to a unit impulse. The automated identification of parameters p_i, $i = \overline{1,n_s}$ - by analyzing of the partial autocorrelation function (PACF), and parameters q_i, $i = \overline{1,n_s}$ – by analyzing the autocorrelation function (ACF). The parameters n_s, D_i, S_i are also identified by the analysis of ACF and PACF of the process. Parametric identification is performed by the method of Levenberg-Marquardt or Davidon-Fletcher-Powell.

In [Седов, 2010], [Бэнн, Фармер, 1987] presents other additive, multiplicative and hybrid forecasting models. There also offered a variety of models for simulating and forecasting the trend, seasonal, weekly, residual components of the processes.

Trend approach of time series forecasting

The main requirements to the mathematical models construction in 70th – 90th years of the last century, is an economical number of parameters, the velocity of the model determination and its resource-intensity for use on available then computers with low productivity. However, modern computer technology and mathematical modeling methods provide a great possibilities for analysis, modeling and forecasting time series of the different nature. Therefore, at present these requirements are not crucial and modern computing tools and systems allow to stand on the first plan the requirement of modeling accuracy, quality of the analysis and forecasting.

One of the most widely used models that corresponding to above requirements are the ARIMA models. Box-Jenkins method works only with pre-reduced to the stationary form time series. Nonstationary series are usually characterized by the presence of high power at low frequencies. However, in many practical applications of interest information may be concentrated at high frequencies. In such cases, all that was done - it is filtered out non-stationary low-frequency components and was used the remainder of the series for further analysis. At the same time as a filter to eliminate low-frequency component in the ARIMA model used a filter of the first differences or maximum second. Watching the gain of the filter can be seen that low frequency considerably weakened and, therefore, be less visible at the filter output. So the method of seasonal ARIMA model was satisfactorily predicted only with a relatively simple structure time series.

In the 80th years of last century Granger and Joyeux [Granger, Joyeux, 1980] proposed a new class of ARFIMA models which is convenient to describe the financial and economic time series with the effects of long and short memory.

Known publications using the "Caterpillar"-SSA method in various branches of science and technology as a method of fairly good description of non-stationary time series with linear, parabolic or exponential trend with not always stable oscillatory component, however studies have identified a number of significant shortcomings of the method, greatly limiting its applicability. Method for modeling uses suboptimal in terms of accuracy of some time series of orthogonal basis vectors of the trajectory matrix. Therefore, the main idea of the origin of the proposed method was first concluded in joint use the "Caterpillar"-SSA method and models of autoregressive moving average, trained on a competitive base, with account generalized criterion of the accuracy and adequacy [Щелкалин, 2010]. Using such combination was dictated by the fact that individually, these approaches have several disadvantages, but their joint usage brings synergy, increasing their efficiency, robustness and adequacy. However, the trend separation by "Caterpillar"-SSA method, as well as any other method, the residual component of the series in most cases is non-stationary, and therefore hereinafter "Caterpillar"-SSA method has been used in combination with the model of autoregressive integrated moving average (ARIMA).

In standard “Caterpillar”-SSA method the signal or the model are defined only from condition of the dispersions reproduction of the time series, but the nature of the errors of the reproduction in model is not included. The “Caterpillar”- SSA method, founded on LS or MV estimation, received for decision of this problem more applicable in the theory of filtration and does not include any information whether the noise is white or not. Therefore, at present there are two approaches to solve this problem. In base of the first approach lies the idea of the increasing the order of the linear recurrence formula (LRF) of the recurrence forecast of the “Caterpillar”-SSA method by HTLS method - a modification of the ESPRIT method [Голяндина, Шлемов, 2012]. The second - by adding to the SSA-forecasts the Box-Jenkins forecasts, constructed on the remaining part of the time series after removing from it the signal recovered by “Caterpillar”-SSA method [Щелкалин, 2012]. In fact - by adding to the LRF the ARIMA model. Beneficial effects appearing already as a result of arising from the using such additive model (5) is described in [Щелкалин, 2012]. Identified by the “Caterpillar”-SSA signal is well approximated by ARIMA models (see model (8)). Subsequently, the model has taken the form (7), and most importantly, all of its parameters were already adjusted by optimization method to target function of integrated criterion of accuracy and adequacy. The author called model (7) as autoregressive model spectrally integrated moving average (ARSIMA) [Shchelkalin, 2011]. For the case of several seasonal components and several exogenous variables in the model are summarized in a similar manner as, for example, model (8) applies to model (10).

$$\mathrm{y}_t = g(B)w_t + \frac{\theta(B)}{\nabla\varphi(B)}e_t\,; \tag{5}$$

$$\mathrm{y}_t = g(B)y_t + \frac{\theta'(B)}{\nabla\varphi'(B)}e_t \tag{6}$$

$$g'(B)y_t = \frac{\theta''(B)}{\omega(B)\varphi''(B)}e_t \tag{7}$$

$$\begin{cases} \hat{w}_t = \dfrac{\theta'(B)}{\nabla\varphi'(B)}\varepsilon_t; \\ y_t = \hat{w}_t + \dfrac{\theta(B)}{\nabla\varphi(B)}e_t; \end{cases} \Rightarrow y_t = \frac{\theta'(B)}{\nabla\varphi'(B)}\varepsilon_t + \frac{\theta(B)}{\nabla\varphi(B)}e_t; \tag{8}$$

$$y_t = g(B)\frac{\theta'(B)}{\nabla\varphi'(B)}\varepsilon_t + \frac{\theta'''(B)}{\nabla\varphi'''(B)}e_t \tag{9}$$

$$y_t = \left(\sum_{i=1}^{N}\frac{\omega_i'(B)}{\delta_i'(B)} + \sum_{i=1}^{N}\frac{\omega_i(B)}{\delta_i(B)}\right)B^{b_i'+b_i}x_t^i + \frac{\prod_{i=1}^{S_n'}\theta'^{S_i'}(B)}{\prod_{i=1}^{S_n'}\nabla_{S_i'}^{D_i'}\prod_{i=1}^{S_n'}\varphi'^{S_i'}(B)}\varepsilon_t + \frac{\prod_{i=1}^{S_n}\theta^{S_i}(B)}{\prod_{i=1}^{S_n}\nabla_{S_i}^{D_i}\prod_{i=1}^{S_n}\varphi^{S_i}(B)}e_t, \tag{10}$$

where w_t - identified by the "Caterpillar"-SSA method deterministic component of the process; L - a window length of method SSA; B - an operator of delay; $g(B) = \sum_{i=1}^{L-1} g_{L-i}B^i$ - polynomial of the delay operator B the initial coefficients of which are the coefficients of minnormLRF of the method "Caterpillar»-SSA g_i, $i = \overline{1, L-1}$ [Голяндина, Шлемов, 2012]; $g'(B) = 1 - g(B)$ = $\sum_{i=1}^{R-1} g''_{R-i}B^i$, where R - the order of a minimal length LRF; The operator $g(B)$ can be applied directly to the process y_t, then (5) can be written as (6), and in (7) $\omega(B)$ = ∇, and in the most cases $\omega(B)$ can be taken equal to $(1-B)$, because after applying of the method "Caterpillar»-SSA residual time series or immediately becomes stationary, or becomes after a single applying of the operator $(1-B)$, what increases the stability of the model, because repeated applying leads to the appearance of multiple roots of characteristic polynomial of the model that lying on the boundary of stability [Shchelkalin, 2011].

Structural identification of the models is performed, in addition to the analysis of the ACF, PACF and the response function to a unit impulse, by selecting of the moving window at formation of embedding vectors of time series, by analysis of the eigenvalues and eigenvectors of the SVD-decomposition of the trajectory matrix of the processes.

By analyzing of changes in time of the first principal components of the SVD decomposition of the trajectory matrix of the time series we can detect the change-points in time series structure.

In the scientific literature have long been known combined probability and deterministic model presented in [Бэнн, Фармер, 1987]. In [Щелкалин, 2011] is offered next modification of the ARIMA and the GARCH models and at first proposed "Caterpillar"-SSA – ARIMA – SIGARCH method and combined probabilistic and deterministic model of autoregression spectrally integrated moving average with spectrally integrated generalized autoregressive heteroskedasticity (ARSPSS – SIGARCH) and the method of its construction, which allows greater flexibility in time series analyzing, modeling and forecasting in comparison with the ARIMA – GARCH models.

The method "Caterpillar"-SSA is applied by author:

for structural identification of the determined component of processes;

for division into long and short memory of processes;

for cointegration interconnected processes;

for time series decomposition on independence components;

for time series decomposition on trend, weekly and seasonal components;

for separation for a finite and separately for deadbeat regulators in the case of use the proposed models in control theory;

for preliminary rough structural identification of the decomposing artificial neural network.

And the Box-Jenkins method is used for structural identification of a remaining stationary (or kvazi-stationary) additional part of processes.

In the time series analysis and forecasting that depending from several other time series it is essential the balancing of the dynamic properties of the variables that appearing in the left and right sides of the model equation. In this case, the idea of the "Caterpillar"-SSA method stand in preliminary generalized cointegration of time series and the model can be represented as follows:

$$\tilde{w}_t^{y} = \frac{\omega_{y\ c_y^{w^y}}^{w^y}(B)}{\delta_{y\ r_y^{w^y}}^{w^y}(B)} \cdot y_{t-b_y^{w^y}} + \sum_{i=1}^{N} \frac{\omega_{x^i\ c_{x^i}^{w^y}}^{w^y}(B)}{\delta_{x^i\ r_{x^i}^{w^y}}^{w^y}(B)} \cdot x_{t-b_{x^i}^{w^y}}^{i} + \frac{\theta_{q_{w^y}^*}^{w^y\ *}(B)}{\varphi_{p_{w^y}^+}^{w^y\ +}(B)} \cdot e_t^{w^y};$$

$$y_t = g^y(B) \cdot \tilde{w}_t^y + \sum_{i=1}^{N} \frac{\omega_{x^i\ c_{x^i}^y}^{y}(B)}{\delta_{x^i\ r_{x^i}^y}^{y}(B)} \cdot x_{t-m_{x^i}^y}^{i} + \frac{\theta_{q_y^*}^{y\ *}(B)}{\varphi_{p_y^+}^{y\ +}(B)} \cdot e_t \tag{11}$$

or

$$g'^y(B) y_t = \sum_{i=1}^{N} \frac{\omega'^{y}_{x^i\ c_{x^i}^y}(B)}{\delta'^{y}_{x^i\ r_{x^i}^y}(B)} \cdot F_{t-m_{F^i}^Q}^{i} + \frac{\theta'^{y\ *}_{q_y^*}(B)}{\varphi'^{y\ +}_{p_y^+}(B)} \cdot e_t .$$

In such statement of the problem this models is closely connected with so named subspace based methods, founded on estimation of signal subspace and then use characteristics of this subspace both for analysis of the signal, and for its continuations.

Decomposition approach of time series forecasting

Recently, in various branches of science and technology the models and methods of digital signal processing for modeling and forecasting of processes are beginning to be used.

SARIMAX model is well applicable for predicting both deterministic and stochastic processes. So, returns to the models (8), (11) in decomposition forecasting method (DFM) involves identifying and building ARIMAX model is not only of time series $\hat{\tilde{w}}_t^y$ and time series $\tilde{w}^{x^i}{}_0$, $\tilde{w}^{x^i}{}_1$, …, $\tilde{w}^{x^i}{}_{n-1}$, $i = \overline{1, N}$, $t = \overline{1, n}$ obtained at the fourth stage of diagonal averaging of "Caterpillar"-SSA method of matrixes Z^i, $i = \overline{1, N+1}$ that consisting of K columns from $(i-1) \cdot K$ th to $(i-1) \cdot K$ th of matrix Z, where $Z = \tilde{Z}^i + \ldots + \tilde{Z}^j$ - the amount of decompositions of the matrix $\widetilde{Z}^i = \left(U^i \cdot \left(U^i\right)^T \cdot X_1 \quad U^i \cdot \left(U^i\right)^T \cdot X_2 \quad \ldots \quad U^i \cdot \left(U^i\right)^T \cdot X_N \quad U^i \cdot \left(U^i\right)^T \cdot Y \right)$, that selected by standard analysis of the eigenvalues of the SVD-decomposition of trajectory matrix in the method of "Caterpillar"-SSA, but to identify and build ARIMAX models of each time series $w_t^{(j)}$ of decomposition (diagonal averaging of submatrixes $\widetilde{Z}^{j\,i}$, $i = \overline{1, L^y}$, which consisting of K columns from $(j-1)\cdot K$ th to $j \cdot K - 1$ th of matrix $\widetilde{Z}^i$, $i = \overline{1, L^y}$), which can be distributed on time series with more simple structure (model (12), figure 1). Thus, it is can potentially to generate $L^y \times (N+1)$ time series of expansion (components) of the original predicted time series and exogenous time series, which are, as was mentioned above, subject to modeling, after selection from these components of the constructive and remove destructive. However, there is no need create all $L^{\mathrm{y}} \times (N+1)$ models, but are formed only meaningful, ie which modeling the structural components. To selection of the most meaningful components (most correlated with the projected time series) author proposed to use the algorithm of fast orthogonal search (FOS) [Ahmed, 1994] or some other method. In this case the columns of the algorithm matrix are the values obtained by the "Caterpillar"-SSA components and exogenous expansions of projected time series, the initial values and exogenous and projected time series, as well as their delay up to m order. The values of the constructed models of constructive components necessary for their further use or as an ensemble of models by applying the model to the input of Box-Jenkins model, or use a combination of models, adjusting their parameters together $y_t = \sum_{k \in M} \hat{w}_t^{(k)}$, where M - the set of indices of selected structural components. In such models as inputs can be also include the instantaneous amplitudes, obtained after applying the Hilbert transform to the components of the expansions (see figure 1 and model (12)). Thus, the model (11) becomes:

$$\hat{w}_t^{(k)} = \frac{\omega_y^{w^{(k)}}{}_{c_y^{w^{(k)}}}(B)}{\delta_y^{w^{(k)}}{}_{r_y^{w^{(k)}}}(B)} \cdot y_{t-b_y^{w^{(k)}}} + \sum_{i=1}^{N} \frac{\omega_{x^i}^{w^{(k)}}{}_{c_{x^i}^{w^{(k)}}}(B)}{\delta_{x^i}^{w^{(k)}}{}_{r_{x^i}^{w^{(k)}}}(B)} \cdot x^i_{t-b_{x^i}^{w^{(k)}}} +$$

$$+ \sum_{i=1, i \neq j}^{M} \frac{\omega_{w^{(i)}}^{w^{(k)}}{}_{c_{w^{(i)}}^{w^{(k)}}}(B)}{\delta_{w^{(i)}}^{w^{(k)}}{}_{r_{w^{(i)}}^{w^{(k)}}}(B)} \cdot \hat{w}^{(i)}_{t-b_{w^{(i)}}^{w^{(k)}}} + \frac{\theta^{w^{(k)}\,*}_{q^*_{w^{(j)}}}(B)}{\varphi^{w^{(k)}\,+}_{p^+_{w^{(k)}}}(B)} \cdot e_t^{w^{(k)}}, \; k \in M; \qquad (12)$$

$$y_t = \sum_{k \in M} \frac{\omega^y_{w^{(k)} c^y_{w^{(k)}}}(B)}{\delta^y_{w^{(k)} r^y_{w^{(k)}}}(B)} \cdot \hat{w}^{(k)}_{t-b^y_{w^{(k)}}} + \sum_{i=1}^{N} \frac{\omega^y_{x^i c^y_{x^i}}(B)}{\delta^y_{x^i r^y_{x^i}}(B)} \cdot x^i_{t-b^y_{x^i}} + \sum_{k \in \mathrm{M}} \frac{\omega^y_{A^k c^y_{A^k}}(B)}{\delta^y_{A^k r^y_{A^k}}(B)} A^{\mathrm{k}}_{\mathrm{t}} + \frac{\theta^{y\,*}_{q^*_y}(B)}{\varphi^{y\,+}_{p^+_y}(B)} \cdot e_t$$

where M - is the set of indices of selected structural components; A_t^k, $k \in \mathrm{M}$ - instantaneous amplitudes obtained after applying of the Hilbert transform to the selected structural components.

Also in the next paper will be offered the decomposition artificial neural network. These models will be able to determine the relationship between the internal structural components defined by the decomposition of time series.

In contrast to SARIMAX model this decomposition model uses SARIMAX for modeling and forecasting of simplified time series of decomposition, while previously model SARIMAX modeled the entire process. However, most processes are heterogeneous nonstationary stochastic processes with polyharmonic, polynomial and stochastic trends, modulated in amplitude and frequency, have a complex correlation structure and for an adequate description of the SARIMAX model time series were reduced to stationary form by taking first differences or the maximum of the latter. Therefore, the SARIMAX method satisfactorily modeled time series only with a relatively simple structure, and the capture of higher-order differences, the stability of the model was lost. Thus, the use of (12) to simulate of signals increases the stability of the model and its accuracy and allows to simulate the signals which are modulated by amplitude and frequency.

Combined approach of time series forecasting

2000th years are characterized by the using for a wide range of models for time series analyzing and forecasting, as well as ensembles of models with different structures. With the advent of high-speed computer the transition from ensembles of predictive models to its combinations was occurred. The difference between the combined models and its ensembles lies in the simultaneous adjustment of model parameters.

For each specific area, selecting the most appropriate models and methods of processes forecasting taking into account the following characteristics:

the way of modeling the various components (trend, cyclical, seasonal, residual, etc.) [Бэнн, Фармер, 1987], [Седов, 2010] or less interpretable components of time series decomposition;

the way of accounting for the influence of external factors on the process;

the way of accounting the influence of expansion components, corresponding to different time series, each to other;

the method of modeling the relationships of latent time series;

the way of modeling the relationship between latent time series and forecasted time series;

the methods of modeling of the random components of time series;

the way of time series clustering on areas with a similar structure, etc.

The combined forecasting method (CFM) consists in decomposing by any method (in this case by the "Caterpillar"-SSA method) of exogenous and forecasted time series into components, which in turn can be decomposed into components with a simpler to identify structure (figure 1) or grouped into more interpretable components of the time series (figure 2), such as: trend, seasonal, weekly and residual, and in the selection by any methods the constructive and dropping the destructive of these components, and in the identification of those constructive components that have a pre-emptive nature on the forecasted time series, or vice versa which delay interval is less than the required interval of pre-emption of forecasting, the mathematical models with the most appropriate structures for each specific component of the time series and calculation of their predictions with the required lead time, to use the obtained models or as an ensemble of models, setting the inputs of MISO-models, or used as components of a model which parameters are adjusted collectively by optimization method.

The essence of the combined approach is to expand in any method of forecasted time series into components: y_t^T (trend), y_t^A (seasonal), y_t^D (weekly) и y_t^R (remain), and subsequently finding the forecasts of each of the components $y_t^T(l)$, $y_t^A(l)$, $y_t^D(l)$ и $y_t^R(l)$, and in finding the generalized prediction. Moreover, when calculating the forecasts of each of the components of time series are recommended certain models.

In order to predict the trend-seasonal component is proposed to use:

– a model of the moving average;
– a model based on decomposition on a finite Fourier series;
– a model based on the Kalman filter;
– a model based on polynomial interpolation;
– an exponential smoothing model;
– a weighted moving average model;
– the neural network model;
– Group Method of Data Handling (GMDH);
– structurally flexible polynomials and harmonic series [Крисилов, Побережник, 2003];
– bordering functions [Седов, 2010];
– wavelets;
– others.

In order to predict weekly component:

– a model of the moving average;
– an exponential smoothing model.
– a model based on polynomial interpolation;
– ARIMA model;
– others.

To account for the exogenuouse factors:

– a model of the moving average;
– a model based on decomposition into finite Fourier series.

To predict the residual component:

– an autoregressive model;
– an exponential smoothing model;
– a model of spectral decomposition;
– ARIMAX model;

Thus, to obtain adequate models of complex non-stationary processes, particularly generated by multiple sources, and high-quality predictions it is necessary to produce their decomposition and combine the models with miscellaneous structure. On these considerations are based the combined model that based on deterministic and statistical models, which differ from those offered models by the simultaneous computation of the model coefficients by the optimization method such as Levenberg-Marquardt or Davidon–Fletcher–Powell algorithms.

As shown in [Смоленцев, 2008], [Щелкалин, 2011] for filtering and signal simulation it is well used principal component analysis (PCA), which lies at the basis of the "Caterpillar"-SSA with wavelets. A promising development of such methods is the combination of multiscale principal component analysis (MPCA), in which PCA is applied not only to the signal, but also to the wavelet coefficients and the wavelet components of a multidimensional signal. Thereby, such way it is possible to create the method "Caterpillar"-SSA based on wavelet analysis. In Kurbatskii, Sidorov, Spiryaev, Tomin, 2011] proposed a two-stage adaptive approach for time series forecasting, whose ideas are similar to the MPCA. In this approach, the first stage involves the decomposition of the initial time series into basis functions by the method of empirical mode decomposition and application to them of the Hilbert transform. In the second step the obtained functions and their instantaneous amplitudes are used as input variables of neural network forecasting.

Since in the proposed decomposition methods accurate convergence of the sum of all components of the process to the original process has not been proved mathematically rigorous, we introduce weights β_T, β_A, β_D and β_R for each of the components of the expansion, respectively, then the resulting prediction is $y_t(l) = \beta_T \cdot y_t^T(l) + \beta_A \cdot y_t^A(l) + \beta_D \cdot y_t^D(l) + \beta_R \cdot y_t^R(l)$. However, for the extraction of qualitative dependencies between predicted time series and components of the expansion of predicted and exogenous time series is necessary to build the next Box-Jenkins model:

$$y_t(l) = \frac{\omega^{y^T}_{c^{y^T}}(B)}{\delta^{y^T}_{r^{y^T}}(B)} \cdot y^T_{t-b_{y^T}}(l) + \frac{\omega^{y^A}_{c^{y^A}}(B)}{\delta^{y^A}_{r^{y^A}}(B)} \cdot y^A_{t-b_{y^A}}(l) + \frac{\omega^{y^D}_{c^{y^D}}(B)}{\delta^{y^D}_{r^{y^D}}(B)} \cdot y^D_{t-b_{y^D}}(l) +$$

$$+ \frac{\omega^{y^R}_{c^{y^R}}(B)}{\delta^{y^R}_{r^{y^R}}(B)} \cdot y^R_{t-b_{y^R}}(l) + \sum_{j=1}^{N} \left(\frac{\omega^{x^{jT}}_{c^{x^{jT}}}(B)}{\delta^{x^{jT}}_{r^{x^{jT}}}(B)} \cdot x^{j\,T}_{t-b_{x^{jT}}}(l) + \frac{\omega^{x^{jA}}_{c^{x^{jA}}}(B)}{\delta^{x^{jA}}_{r^{x^{jA}}}(B)} \cdot x^{j\,A}_{t-b_{x^{jA}}}(l) + \frac{\omega^{x^{jD}}_{c^{x^{jD}}}(B)}{\delta^{x^{jD}}_{r^{x^{jD}}}(B)} \cdot x^{j\,D}_{t-b_{x^{jD}}}(l) + \right.$$

$$\left. + \frac{\omega^{x^{jR}}_{c^{x^{jR}}}(B)}{\delta^{x^{jR}}_{r^{x^{jR}}}(B)} \cdot x^{j\,R}_{t-b_{x^{jR}}}(l) \right) + \frac{\theta^{*}_{q^{*}}(B)}{\varphi^{+}_{p^{+}}(B)} \cdot e_t \qquad (13)$$

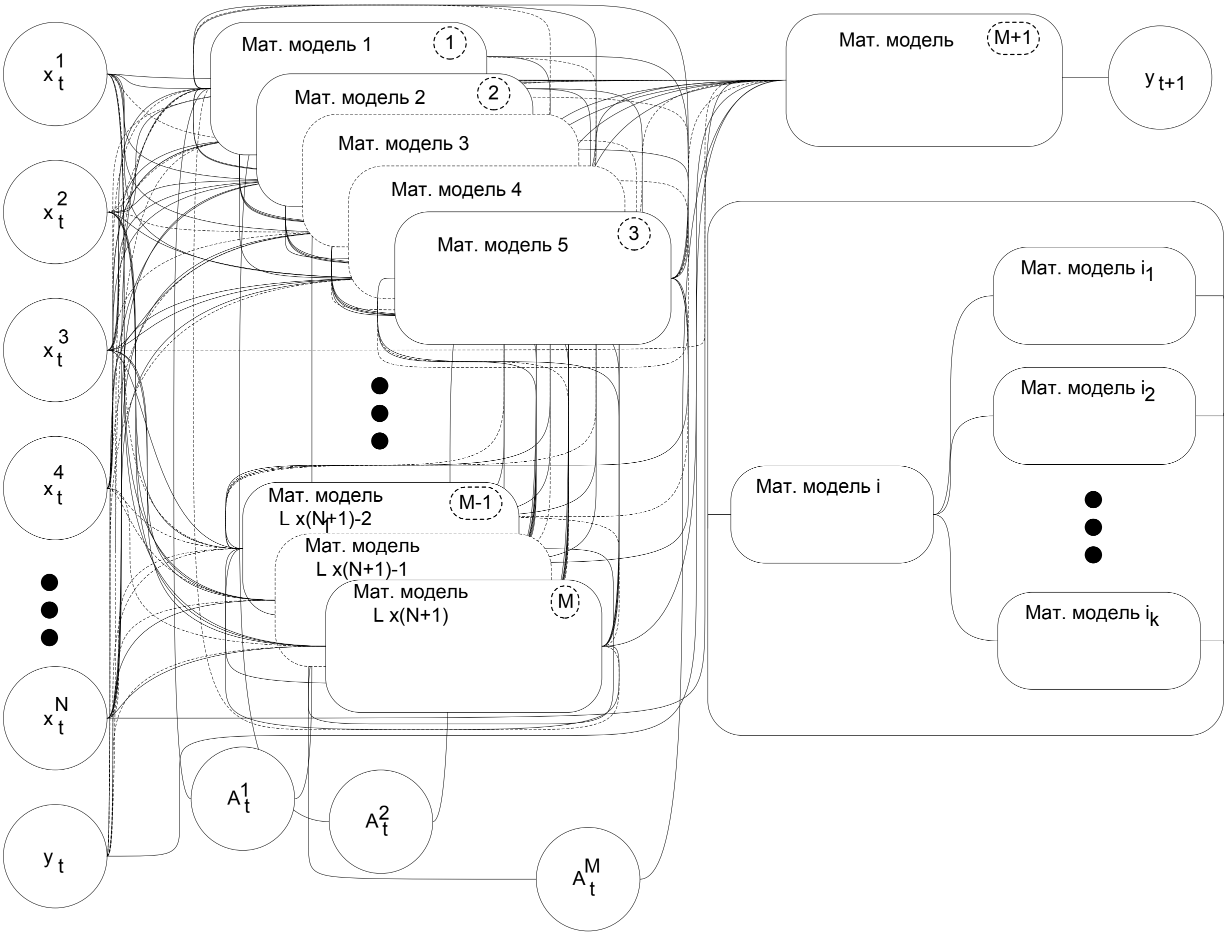

Figure 1. The first block diagram of the model of decomposition/combined forecasting method

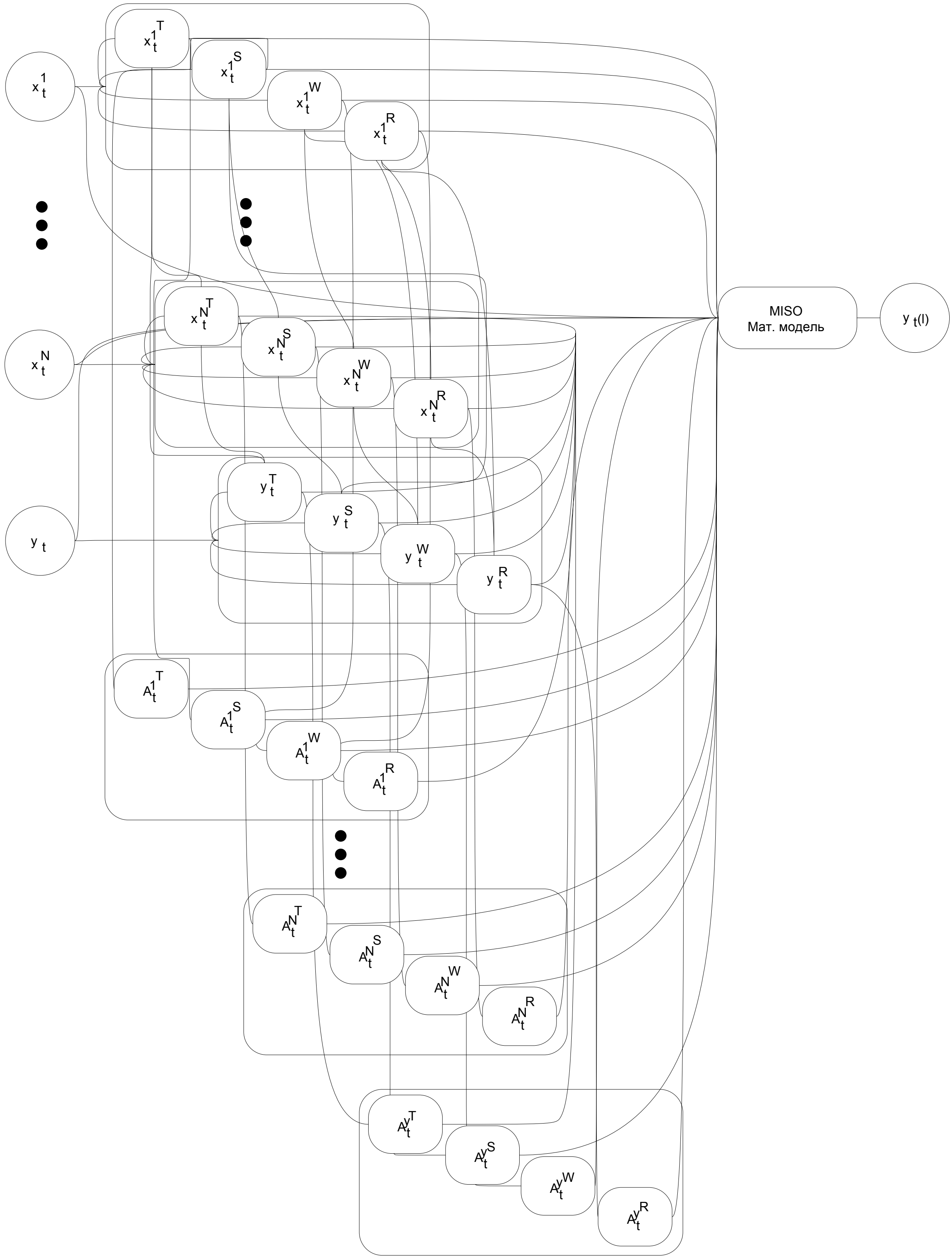

Figure 2. The second block diagram of the model of combined forecasting method

Results

In [Shchelkalin, 2011] the trend approach based on "Caterpillar"-SSA method for predicting natural gas consumption taking into account the changes in air temperature was used.

Testing of described models (12), (13) was conducted on real data of daily average electricity consumption and air temperature changes over a three year period of time.

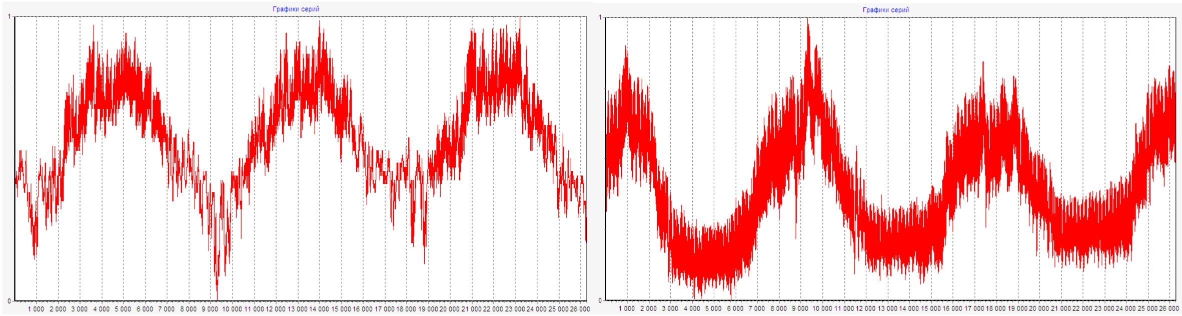

Figure 3. Chart of normalized hourly data of air temperature changes (left chart) and electricity consumption changes (right chart)

The "Caterpillar"-SSA method is made time series decomposition on trend-seasonal, weekly and remaining components.

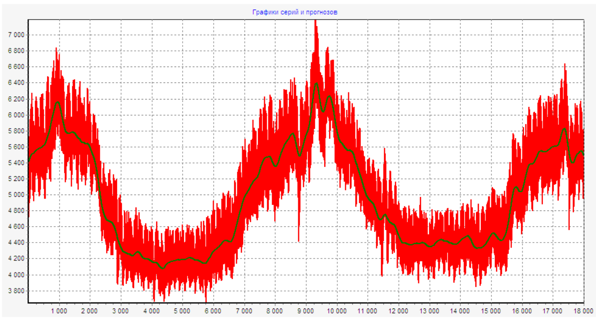

Figure 4. Trend-seasonal component time series of electricity consumption changes

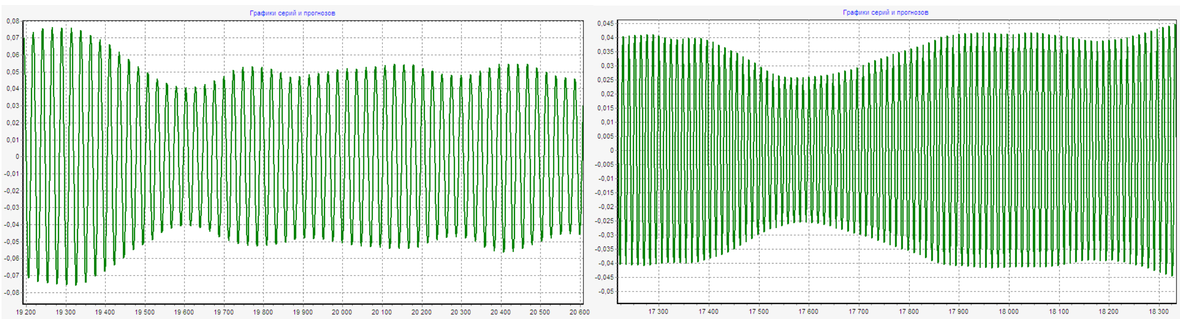

Figure 5. Monthly and weakly components of time series of electricity consumption changes

By analyzing of time series of the variances of residual errors of the model, we found that it is necessary to calculate the GARCH model of the analyzed residual time series to account a heteroscedasticity and to adequate computing of forecasts confidence intervals.

To calculate the qualitative forecasts of the electricity consumption processes it is necessary to apply cluster analysis to form training samples with similar daily images (figure 7).

Considering the charts in figure 8 we conclude that it is need to multiplication of time series weekend elements on the correction coefficients.

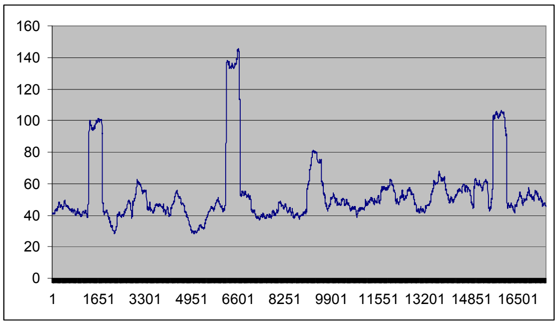

Figure 6. Time series of the variances of residual errors of the model

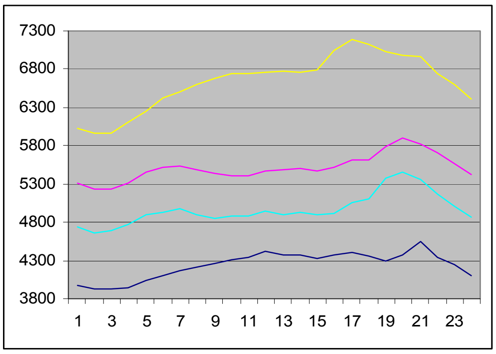

Figure 7. Charts of the daily electricity consumption at different times of the year

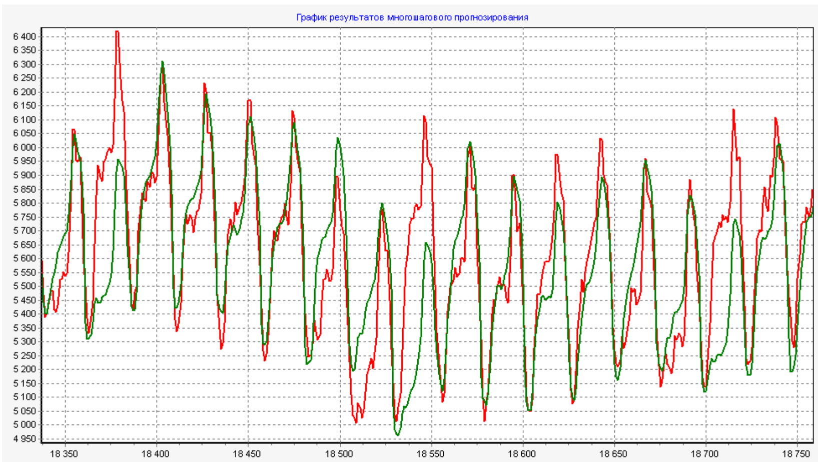

Figure 8. The original time series and time series obtained in the group stage of the "Caterpillar»-SSA method

The charts of different components forecasts of the energy consumption process are presents below.

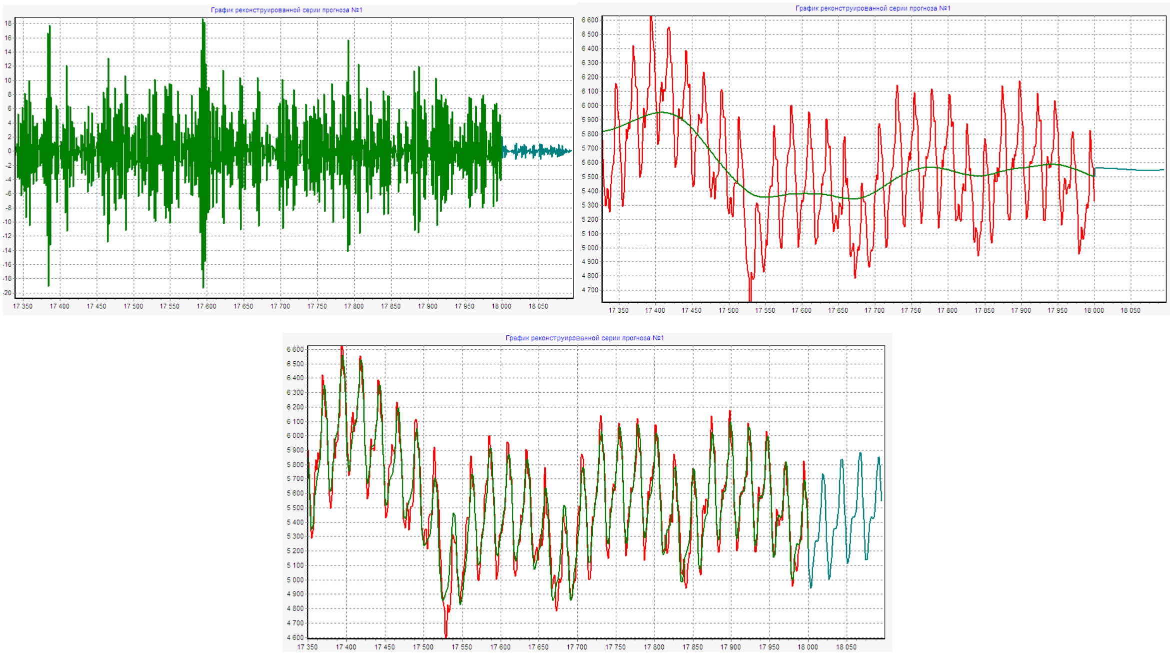

Figure 9. Charts of different components forecasts of the energy consumption process

On figure 9 the general forecast of the energy consumption process is presented.

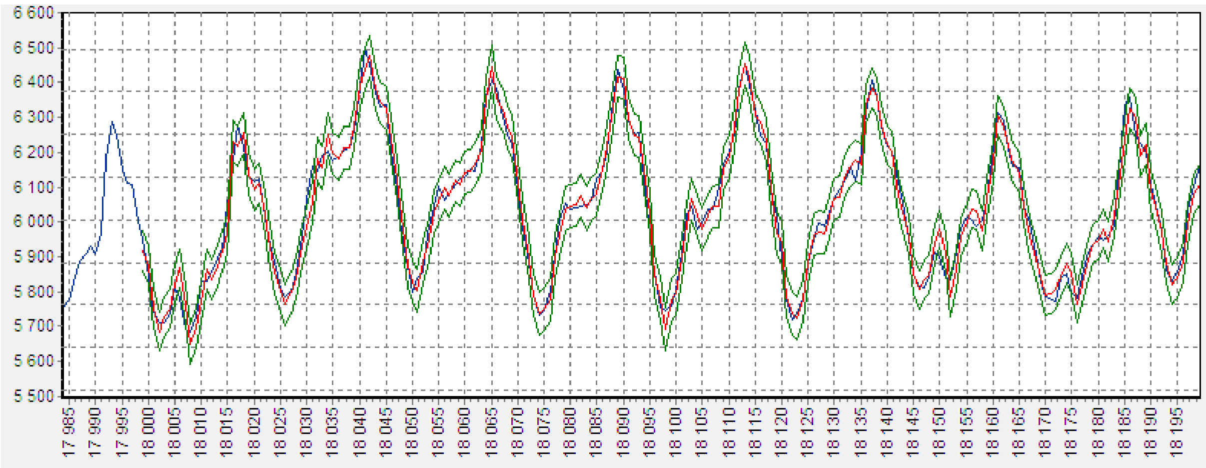

Figure 10. Charts of electricity consumption forecasts with confidence intervals.

Proposed decomposition forecasting method has reduced the mean absolute percentage error (MAPE) of presented time series of electricity consumption from 1.96% to 1.58% respectively in comparison to the prediction by SARIMAX models.

Conclusion

Thereby, to obtain adequate models of the complex processes, high-quality forecasts it is necessary to combine the models with miscellaneous structures, including nonlinear models, which are complementary in their competitive learning.

The main advantage of the proposed method of constructing an adequate model of the process under study is its rigorous formalization and, consequently, the ability to fully automate all phases of construction and use of the model.

The proposed methods in the construction of models are some intermediate approach between the classical and modern regression neural network, and a more formalized in structure and economical choice for time-consuming, and their models are quasi-optimal for detail.

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