ISSN 1407-5806

COMPUTER MODELLING AND NEW TECHNOLOGIES

Volume 15
No 3

2011

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Computer Modelling and New Technologies

Volume 15, No.3 – 2011

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

Riga – 2011

Host Organization:
Transport and Telecommunication Institute

Supporting Organizations:
Latvian Transport Development and Education Association
Latvian Academy of Sciences
Latvian Operations Research Society

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

- mathematical and computer modelling
- mathematical methods in natural and engineering sciences
- physical and technical sciences
- computer sciences and technologies
- material science, solid state physics and chemistry
- nanomaterials, nanodevices and nanotechnologies
- aviation and aerospace technologies
- electronics and telecommunication
- transport and logistics
- economics and management
- innovative education
- social sciences

In journal articles can be presented in English. All articles are reviewed.

EDITORIAL CORRESPONDENCE
Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371) 67100593. Fax: (+371) 67100535
E-mail: journal@tsi.lv, www.tsi.lv

COMPUTER MODELLING AND NEW TECHNOLOGIES, 2011, Vol. 15, No.3
ISSN 1407-5806, **ISSN** 1407-5814 (on-line: www.tsi.lv)
Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

The papers published in Journal "Computer Modelling and New Technologies" are included in **INSPEC** (since 2010), **VINITI** (since 2011)
www.theiet.org/resources/inspec/
http://www2.viniti.ru/

Computer Modelling and New Technologies, 2011, Volume 15, No.3

CONTENTS

Editors' Remarks

INFERNO

"Midway in our life's journey, I went astray
from the straight road and woke to find myself
alone in a dark wood. How shall I say

what wood that was! I never saw so drear,
so rank, so arduous a wilderness!
Its very memory gives a shape to fear.

Death could scarce be more bitter than that place!
But since it came to good, I will recount
all that I found revealed there by God's grace."

****

From THE DIVINE COMEDY, *Inferno, Canto I,* **Dante Alighieri** ♣

The 15th volume No.3 presents the papers on the actual topics such as **Operations Research**, **Applied Statistics, Information Technologies** and **Solid State Physics**.

Our journal policy is directed on the fundamental and applied sciences researches, which are the basement of a full-scale modelling in practice.

The current edition is the continuation of our publishing activities. We hope our journal will be interesting for research community, and we are open for collaboration both in research and publishing. We hope that journal's contributors will consider the collaboration with the Editorial Board as useful and constructive.

EDITORS

Yu.N. Shunin

I.V. Kabashkin

♣ **Dante Alighieri** (1265–1321) – Italy's greatest poet. He was born in the city of Florence, in the region of Tuscany, Italy in the spring of 1265. He wrote the Divine Comedy (Commedia) from 1308 to 1320, completing the work the year before he died. The Divine Comedy is one of literature's boldest undertakings, as Dante takes us through Hell (Inferno), Purgatory (Purgatorio), and then reaches Heaven (Paradiso), where he is permitted to partake of the Beatific Vision. Dante's journey serves as an allegory of the progress of the individual soul toward God.

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 7–15
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

LONG-TERM INNOVATIVE CONSTRUCTION PROJECTS WITH ALTERNATIVE OUTCOMES AND BRANCHING NODES

***D. Golenko-Ginzburg*[1], *D. Greenberg*[2]**

[1]*Department of Industrial Engineering and Management*
Ben-Gurion University of the Negev
P.O. Box 653, Beer-Sheva, 84105, Israel, and
Department of Industrial Engineering and Management
Ariel University Center (AUC) of Samaria, 44837, Israel
E-mail: dimitri@bgu.ac.il

[2]*Department of Economics and Business Administration*
Faculty of Social Science, Ariel University Center (AUC) of Samaria
P.O. Box 3, Ariel, 40700, Israel
E-mail: dorongreen2@gmail.com

We will consider a new financial account policy for long-term construction projects with stochastic alternative multivariant outcomes. The policy is based on the optimal subproject which is singled out from the initial stochastic alternative network.

Keywords: *Stochastic alternative networks; Controlled alternative networks; Joint variant; Outcome tree; Consecutive financial agreements*

1. Introduction

In [9] we have presented various decision-tree models which have great usefulness in practice, when operating long-term innovative construction projects under random disturbances, e.g., constructing a major Arctic pipeline [3]. Long-term innovative construction projects (LTICP) are characterized by a high level of indeterminacy, and with various types of branching nodes in key events. Those nodes may be the result of unpredictable outcomes of future pioneering hi-tech experiments, geological surveys with possible alternative outcomes, etc.

What is the essence of our philosophy [1, 10–11] when controlling an innovative project with uncertainty and being, at the outset, something which is basically indeterminate? Many examples from high performance practice show that under such circumstances, the control system should not work to a predetermined plan, but should be inherently adaptable, seeking at each decision node to assess *the best route forward*, reconfiguring the ultimate goals, if appropriate.

Note that the sub-problem of determining *the best route* may be very difficult and complicated, especially for systems with a high level of indeterminacy. Solving this sub-problem usually results in solving the general control problem.

Our philosophy in project planning and control with indeterminacy centers on avoiding predetermining the initial network model; moreover, in certain cases the structure of such a model may be indeterminate. At the initial stage of the project's realization, the network may be restricted to a source node and several alternative sink nodes (goals) together with some milestones (a decision-tree model). Such a restricted project is called an aggregated project. Various activities are usually of random duration. Such a stochastic alternative network is renewed permanently over time, including changes in the ultimate goals. At each decision node, our techniques enable us to choose the optimal outcome. Decision-making is repeatedly introduced for the renewed network at every sequentially reached decision node.

We will examine henceforth a LTICP network model with a very high level of uncertainty – a branching network to control a project with two kinds of alternative events: stochastic (uncontrolled) branching of the development of a project, as well as deterministic branching where the outcome direction is chosen by the project's decision maker [3, 5–8].

Note that while the literature on PERT and CPM network techniques is quite vast, the number of publications on *alternative networks* remains very scanty. Various authors, e.g., Elmaghraby [4], introduced the concept of a research and development (R&D) project as a complex of actions and problems towards achieving a definite goal. Several adequate network models for such projects have been considered [2–3, 12]. Note that those projects, being alternative, remain uncontrollable.

Golenko-Ginzburg [5–11] developed the novel controlled alternative activity network (CAAN model) for projects with both random and deterministic alternative outcomes at key nodes. At each routine decision-making node the developed algorithm based on lexicographic scanning singles out all the sub-networks (the so-called joint variants) that correspond to all possible outcomes from that node. The joint variants of the CAAN model are enumerated by introducing a lexicographic order to the set of maximal paths in the CAAN graph. The corresponding look-over algorithm is very simple in usage. Decision-making results in determining the optimal joint variant and following the optimal direction up to the next decision-making node.

We will use the CAAN alternative network model which suits mostly the LTICP.

2. Formal Description of the Alternative Stochastic Model

The alternative CAAN network model [5, 8] is generally a finite compendent directed graph $G(U,Y)$, with the following properties:

(1) Graph G has one initial event, y_0 (the network entry), for which $\Gamma^{-1}y_0 = \emptyset$ and $\Gamma y_0 \neq \emptyset$.

(2) Graph G contains a set Y' of events y' (called terminal events, or network exits), where $\Gamma y' = \emptyset$, $\Gamma^{-1}y' \neq \emptyset$ and $|Y'| \geq 2$.

(3) The set of events Y of graph G is not uniform and consists of events of type $\tilde{\chi} \in \tilde{X}$ (classical PERT model) and of more complex logical types, $\tilde{\alpha} \in \tilde{A}$, $\tilde{\beta} \in \tilde{B}$, and $\tilde{\gamma} \in \tilde{\Gamma}$, being represented in the below Table 1:

Table 1. Logical possibilities of alternative network model events

Designation of an event in the model	Logical relations at the event's receiver	Logical relations at the event's emitter
$\tilde{\chi}$	and	and
$\tilde{\alpha}$	and	exclusive "or"
$\tilde{\beta}$	exclusive "or"	and
$\tilde{\gamma}$	exclusive "or"	exclusive "or"

(4) The set of arcs U of graph G is split into a subset U' of arcs corresponding to the actual functioning of the alternative network, and subset U'' of arcs representing the logical interconnections between actual and imaginary functions.

(5) Vector W_{kl} of values characterizing actual work is constructed preliminary for every arc, $U_{kl} \in U'$, representing an actual activity. Among such values are the time of the activity duration t_{kl}; the required cost C_{kl}; and other components of this vector. The vector's components $\omega_{kl}^{(\rho)}$ ($\rho = 1-k$, k being the vector' dimension) can be represented, depending on the degree of indeterminacy, either by determined estimations or by random values with a given distribution function, $f\left(\omega_{kl}^{(\rho)}\right)$ on the interval $\left[\alpha\left(\omega_{kl}^{(\rho)}\right), \beta\left(\omega_{kl}^{(\rho)}\right)\right]$, where $\alpha\left(\omega_{kl}^{(\rho)}\right)$ and $\beta\left(\omega_{kl}^{(\rho)}\right)$ are boundary estimations of the ρ-th component of vector W_{kl}.

(6) For the stochastic alternative model of a combined type, the set of alternative events, $\tilde{A} \cup \tilde{\Gamma}$, is split into subsets $\overline{A}$ – alternative events that show the branching of determined variants, and $\overline{\overline{A}}$ – alternative events that represent the situations of branching stochastic variants, where $\tilde{A} \cup \tilde{\Gamma} = \overline{A} \cup \overline{\overline{A}}$.

(7) When the network event is of alternative nature, it is assigned a set of estimations of corresponding local variant probabilities. In other words, a nonnegative number, $\overline{\overline{p}}_{ij} \leq 1$, such that $\sum_{j=1}^{n_i} \overline{\overline{p}}_{ij} = 1$

(where $\overline{\overline{p}}_{ij}$ is the *a priori* probability of transferring from i to j and n_i stands for the number of local variants appearing in event i), is related to each alternative path starting from event i of type $\tilde{\alpha} \in \overline{\overline{A}}$ or $\tilde{\gamma} \in \overline{\overline{A}}$ and leading to outcome j .

(8) If event i is related to an alternative event of class $\tilde{A}$, the corresponding conditional transfer probability, $\overline{\overline{p}}_{ij}$, is usually assumed to be equal 1. This means that the process of choosing the direction in which the system has to move towards its target is of a determined character; it is the prerogative of the system's controlling device.

Problems of alternative network model analysis and synthesis are solved by applying the principle of network enlarging and obtaining a special graph – the outcome tree [1, 5–8], which is usually designated as $D(A,V)$ and represents a graph that can be constructed by modifying the original model $G(Y,U)$ as follows:

(a) The set, which consists of the initial event, finite events, and events that are branching points of alternative paths of graph G, is taken as the set of events of graph D. The initial event, $\alpha_0 = y_0$, is called a hanging event.

(b) The set of arcs $V = \{v_{ij}\}$ of graph D is obtained thorough an equivalent transformation of a set of sub-graphs, $\{G_{ij}\}$, extracted from network G according to the following procedure:

- any event α_i, except for the finite ones, α', can be the initial event of sub-graph $G_{ij} = (L_{ij}, U_{ij})$, where $\alpha' \in y_{ij}$ and $\Gamma^{-1}\alpha_i \cap Y_{ij} = \emptyset$;
- $Y_{ij} \subset \tilde{\Gamma}\alpha_i$, where $\tilde{\Gamma}\alpha_i$ stands for the transitive closure of mapping α_i ;
- only an α -event of graph G, except for the initial event, $\alpha_0 = y_0$, can be a finite event of sub-graph G_{ij}, and
- no $(\alpha_i,...,\alpha_j)$-type paths that connect the initial event, α_i, with sub-graph finite event α_j in G_{ij}, contain other α -events of graph G.

(c) every arc, v_{ij}, of outcome tree D is obtained by reducing fragment G_{ij} of network $G(Y,U)$ to one arc beginning at α_i and ending at α_j. In addition, realization probability p_{ij}, fulfillment time t_{ij}, and other parameters equivalent to the corresponding characteristic values for initial fragment G_{ij} are brought into correspondence with the enlarged arc v_{ij}.

If different fragments, G_{ij}, of the model do not intersect, the alternative network is called entirely divisible; all events of the corresponding outcome tree prove to be γ -type events.

We will require a supplementary definition. A partial variant is a variant of the network model's realization; it corresponds to a definite direction of its development at an individual stage, characterizes one of the possible ways of reaching the intermediate target, and does not contain alternative situations. The variant of realization of the whole project, which does not contain alternative branching and is formed by a sequence of partial variants, is called a full variant. On the outcome tree, $D(A,V)$, a certain arc, v_{ij}, corresponds to the partial variant, while some path connecting root event α_0 with one of the hanging events, corresponds to the full variant.

The combined outcome tree, $D(A,V)$, can be regarded as a union of purely stochastic outcome trees that reflects some homogenous alternative stochastic network models. The latter are obtained by choosing different directions in the controlled devices. Such stochastic outcome trees, which are all part of the combined outcome tree, $D(A,V)$, are called joint variants of realizing the stochastic network model.

The joint variant can be extracted from the original graph, $D(A,V)$, by “fixing” certain directions in interconnected events of type $\overline{\alpha}$ and excluding unfixed directions. In other words, every joint variant can be regarded as a realization variant of the network model. Such a variant has a determined topology, but it contains probability situations and has certain possible stochastic finite states.

Let us examine an outcome tree of a CAAN type alternative project presented on Figure 1. Here $\{\overline{\alpha}\}$ denote decision-making nodes of deterministic nature, where the outcome direction is fully governed by the project's manager.

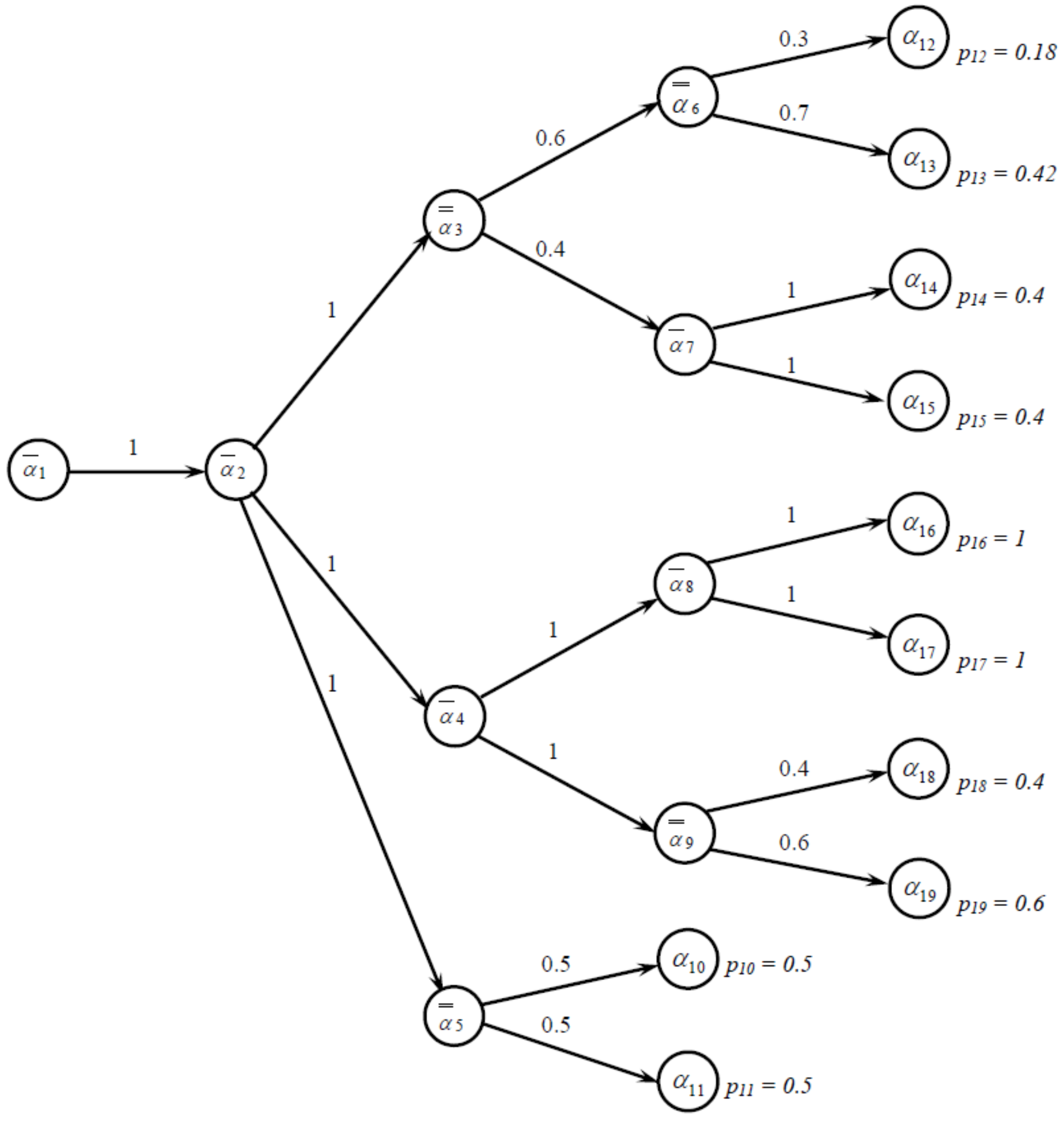

Figure 1. Controlled alternative network project

Nodes $\{\overline{\overline{\alpha}}\}$ are of stochastic nature and, as such, are not controlled. Each $\overline{\overline{\alpha}}$ -type node comprises several outcome probabilities which form a full group of events.

Stage a) on Figure 2 presents six joint variants which can be singled out by analyzing the outcome tree. Note that none of the joint variants comprise alternative deterministic nodes and are determined by choosing non-contradictive directions in nodes $\overline{\alpha}$. Thus, all joint variants are either purely alternative stochastic non-controllable networks of α -type, or non-alternative fragments. Stage b) on Figure 2 demonstrates simplified joint variants of both types.

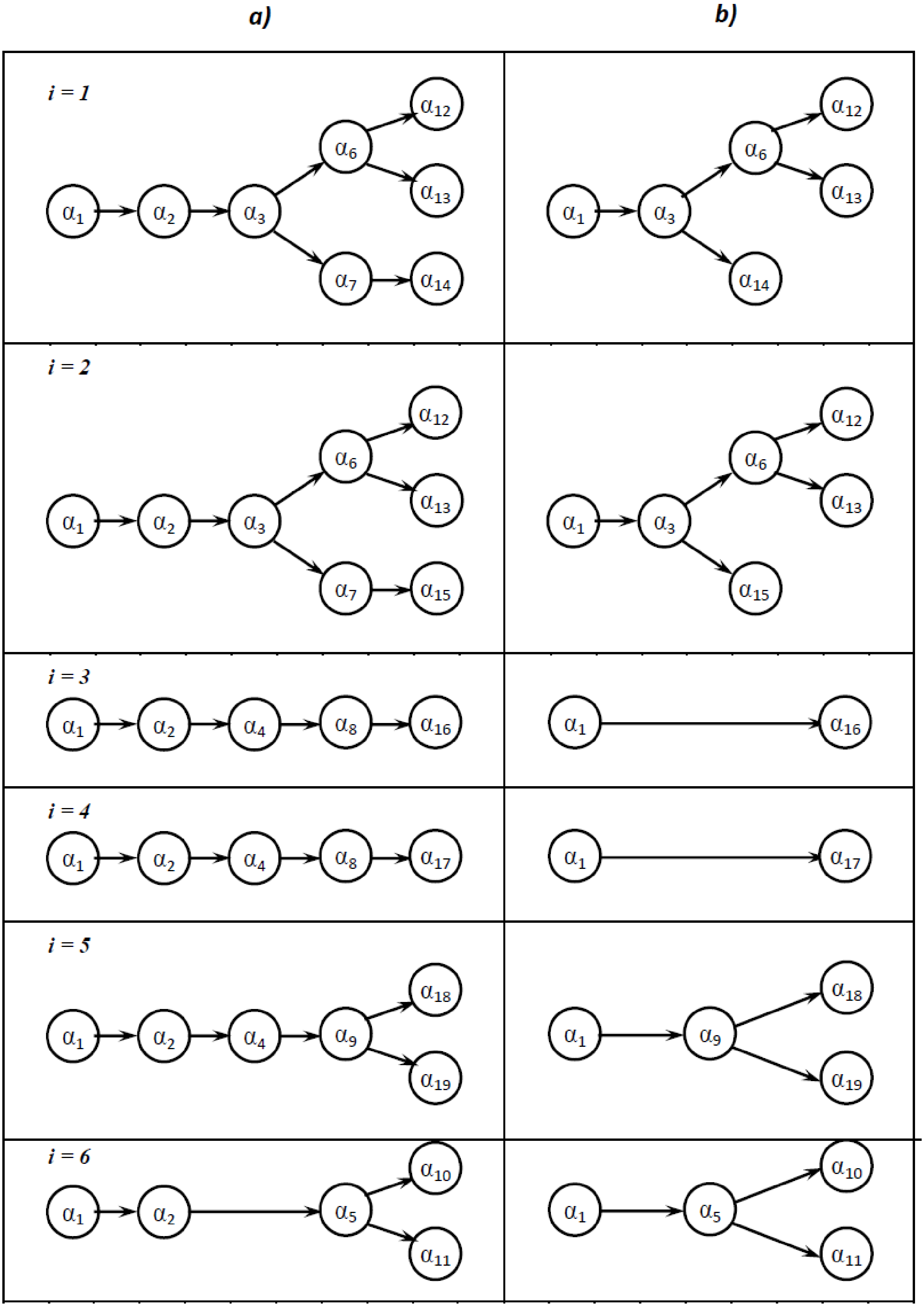

Figure 2. The project's joint variants

3. Optimal Joint Variant

The managing a controlled alternative activity network with two types of branching events means choosing an optimal joint variant, which optimizes the project's goal function. For the case of a LTICP we consider several optimality criteria:

A. Since a joint variant can be regarded as a purely stochastic alternative project, we may calculate the entropy level as a measure of indeterminacy for each joint variant. The joint variant with the least entropy level has to be chosen.

B. For the case of an averse risk manager the strategy is as follows. Calculate (for each joint variant) the objective for the *worst possible probability outcome* (i.e., the worst possible full variant). In other words, we determine the worst objective value which may be actually (i.e., with probability exceeding zero) achieved in the course of realizing the joint variant. Call such an objective value for the i-th joint variant $G_{\min}(J_i)$. The joint variant, which delivers an optimal value from all $G_{\min}(J_i)$, $1 \le i \le n$, has to be chosen as the optimal one.

C. Calculate for each i-th joint variant J_i, $1 \le i \le n$, the average value of the objective, i.e., the mathematical expectation given in the form

$$\overline{G}(J_i) = \sum_{j=1}^{n_i} p_j G(F_j), \tag{1}$$

where p_j denotes the probability of realizing the full variant F_j, and $G(F_j)$ stands for the objective of that full variant. Joint variant J_ξ satisfying

$$\overline{G}(J_\xi) = \max_{1 \le i \le n} \left\{ \sum_{j=1}^{n_i} p_j G(F_j) \right\}, \tag{2}$$

has to be preferred as the optimal one.

D. *Criterion D* is contrary to *Criterion B*. We have to calculate for each joint variant the goal function corresponding to the *best objective outcome* which may be actually obtained in the course of realizing the joint variant. Call it $G_{\max}(J_i)$, $1 \le i \le n$. Joint variant J_η satisfying

$$G_{\max}(J_\eta) = \max_{1 \le i \le n} \left[G_{\max}(J_i) \right], \tag{3}$$

has to be chosen as the optimal one.

The choice of the optimal strategy depends on the nature of LTICP. If the value of the quality of the project's product is extremely important, *Strategy D* has to be preferred. Note that both *Strategies B* and *D* are, in fact, game strategies. In case we are interested in a less nervous progress of the regarded projects, *Strategy C* seems to us to be a better choice.

4. Numerical Example

Let us present a numerical example for the outcome tree appearing on Figures 1 and 2. The alternative model of CAAN type comprises 6 joint variants $J_1,...,J_6$ and 10 full variants F_{11}, F_{12}, F_{13}, F_{21}, F_{22}, F_{23}, F_{31}, F_{41}, F_{51}, F_{52}, F_{61}, F_{62} (note that full variants F_{11} and F_{12} coincide with full variants F_{21} and F_{22}). Let the goal function be the project's cost (to be minimized) and preset the local activities' costs as follows: $C_{12} = 10$, $C_{23} = 6$, $C_{24} = 15$, $C_{25} = 12$, $C_{36} = 14$, $C_{37} = 9$, $C_{6,12} = 10$, $C_{6,13} = 16$, $C_{7,14} = 15$, $C_{7,15} = 20$, $C_{48} = 11$, $C_{49} = 13$, $C_{8,16} = 15$, $C_{8,17} = 8$, $C_{9,18} = 10$, $C_{9,19} = 18$, $C_{5,10} = 12$, $C_{5,11} = 36$. Assume, further, that the alternative graph under consideration refers to the LTICP class of projects.

It can be well-recognized from examining Figures 1 and 2 that implementing *Strategy A* results in comparing two alternative joint variants J_3 and J_4, both with zero level of entropy. Since

$C(J_3) = C_{12} + C_{24} + C_{48} + C_{8,16} = 51$

exceeds

$C(J_4) = C_{12} + C_{24} + C_{48} + C_{8,17} = 44$,

joint variant J_4 has to be determined as the optimal one.

Implementing *Strategy B*, i.e., risk-averse decision-making, boils down to calculating the following values:

$$C_{\max}(J_1) = \max\begin{bmatrix} C_{12} + C_{23} + C_{36} + C_{6,12} = 40; \ C_{12} + C_{23} + C_{36} + C_{6,13} = 46; \\ C_{12} + C_{23} + C_{37} + C_{7,14} = 40 \end{bmatrix} = 46;$$

$C_{\max}(J_2) = \max[40;\ 46;\ 45] = 46$;

$C_{\max}(J_3) = C_{12} + C_{24} + C_{48} + C_{8,16} = 51$;

$C_{\max}(J_4) = C_{12} + C_{24} + C_{48} + C_{8,17} = 44$;

$C_{\max}(J_5) = \max[C_{12} + C_{24} + C_{49} + C_{9,18} = 48;\ C_{12} + C_{24} + C_{49} + C_{9,19} = 56] = 56$;

$C_{\max}(J_6) = \max[C_{12} + C_{25} + C_{5,10} = 34;\ C_{12} + C_{25} + C_{5,11} = 58] = 58$.

Thus, joint variant J_4 which delivers the extreme (the minimal) goal function value if the worst comes to the worst for all joint variants, has to be chosen as the optimal one.

Using the "opposite" *Strategy D*, we may calculate

$C_{\min}(J_1) = \min[40;\ 46;\ 40] = 40$;

$C_{\min}(J_2) = \min[40;\ 46;\ 45] = 40$;

$C_{\min}(J_3) = 51$;

$C_{\min}(J_4) = 44$;

$C_{\min}(J_5) = 48$;

$C_{\min}(J_6) = 34$.

Thus, when implementing risky decision-makings, the result of the procedure is different, namely: joint variant J_6 has to be determined as the optimal one.

When adopting *Strategy C*, the mathematical expectations of the cost to realize the considered joint variants may be calculated as follows (refer again to Figures 1 and 2):

$\overline{C}(J_1) = (10+6+14+10)\cdot 0.18 + (10+6+14+16)\cdot 0.42 + (10+6+9+15)\cdot 0.4 = 7.20+19.32+16 = 42.52;$

$\overline{C}(J_2) = 40\cdot 0.18 + 46\cdot 0.42 + 45\cdot 0.4 = 7.20+19.32+18 = 44.52;$

$\overline{C}(J_3) = 51;$

$\overline{C}(J_4) = 44;$

$\overline{C}(J_5) = (10+15+13+10)\cdot 0.4 + (10+15+13+10)\cdot 0.6 = 19.2+28.8 = 48;$

$\overline{C}(J_6) = (10+12+12)\cdot 0.5 + (10+12+36)\cdot 0.5 = 46$.

Since J_1 results in the minimal mean cost expenses required, it has to be chosen as the optimal one. Thus, adopting different optimality concepts may result in corresponding changing of the joint variant determined as optimal.

5. Capital Investments in Long-Term Alternative Projects under Random Disturbances

It can be well-recognized that in recent years undertaking capital investments and contracting long-term projects which are carried out under random disturbances, has been the subject of lengthy debate and a very sharp criticism (see, e.g., [1–2]). This is because nowadays it is extremely difficult to implement into commercial agreements both the projects' durations and especially the required volume of the corresponding capital investments. This refers mostly to long-term innovative construction projects based on future geological surveys with a high level of indeterminacy, projects involving implementation of new unique technology, etc. It goes without saying that for LTICP comprising both deterministic and stochastic alternative variants, the challenge of determining with more or less accuracy the future project's parameters (like cost, duration, reliability attributes, etc.) becomes practically impossible. However, something has to be decided and has to be done immediately, otherwise the losses originating from failure to compete with accelerating technical and technological progress, may prove to be tremendous.

To meet the challenge, we suggest a new step-wise procedure in order to manage LTICP with alternatives of both deterministic and stochastic nature. The main stages of the procedure are as follows:

Stage I. If possible, determine an alternative graph of the future LTICP. The graph has to be similar to that outlined on Figure 1.

Stage II. Determine all the joint variants entering the graph. The corresponding algorithm is outlined in [5–8], and is based on lexicographical simulation.

Stage III. Determine the strategy for recognizing the optimal joint variant. We remind that different conceptual strategies may result in different principles of optimality and indeterminacy and, thus, result in variety of the optimal joint variant identity, as it was demonstrated in the previous *Section*. In our opinion, the majority of LTICP projects may use the average criterion value in order to determine the optimal joint variant, i.e., *Strategy C*.

Stage IV. After determining the optimal joint variant, one may start the contracting process. We suggest undertaking this process sequentially. On the first step the capital investments have to cover the progress of the project from the very beginning until the first branching node of stochastic type. If, for example, we have chosen J_1 presented on Figure 2, as the optimal one, the signed agreements have to cover expenses starting from event $\bar{\alpha}_1$ until the next alternative (branching) node $\bar{\bar{\alpha}}_3$, i.e., the primary capital investments have to cover the realization of fragment $\bar{\alpha}_1 \to \bar{\alpha}_2 \to \bar{\bar{\alpha}}_3$. Thus, the corresponding contract has to cover expenses estimated as $C_{12} + C_{23} = 16$.

Stage V. After reaching event $\bar{\bar{\alpha}}_3$ the contract has to be rewritten anew, depending on the realization of the uncontrolled direction ($\bar{\bar{\alpha}}_3 \to \bar{\bar{\alpha}}_4$ or $\bar{\bar{\alpha}}_3 \to \bar{\bar{\alpha}}_5$) of the progress of the project.

Stage VI. In the course of the project's realization the joint variant we have chosen before, besides being updated, may undergo other changes as well, both in the structure of the graph itself and in the values of the probability outcomes. Thus the consecutive progress of the project results in consecutive updating the contract's agreement. We do not see another managerial principle applicable to multi-variant alternative projects under consideration. Note that such a form of monitoring enables both on-line and financial control procedures.

6. Conclusions

The following conclusions can be drawn from the study:

1. Long-Term Innovative Construction Projects may deal with a high level of indeterminacy, as well as with various types of branching nodes in key events. Those nodes may be the result of unpredictable outcomes of future pioneering hi-tech experiments, geological surveys with possible alternative outcomes, etc.
2. We have described and presented an on-line stochastic alternative network model comprising both decision-making nodes with deterministic branching and un-controllable alternative nodes with probabilistic outcomes.
3. We have demonstrated the possibility of singling out an optimal joint variant from the previously given stochastic alternative network graph. The structure of the optimal joint variant depends on the concept of optimality, as it has been presented by means of the numerical example. A joint variant does not comprise controllable branching events and is, in fact, a purely homogenous alternative stochastic network.
4. We have suggested a new procedure of contracting capital investments for the considered stochastic alternative model. On our opinion, the suggested mechanism may be effectively used in the course of drawing out financial contracts and other agreements in order to supply complicated long-term innovative construction projects of alternative structure.

References

1. Ben-Yair, A. et al, Risk Assessments in Managing Long-Term Construction Projects with Alternative Outcomes, *Communications in DQM*, Vol. 10, No. 1, 2007, pp. 98–109.
2. Chapman, C. B. and Cooper, D. F. Risk Engineering: Basic Controlled Interval and Memory Models, *J. Oper. Res. Soc.*, Vol. 34, No. 1, 1983, pp. 51–60.
3. Cooper, D. F. and Chapman, C. B. *Risk Analysis for Large Projects*. New-York: Wiley, 1987.
4. Elmaghraby, S. E. *Activity Networks: Project Planning and Control by Network Models*. New-York: Wiley, 1977.
5. Golenko, D. I. *Statistische Methoden der Netzplantecknik*. Leipzig: BSB B.G. Teubner Verlagsgesellschaft, 1972 (in German, translated from Russian: *Statistical Methods in Network Planning and Control*. Moscow: Nauka, 1968).
6. Golenko, D. I. *Statistical Models in Production Control*. Moscow: Statistika, 1973. (In Russian)
7. Golenko, D. I. et al. *Statistical Modeling in R&D Projecting*. Leningrad: Leningrad University Press, 1976. (In Russian)
8. Golenko-Ginzburg, D. *Stochastic Network Models in R&D Projecting*. Voronezh: Nauchnaya Kniga, 2010. (In Russian)
9. Golenko-Ginzburg, D., Burkov, V. and Ben-Yair, A. *Planning and Controlling Multilevel Man-Machine Organization Systems under Random Disturbances*. Voronezh: Nauchnaya Kniga, 2011. (In Russian)
10. Golenko-Ginzburg, D. and Blokh, D. A Generalized Activity Network Model, *J. Oper. Res. Soc.*, Vol. 48, 1997, pp. 391–400.
11. Golenko-Ginzburg, D. and Gonik, A. Project Planning and Control by Stochastic Network Models. In: *Managing and Modeling Complex Projects / Williams, T. M. (Ed.), NATO ASI Series.* The Netherlands: Kluwer Academic Publishers, 1997.
12. Shtub, A., Bard, J. and Globerson, S. *Project Management: Engineering, Technology and Implementation*. New-York: Prentice Hall International, Inc., 1994.

Received on the 10th of September, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 16–20
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

MARKOV CHAINS APPLICATION TO THE FINANCIAL-ECONOMIC TIME SERIES PREDICTION

V. Soloviev[1], V. Saptsin[2], D. Chabanenko[1]

[1]Cherkasy National University named after B. Khmelnitsky
Shevchenko blvd, 81, Cherkasy, 18031 Ukraine

[2]Kremenchug National University named after M. Ostrogradskii
Pershotravneva str. 20, Kremenchuk, 39600 Ukraine

In this research the technology of complex Markov chains is applied to predict financial time series. The main distinction of complex or high-order Markov Chains and simple first-order ones is the existing of after-effect or memory. The technology proposes prediction with the hierarchy of time discretization intervals and splicing procedure for the prediction results at the different frequency levels to the single prediction output time series. The hierarchy of time discretizations gives a possibility to use fractal properties of the given time series to make prediction on the different frequencies of the series. The prediction results for world's stock market indices are presented.

Keywords: *Prediction, time series, complex Markov chains, discrete time, fractal properties*

1. Introduction

Successful modelling and prediction of processes peculiar to complex systems, such as ecological, social, and economical (ESE) ones, remain one of the most relevant problems as applied to the whole complex of natural, human and social sciences ([1–2]). The diversity of possible approaches to modelling such systems and, usually, more than modest success in the dynamics prediction, compel us to look for the reasons of failure, finding them not only in details, but also in the axiomatics, which relates to problem statement, chosen modelling methods, results interpretation, connections with other scientific directions.

With the appearance of quantum mechanics and relativity theory in early twentieth century new philosophical ideas on physical values, measuring procedures and system state have been established, the ones that are completely different from Newtonian notions [3].

For more than 70 years basic concepts of classical and neoclassical economic theories have been discussed by leading scientists, generating new approaches. The general systems theory has acquired recognition in the middle of the 20th century giving way to development of the new, systemic, emergent, and quantum in essence approach to investigation of complex objects, which postulates the limited nature of any kind of modelling and is based upon fixed and closed system of axioms [4].

However, the development of this new philosophical basis of ESE systems modelling is still accompanied with numerous difficulties, and new principles are often merely declared. Current research is devoted to investigation and application of the new modelling and prediction technology, suggested in [5–6], based on concepts of determined chaos, complex Markov chains and hierarchic (in terms of time scale) organization of calculating procedures.

2. Analysis of Prominent Publications Relevant to the Subject

Prediction of financial-economic time series is an extremely urgent task. Modern approaches to the problem can be characterized by the following directions: 1) approximation of a time series using an analytical function and extrapolation of the derived function towards future – so-called trend models [7]; 2) investigation of the possible influence various factors might have on the index, which is being predicted, as well as development of econometric or more complicated models using the Group Method of Data Handling (GMDH) [2, 8]; 3) modelling future prices as the decisions-making results using neuronal networks, genetic algorithms, fuzzy sets [8–9]. Unfortunately, these techniques don't produce stable forecasts, what can be explained by complexity of the investigated systems, constant changes in their structure. Although we are trying to join these directions in one algorithm, it is the latter option that we prefer, with it consisting in creating a model adequate to the process generating a price time series [10–11]. This very approach gives a chance to approach the complexity of the system, which generates the observed series, develop the model and use its properties as the prognosis.

3. Aims of the Paper, Problem Statement

Let's assume the time series is set by a sequence of discrete levels with constant step of time sampling Δt. We need to generate variants of the time series continuation (prognosis scenarios) according to the relations between the sequences of absolute and relative changes discovered with the help of complex Markov chains.

4. Markov Chains Prediction Technology

Let's suppose there is a sequence of a certain system discrete states. From this sequence we can determine transitions probabilities between the two states. Simple Markov chain is a random process, in which the next state probability depends solely on the previous state and is independent from the rest of them. Complex Markov chain, unlike the simple one, stands for the random process, in which the next state probability depends not only on the current, but also on the sequence of several previous states (history). The amount of states in history is the order of the Markov chain.

Theory of simple Markov chains is widely presented in literature, for example [12]. Developing complex or high order Markov chain's properties is not widely presented in modern scientific publications. It's necessary to mention the papers [13, 14] where properties of complex Markov Chains are developed, but no prediction algorithm is proposed there. The development of prediction method, based on complex Markov chains, is proposed in this paper.

Markov chain of the higher order can be brought to a simple Markov chain by introducing the notion of a "generalized state" and including a series of consequent system's states into it. In this case, tools of simple Markov chains can be applied to the complex ones.

Investigated dynamic series is a result of a certain process. It is assumed that this process is determined, which implies the existence of a causal dependence of further states on history. It is impossible to fix and analyse the infinite history, which puts obstacles in the way of an accurate detection of this influence and making precise predictions.

The problem consists in the maximal use of information, which is contained in the known segment of the time series, and subsequent modelling of the most probable future dynamics scenario.

The observed process is described as a time series of prices pt with the given sampling time span Δt:

$$p_{\mathrm{t}i} = p\,(\mathrm{t}_0 + i\Delta t). \qquad (1)$$

Discrete presentation of the time series is in fact a way of existence of this very system. New prices are formed on the basis of contracts or deals, made on the market in certain discrete moments of time, while the price time series is a series of the averaged price levels during the chosen time intervals. While making a decision each trader, who is an active part of the pricing system, works solely with discrete series of the chosen time interval (e.g. minute, 5-minute, hourly, daily, etc.). For $\Delta t \to 0$ the accuracy of data presentations reaches a certain limit, since for relatively small Δt the price leaps in the moment of deal, while staying unchanged and equal to the last deal during the time between the two deals. Hence, the discreteness of time series has to be understood not only as a limited presentation of activity of the complex financial system, but also as one of the principles of its operation [3, 5–6].

The time series of initial conditions has to be turned into a sequence of discrete states. Let us denote the amount of chosen states as s, each of them being connected to the change in the quantity of the initial signal (returns).

For example, consider the classification with two states, first of which corresponds to positive returns as the price increases, while the second one – to negative as it descends. Generally all possible increments of the initial time series are divided into s groups. Ways of division will be discussed further.

Next we develop predictions for the time series of sampled states. For the given order of the Markov chain and the last generalized state the most probable state is chosen to be the next one. In case if ambiguity occurs while the state of maximum probability is being evaluated, an algorithm is used that allows reducing the amount of possible prediction scenarios. Therefore we get the series of predicted states that can be turned into a sampled sequence of prognostic values.

Evaluation of increments, prediction, and subsequent restoration are conducted for the given hierarchy of time increments t. To use the given information as effectively as possible, the prediction is conducted for time increments Δt = 1; 2; 4; 8; …, or a more complex hierarchy of increments and subsequent "splicing" of the results derived from different prediction samplings.

The procedure of prediction and splicing is iterative and conducted starting from smaller increments, adding a prediction with the bigger time increment on every step.

As the sampling time step t increases, the statistics for the investigation of Markov chains decreases, whereas the biggest sampling step, which takes part in the prognostication, limits itself. To supplement the prediction with the low-frequency component the approximation of zero order is being used in the form of a linear trend or a combination of a linear trend and harmonic oscillations [15].

5. Prediction Construction Algorithm

A Let us consider the consequence of operations, required for the prognostic time series construction. To do this we need to set the following parameters:

1) The type of time increments hierarchy (simple – powers of two, complex – product of powers of the first prime numbers).

2) Values of s – the amount of states and r – the order of the Markov chain. These parameters can be individual for every sampling level; finding of optimal parameters is done experimentally.

3) Threshold values δ, and minimal number of transitions $N_{\min}$.

Prediction construction algorithm includes the following steps:

1) Generating hierarchy of time increments – Δt sequence. The maximal of them has to correspond to the length of a prognostic interval $N_{\max}$.

2) For every time increment Δt, as the increments increase, a prediction of states and restoration of the time series along the prognostic states is conducted. Current stage includes following actions:

2.1. Evaluating increments (returns) of the series with Δt sampling. Increment or returns of the time series serves as the basis for states classification [15]. Absolute r_a and relative r_t increments of the time series are considered:

$$r_a = p_t - p_{t-\Delta t}; \tag{2}$$

$$r_t = \frac{p_t - p_{t-\Delta t}}{p_t}; \tag{3}$$

where p_t is the input time series of price dynamics, Δt – sampling interval, which is chosen for subsequent analysis.

2.2. Transforming the time series of increments into the series of state numbers (1..s), i.e. definition of limit values $\{r_{\lim;i}\}$, which are used afterwards during transformation of the returns into class numbers.

2.3. Calculating transition probabilities for generalized states.

2.4. Constructing the series of prognostic states using the procedure of defining the most probable next state. The process of prediction implies the following: the last state is chosen (in case of Markov chains of an order $r > 1$ a sequence of r latest states is taken). The probability of transition from current state to all possible states is defined.

From all possible states a state with maximal probability is chosen. It is possible that several states with maximal probability occur, which can be explained by the bimodal probability distribution. The process of decision-making in this case is described in [10–11].

The chosen most probable state is taken as the next prognostic state and the procedure is repeated for the next (last added) state. Thus we receive a time series of prognostic states for the given sampling time Δt.

2.5. Restoring the value series from the state series with Δt sampling.

2.6. Splicing the prediction of Δt sampling with the time series derived from splicing of the previous layers (with the lesser step Δt). In case if the current time series is the first one, the unchanged time series will come as a result of splicing.

3) To splice the last spliced time series with the continuation of the linear trend, created along all previously known points.

The time series, spliced with the linear trend, is the result of prediction. Detailed algorithm description is published in [10–11]. Our software for time series forecasting by the proposed methods is available from our website: http://kafek.at.ua/MarkovChains1_2_20100505.rar.

6. Results of Stock Indices Prediction

In this section we offer the results of stock indices prediction. The stock's indices databases are available from http://finance.yahoo.com. Prediction's time series with different input learning set's length are shown on Figure 1. The time of prediction series beginning on the next figure is the point 1000 and corresponds to December 1, 2011. The mean and the standard deviation for the all prediction series is shown on Figure 2.

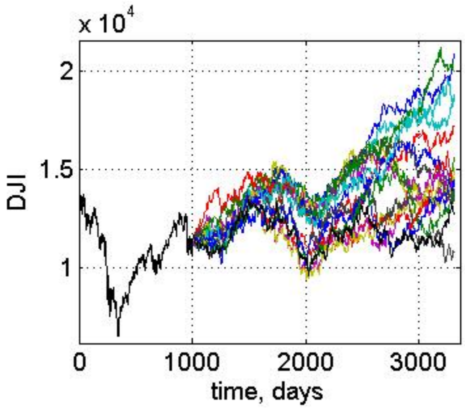

Figure 1. Prediction series, calculated with different learning set's length

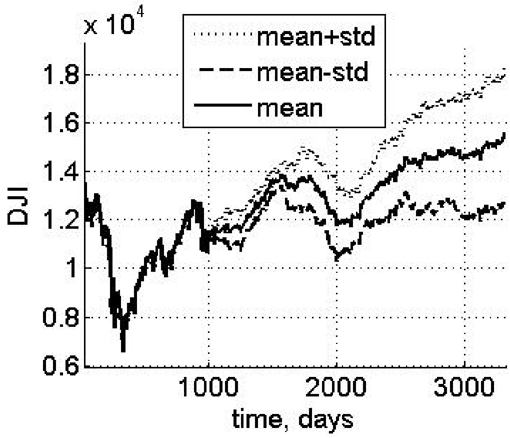

Figure 2. Mean value and standard deviations for prediction time series

The normalization procedure is proposed in order to compare indices and its prediction series with different absolute values. The normalized values calculated with the following formula:

$$y_n(t) = \frac{y(t) - \min\{y(t)\}}{\max\{y(t)\} - \min\{y(t)\}}. \quad (4)$$

Normalized prediction time series are shown on Figure 3. Americas, Asia and Europe are weighted average of country's stock indices predictions, weighted with GDP values for the corresponding countries. Americas includes Brazil, Mexico, Canada, Argentina, and USA. Europe consists of Great Britain, Germany France, Netherlands, Portugal, Italy, Ireland, Greece and Spain. Asian stock indices: China, Korea, Japan, India, New Zealand. For details of the averaging procedure see [11].

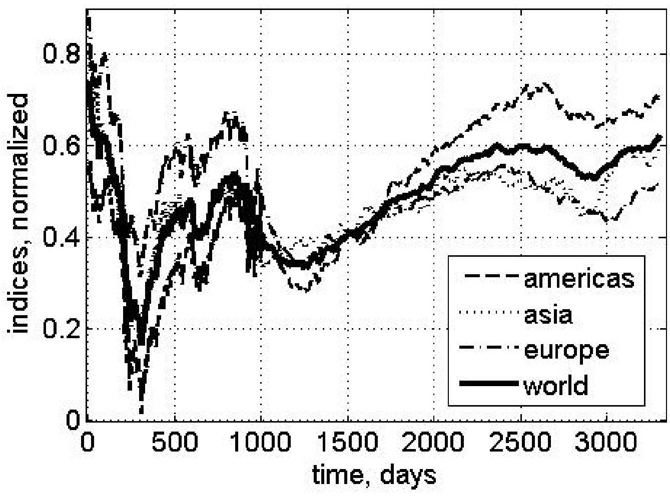

Figure 3. Mean values of normalized World's powerful economies indices prediction series

7. Conclusions and Further Work

The current paper suggests an algorithm of time series prediction based on complex Markov chains. Hierarchy of time increments principle allows using the information, which is contained in the time series during the prognosis construction, to its fullest. Experimental work on stock market indices time series prediction shows the efficiency of the algorithm and confirms the relevance of further research of the offered method.

References

1. Samarskii, A. A. and A. P. Mikhailov. *Mathematical Modeling: Ideas. Methods. Examples.* Moscow: Fizmatlit, 2001.
2. Ivakhnenko, O. G. Grouping Method of Data Handling – the Concurrent of Stochastic Approximation Methods (in Ukrainian), *Automatika*, Vol. 3(3), 1968, pp. 58–72.
3. Saptsin, V. and Soloviev, V. *Relativistic Quantum Econophysics – New Paradigms in Complex Systems Modelling.* arXiv:0907.1142v1 [physics.soc-ph].
4. Von Bertalanffy, L. General System Theory – a Critical Review, *General Systems*, VII, 1962, pp. 1–20.
5. Kurbanov, K. R. and V. M. Saptsin. Markov Chains as Technology for Social, Economic and Ecological Processes Forecasting. In: *Problems of Regional Perspectives of the Market Economy, Kremenchuk, May, 11–13 2007*, pp. 10–14. (In Russian)
6. Saptsin, V. M. Experience of Using Genetically Complex Markov Chains for the Neural Network Technology Forecasting, *Visnyk Krivorizkogo ekonomichnogo institutu KNEU*, Vol. 2 (18), pp. 56–66, 2009.
7. Lukashin, Y. P. *Adaptive Methods of Time Series Forecasting: Textbook.* Moscow: Finance and Statistics, 2003.
8. Zaichenko, Y. P. *Fuzzy Models and Techniques in Intelligent Systems: Monograph.* Kiev: Slovo, 2008. (In Russian)
9. Ezhov, A. A. and S. A. Shumsky. *Neurocomputing and its Application in Economics and Business (Series "Textbooks" of Economic-Analytical Institute MEPI) / Ed. by Professor V. V. Kharitonov.* Moscow: MEPI, 1998.
10. Soloviev, V., Saptsin, V. and D. Chabanenko. Financial time series prediction with the technology of complex Markov chains, *Computer Modelling and New Technologies*, Vol. 14(3), 2010, pp. 63–67. http://www.tsi.lv/RSR/vol14 3/14 3-7.pdf
11. Soloviev, V., Saptsin, V. and D. Chabanenko. *Markov Chains application to the financial-economic time series prediction*. – arXiv:1111:5254, November 2011.
12. Tikhonov, V. I. and V. A. Mironov. *Markov Processes*. Moscow: Soviet Radio, 1977.
13. Raftery, Adrian E. A Model for High-Order Markov Chains, *Journal of the Royal Statistical Society*, 1985.
14. Raftery, Adrian and Simon Tavare. Estimation and Modelling Repeated Patterns in High Order Markov Chains with the Mixture Transition Distribution Model, *Appl. Statist*., Vol. 43(1), 1994, pp. 179–199.
15. Chabanenko, D. M. Discrete Fourier-Based Forecasting of Time Series, *Sistemni tehnologii. Regionalny mizhvuzivsky zbirnik naukovyh pratz* (in Ukrainian), Vol. 1(66), 2010, pp. 114–121. – http://www.nbuv.gov.ua/portal/natural/syte/2010 1/15.pdf

Received on the 12th of September, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 21–26
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

HEISENBERG UNCERTAINTY PRINCIPLE AND ECONOMIC ANALOGUES OF BASIC PHYSICAL QUANTITIES

V. Soloviev[1], V. Saptsin[2]

[1]Cherkasy National University named after B. Khmelnitsky
Shevchenko blvd, 81, Cherkasy, 18031 Ukraine

[2]Kremenchug National University named after M. Ostrogradskii
Pershotravneva str. 20, Kremenchuk, 39600 Ukraine

From positions, attained by modern theoretical physics in understanding of the universe bases, the methodological and philosophical analysis of fundamental physical concepts and their formal and informal connections with the real economic measuring is carried out. Procedures for heterogeneous economic time determination, normalized economic coordinates and economic mass are offered, based on the analysis of time series, the concept of economic Plank's constant has been proposed. The theory has been approved on the real economic dynamic's time series, including stock indices, Forex and spot prices, the achieved results are open for discussion

Keywords: *quantum econophysics, uncertainty principle, economic dynamics time series, economic time*

1. Introduction

The instability of global financial systems depending on ordinary and natural disturbances in modern markets and highly undesirable financial crises are the evidence of methodological crisis in modelling, predicting and interpretation of current socio-economic conditions.

In papers [1–2] we have suggested a new paradigm of complex systems modelling based on the ideas of quantum as well as relativistic mechanics. It has been revealed that the use of quantum-mechanical analogies (such as the uncertainty principle, notion of the operator, and quantum measurement interpretation) can be applied to describing socio-economic processes.

It is worth noting that quantum analogies in economy need to be considered as the subject of new inter-disciplinary direction – quantum econophysics (e.g. [3, 4]), which, despite being relatively young, has already become a part of classical econophysics [5, 6]. However significant differences between physical and socio-economical phenomena, diversity and complexity of mathematical toolset as well as lack of deep understanding of quantum ideology among the scientists, working at the joint of different fields require a special approach and attention while using quantum econophysical analogies.

Our aim is to conduct methodological and philosophical analysis of fundamental physical notions and constants, such as time, space and spatial coordinates, mass, Planck's constant, light velocity from the point of view of modern theoretical physics, and search of adequate and useful analogues in socio-economic phenomena and processes.

2. About Nature and Interrelations of Basic Physical Notions

Time, distance and mass are normally considered to be initial, main or basic physical notions that are not strictly defined. It is thought that they can be matched with certain numerical values. In this case other physical values, e.g. speed, acceleration, pulse, force, energy, electrical charge, current etc. can be conveyed and defined with the help of the three above-listed ones via appropriate physical laws.

Let us emphasize that none of the modern physical theories, including relativistic and quantum physics, can exist without basic notions. Nevertheless, we would like to draw attention to the following aspects.

As Einstein has shown in his relativity theory, presence of heterogeneous masses leads to the distortion of 4-dimensional time-space in which our world exists. As a result Cartesian coordinates of the 4-dimensional Minkowski space (x, y, z, ict), including three ordinary Cartesian coordinates (x, y, z) and the forth formally introduced time-coordinate ict ($i = \sqrt{-1}$ – imaginary unit, c – speed of light in vacuum, t – time), become curvilinear [7].

It is also possible to approach the interpretation of Einstein's theory from other point of view, considering that the observed heterogeneous mass distribution is the consequence of really existing curvilinear coordinates (x, y, z, ict). Then the existence of masses in our world becomes the consequence of geometrical factors (presence of time-space and its curvature) and can be described in geometrical terms.

If we step away from global macro-phenomena that are described by the general relativity theory, and move to micro-world, where laws of quantum physics operate, we come to the same conclusion about the priority of time-space coordinates in the definition of all other physical values, mass included.

To demonstrate it, let us use the known Heisenberg's uncertainty ratio which is the fundamental consequence of non-relativistic quantum mechanics axioms and appears to be (e.g. [2]):

$$\Delta x \cdot \Delta v \geq \frac{\hbar}{2m_0}, \tag{1}$$

where Δx and Δv are mean square deviations of x coordinate and velocity v corresponding to the particle with (rest) mass m_0, $\hbar$ – Planck's constant. Considering values Δx and Δv to be measurable when their product reaches its minimum, we derive (from (1)):

$$m_0 = \frac{\hbar}{2 \cdot \Delta x \cdot \Delta v}, \tag{2}$$

i.e. mass of the particle is conveyed via uncertainties of its coordinate and velocity – time derivative of the same coordinate.

According to the concept [8, 9], space, time, and four fundamental physical interactions (gravitational, electromagnetic, strong and weak) are secondary notions. They share common origins and are generated by the so-called world matrix which has special structure and peculiar symmetrical properties. Its elements are complex numbers which have double transitions in some abstract pre-space.

At the same time, physical properties of space-time in this very point are defined by the nonlocal ("immediate") interaction of this point with its close and distant neighbourhood, and acquire statistical nature. In other words, the observed space coordinates and time has statistical nature.

In our opinion the afore-mentioned conception of nonlocal statistical origin of time and space coordinates can be qualitatively illustrated on the assumptions of quantum-mechanical uncertainty principle using known ratios (e.g. [2]) $\Delta p \cdot \Delta x \sim \hbar$, $\Delta E \cdot \Delta t \sim \hbar$; $\Delta p \cdot \Delta t \sim \frac{\hbar}{c}$.

Interpreting values $\Delta E, \Delta p, \Delta x, \Delta t$ as uncertainties of particle's energy E, its pulse p, coordinate x and time localization t, let us conduct the following reasoning.

While $\Delta x \to 0$ uncertainty of pulse, and thus particle energy, uncertainty formally becomes as big as possible that can be provided only by its significant and nonlocal energetical interaction with the rest of the neighbourhood. On the other side, while $\Delta p \to 0$ the particle gets smeared along the whole space, i.e. becomes delocalised. It might be supposed that the fact of "delocalised" state of the particle takes place in any other, not necessarily marginal Δx and Δp value ratios.

3. Dynamical Peculiarities of Economic Measurements, Economical Analogue of Heisenberg's Uncertainty Ratio

Speaking of economic laws, based on the results of both physical (e.g. quantities of material resources) and economical (e.g. their value) dynamic measurements, the situation will appear to be somewhat different. Adequacy of the formalisms used for mathematical descriptions has to be constantly checked and corrected if necessary. The reason is that measurements always imply a comparison with something, considered to be a model, while there are no constant standards in economics (they change not only quantitatively, but also qualitatively – new standards and models appear). Thus, economic measurements are fundamentally relative, are local in time, space and other socio-economic coordinates, and can be carried out via consequent and/or parallel comparisons "here and now", "here and there", "yesterday and today", "a year ago and now" etc.

Due to these reasons constant monitoring, analysis, and time series prediction (time series imply data derived from the dynamics of stock indices, exchange rates, spot prices and other socio-economic indicators) becomes relevant for evaluation of the state, tendencies, and perspectives of global, regional, and national economies.

Let us proceed to the description of structural elements of our work and building of the model. Suppose there is a set of M time series, each of N samples that correspond to the single distance T, with an equal minimal time step $\Delta t_{\min}$:

$$X_i(t_n), \;\; t_n = \Delta t_{\min} n; \;\; n = 0,1,2,...N-1; \;\; i = 1,2,...M. \tag{3}$$

To bring all series to the unified and non-dimensional representation, accurate to the additive constant, we normalize them, having taken a natural logarithm of each term of the series:

$x_i(t_n) = \ln X_i(t_n),\;\; t_n = \Delta t_{\min} n;\;\; n = 0,1,2,...N-1;\;\; i = 1,2,...M$.

Let us consider that every new series $x_i(t_n)$ is a one-dimensional trajectory of a certain fictitious or abstract particle numbered i, while its coordinate is registered after every time span $\Delta t_{\min}$, and evaluate mean square deviations of its coordinate and speed in some time window ΔT:

$\Delta T = \Delta N \cdot \Delta t_{\min} = \Delta N,\;\; 1 << \Delta N << N$.

The "immediate" speed of i particle at the moment t_n is defined by the ratio:

$$v_i(t_n) = \frac{x_i(t_{n+1}) - x_i(t_n)}{\Delta t_{\min}} = \frac{1}{\Delta t_{\min}} \ln \frac{X_i(t_{n+1})}{X_i(t_n)}, \tag{4}$$

with variance D_{v_i} and mean square deviation Δv_i.

To evaluate dispersion D_{x_i} coordinates of the i particle are used in an approximated ratio:

$$2D_{x_i} \approx D_{\Delta x_i}, \tag{5}$$

where

$$D_{\Delta x_i} = \;< (x_i(t_{n+1}) - x_i(t_n))^2 >_{n,\Delta N} - (< x_i(t_{n+1}) - x_i(t_n) >_{n,\Delta N})^2 =$$

$$= \;< \ln^2 \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} - \left(< \ln \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} \right)^2, \tag{6}$$

which is derived from the supposition that x coordinates neighbouring subject to the time of deviation from the average value $\bar{x}$ are weakly correlated:

$$< (x_i(t_n) - \bar{x})(x_{i+1}(t_n) - \bar{x}) >_{n,\Delta N} \approx 0. \tag{7}$$

Thus we get:

$$\Delta x_i = \sqrt{\frac{D_{\Delta x_i}}{2}} = \frac{1}{\sqrt{2}} \left(< \ln^2 \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} - \left(< \ln \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} \right)^2 \right)^{\frac{1}{2}}. \tag{8}$$

It is also worth noting that the value

$$|v_i(t_n)| \cdot \Delta t_{\min} = \left| \ln \frac{X_i(t_{n+1})}{X_i(t_n)} \right|,$$

which, accurate to multiplier $\Delta t_{\min}$ coincides with $|v_i(t_n)|$, is commonly named absolute returns, while dispersion of a random value $\ln\left(X_i(t_{n+1}) / X_i(t_n)\right)$, which differs from D_{v_i} by $(\Delta t_{\min})^2$ – volatility [10].

The chaotic nature of real time series allows to $x_i(t_n)$ as the trajectory of a certain abstract quantum particle (observed at $\Delta t_{\min}$ time spans). Analogous to (1) we can write an uncertainty ratio for this trajectory:

$$\Delta x_i \cdot \Delta v_i \sim \frac{h}{m_i}, \tag{9}$$

or:

$$\frac{1}{\Delta t_{\min}} \left(< \ln^2 \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} - \left(< \ln \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} \right)^2 \right) \sim \frac{h}{m_i}, \tag{10}$$

where m_i – economic "mass" of an i series, h – value which comes as an economic Planck's constant.

Having rewritten the ration (10):

$$\Delta t_{\min} \cdot \frac{m_i}{(\Delta t_{\min})^2} \left(< \ln^2 \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} - \left(< \ln \frac{X_i(t_{n+1})}{X_i(t_n)} >_{n,\Delta N} \right)^2 \right) \sim h \tag{11}$$

and interpreting the multiplier by $\Delta t_{\min}$ in the left part as the uncertainty of an "economical" energy (accurate to the constant multiplier), we get an economic analogue of the ratio $\Delta E \cdot \Delta t \sim \hbar$.

Since the analogy with physical particle trajectory is merely formal, h value, unlike the physical Planck's constant $\hbar$, can, generally speaking, depend on the historical period of time, for which the series are taken, and the length of the averaging interval (e.g. economical processes are different in the time of crisis and recession), on the series number i etc. Whether this analogy is correct or not depends on particular series' properties.

Generalization the ratios (10, 11) for the case, when economic measurements on the time span T is done in [10]. Thus, h/m_i ratio on the right side of (10) (or (11)) has to be considered a certain unknown function of the series number i , size of the averaging window ΔN , time $\overline{n}$ (centre of the averaging window), and time step of the observation (registration) k .

To get at least an approximate, yet obvious, formula of this function and track the nature of dependencies, we postulate the following model presentation of the right side (10):

$$\frac{h}{m_i} \cong \frac{\tau(\overline{n}, \Delta N_\tau) \cdot H_i(k, \overline{n}, \Delta N_H)}{\Delta t_{\min} \cdot m_i}, \tag{12}$$

where

$$\frac{1}{m_i} = \; < \varphi_i(n,1) >_{(0 \le n \le N-2)} , \tag{13}$$

m_i is a non-dimensional economic mass of an i – numbered series,

$$\tau(\overline{n}) = \frac{< \varphi_i(n,1,\Delta N_\tau) >_{(\overline{n} - \Delta N_\tau/2 \; < n < \; \overline{n} + \Delta N_\tau/2), \; (1 \le i \le M)}}{< \left(< \varphi_i(n,1,\Delta N_\tau) >_{(\overline{n} - \Delta N_\tau/2 \; < n < \; \overline{n} + \Delta N_\tau/2), \; (1 \le i \le M)} \right) >_{\overline{n}}} \tag{14}$$

– local physical time compression ($\tau(\overline{n}) < 1$) or magnification ($\tau(\overline{n}) > 1$) ratio, which allows to introduce the notion of heterogeneous economic time (for a homogenous $\tau(\overline{n}) = 1$), $H_i(k, \overline{n})$ – non-dimensional coefficient of the order of unit, which indicates differences in the dependence of variance $D_{\Delta x_i}$ (see (13) taking into account the case of $k \ge 1$) on the law $D_{\Delta x_i} \sim k$ for the given i and $\overline{n}$.

$$\varphi_i(n, k, \widetilde{N}) = \frac{1}{k} \left(\ln^2 \frac{X_i(t_{n+k})}{X_i(t_n)} - \left(< \ln \frac{X_i(t_{n+k})}{X_i(t_n)} >_{n,\widetilde{N}} \right)^2 \right) \tag{15}$$

and the multiplier $1/\Delta t_{\min}$ on the right side (12) can be considered as an invariant component of an economic Planck's constant h :

$$\overline{h} = 1/\Delta t_{\min} \; . \tag{16}$$

As you can see, $\overline{h}$ has a natural dimension "time" to the negative first power.

4. Experimental Results and Their Discussion

To test the suggested ratios and definitions we have chosen 9 economic series with $\Delta t_{\min}$ in one day for the period from April 27, 1993 to March 31, 2011. The chosen series correspond to the following groups that differ in their origin:

1) stock market indices: USA (S&P500), Great Britain (FTSE 100) and Brazil (BVSP);
2) currency dollar cross-rates (chf, jpy, gbp);
3) commodity market (gold, silver, and oil prices).

Figure 1 shows averaged coefficients of time $\tau(t)$ compression-expansion (formula (14)) for three groups of incoming series: currency (Forex), stock, and commodity markets.

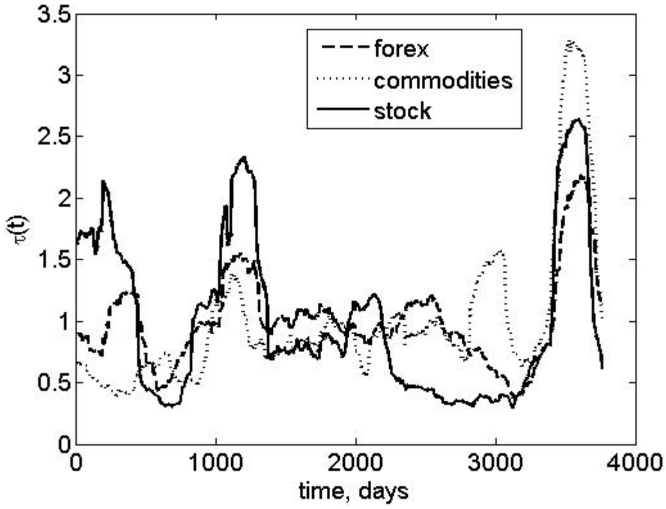

Figure 1. Coefficients of time compression-expansion, market "temperature". The explanation is in the text

The theory show that $\tau(t)$ exists in proportion to the averaged square speed (according to the chosen time span and series), i.e. average "energy" of the economical "particle" (as it is in our analogy), and can be thus interpreted as the series "temperature". Crises are distinguished with the intensification of economic processes (the "temperature" is rising), while during the crisis-free period their deceleration can be observed (the "temperature" is falling), what can be interpreted as the heterogeneous flow of economic time. $\tau(t)$ dependencies shown on Figure 1 illustrate all afore-mentioned. Note that local time acceleration-deceleration can be rather significant.

In Table 1 we give the values of a non-dimensional economic mass of the m_i series, calculated using (13) for all 9 incoming series, as well as average masses of each group [10].

Table 1. Economic series masses

Incoming series		Economic mass	Average economic mass of the group
Commodity market	gold	$2{,}816\cdot10^4$	$4{,}983\cdot10^3$
	silver	$4{,}843\cdot10^3$	
	oil	$2{,}777\cdot10^3$	
Currency market	jpy	$2{,}148\cdot10^4$	$2{,}499\cdot10^4$
	gbp	$3{,}523\cdot10^4$	
	chf	$2{,}180\cdot10^4$	
Stock market	S&P 500	$6{,}251\cdot10^3$	$4{,}748\cdot10^3$
	FTSE 100	$6{,}487\cdot10^3$	
	BVSP	$1{,}507\cdot10^3$	

As you can see from the Table 1, the stock market is distinguished with the lowest mass value, while the currency one shows the maximum number. Oil price series has the lowest mass on the commodity market, gold – the highest one. As for the currency market, British pound (gbp) has the highest value and Japanese yen rates (jpy) demonstrate the minimum mass of the group, although the dispersion is lower than that of the commodity market. The smallest spread is peculiar to the currency market. Dynamic and developing Brazilian market (BVSP) has the lowest mass, while the maximum value, just like in the previous case, corresponds to Great Britain (FTSE 100). It is explained by the well-known fact: Britain has been always known for its relatively "closed" economy as compared with the rest of the European and non-European countries.

The last group of experimental data corresponds to the dependence of Planck's economic constant (calculated for different series) on time $\Delta t = k\Delta t_{\min}$ (time between the neighbouring registered observations), which is characterized by $H_i(k,\bar{n})$ coefficient [10].

On Figure 2 integral dependencies $H_i(k)$ for stock market are depicted. As you can see there are no obvious regularities, which can be explained by various crises and recessions of the world and national economies that took place during the investigated period.

To decide whether it is possible for local regularities of Planck's economic constant dependence on Δt to appear, we have chosen relatively small averaging fragments, $\Delta N = 500$, which approximately equals two years. Corresponding results for some of these fragments on stock markets are given on Figure 3. Evidently figure show clear tendencies of $H_i(k,\overline{n})$ recession and rise for given type of the market (unlike integral dependencies $H_i(k)$).

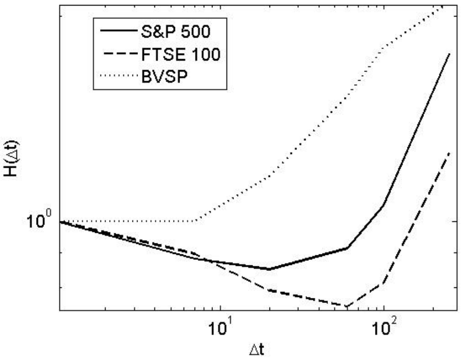

Figure 2. Integral coefficient $H_i(k)$ dependences for stock market

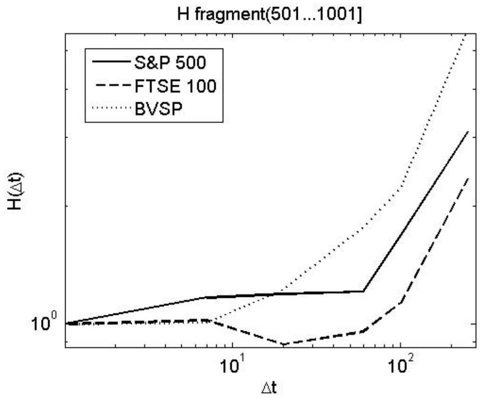

Figure 3. Local coefficient $H_i(k,\overline{n})$ dependences for stock market (averaging time span from 12.06.1995 to 15.07.1997, 500 daily values)

5. Conclusions

We have conducted methodological and philosophical analysis of physical notions and their formal and informal connections with real economic measurements. Basic ideas of the general relativity theory and relativistic quantum mechanics concerning space-time properties and physical dimensions peculiarities are used as well. We have suggested procedures of detecting normalized economic coordinates, economic mass and heterogeneous economic time. The afore-mentioned procedures are based on socio-economic time series analysis and economical interpretation of Heisenberg's uncertainty principle. The notion of economic Planck's constant has also been introduced. The theory has been tested on real economic time series, including stock indices, currency rates, and commodity prices.

References

1. Saptsin, V. M. and V. N. Soloviev. *Relativistic Quantum Econophysics. New paradigms of Complex Systems Modeling: Monograph.* Cherkassy: Brama-Ukraine, 2009.
2. Saptsin, V. and V. Soloviev. *Relativistic Quantum Econophysics - new Paradigms in Complex Systems Modelling* – e-prints: arXiv:0907.1142v1 [physics.soc-ph] 7 Jul 2009 .
3. Baaquie, B. E. *Quantum Finance*. Cambridge: Cambridge University Press, 2004.
4. Maslov, V. *Quantum Economics*. Moscow: Science, 2006.
5. Mantegna, R. N. and H. E. Stanley. *An Introduction to Econophysics: Correlations and Complexity in Finance.* Cambridge, UK: Cambridge Univ. Press, 2000.
6. Derbentsev, V. D., Serdyuk, A. A., Solovievand, V. N., Sharapov, O. D. *Synergetical and Econophysical Methods for the Modeling of Dynamic and Structural Characteristics of Economic Systems: Monograph.* Cherkassy: Brama-Ukraine, 2010. (In Ukrainian)
7. Landau, L., Lifshitz, E. *The Classical Theory of Fields. Course of Theoretical Physics*. – Butterworth Heinemann, 1975. http://books.google.com/books?id=X18PF4oKyrUC.
8. Vladimirov, Y. S. *A Relational Theory of Space-Time Interactions*. Moscow: MGU, 1996. Part 1.
9. Vladimirov, Y. S. *A Relational Theory of Space-Time Interactions*. Moscow: MGU, 1996. Part 2.
10. Soloviev, V. and V. Saptsin *Heisenberg Uncertainty Principle and Economic Analogues of Basic Physical Quantities* – e-prints: arXiv:1111.5289v1 [physics.gen-ph] 10 Nov 2011

Received on the 11th of September, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 27–36
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

ON-LINE CONTROL MODELS FOR MULTI-LEVEL CONSTRUCTION SYSTEMS

***D. Golenko-Ginzburg*[1], *D. Greenberg*[2]**

[1]*Department of Industrial Engineering and Management*
Ben-Gurion University of the Negev
Beer-Sheva, 84105, Israel
and Department of Industrial Engineering and Management
Ariel University Center (AUC) of Samaria, 44837, Israel
E-mail: dimitri@bgu.ac.il

[2]*Department of Economics and Business Administration*
Faculty of Social Sciences
Ariel University Center (AUC) of Samaria, 40700, Israel
E-mail: dorongreen2@gmail.com

A building company, which simultaneously monitors several contractors, is considered. Each contractor operates a building project (house, factory, hospital, etc.) consisting of a chain of operations to be processed in an individual definite technological sequence. Each project's operation utilizes qualified resources of various specialties, i.e., several non-consumable resources with fixed capacities (manpower, scrappers, etc.). For any operation in progress, all the resources remain unchanged until the operation terminates. Each type of resources at the company's disposal is in limited supply, is predetermined and the resource limit remains unchanged at the same level throughout the project's realization, i.e., until the last project is actually completed. Thus, due to the limited resource levels, project's operations may have to wait in lines for resource supply, in order to proceed functioning.

The problem is solved by means of a heuristic algorithm by a combination of the cyclic coordinate descent method (at the upper level) and a simulation scheduling model (at the lower level). Resource allocation between the projects waiting in lines is carried out via an embedded newly developed decision rule. This rule enables to support projects with high delay penalties at the expense of projects with low penalties in the process of the projects' realization.

Keywords: *Building projects; Decision-making rule; Renewable resources; Resource allocation; Simulation model*

1. Introduction

Large-scale construction (building) projects are nowadays one of the most essential parts of the modern technical progress. Such projects are usually monitored by two-level project management (PM) companies. At the upper level (the company level) PM managers transfer to the lower level (the project level) various goal parameters for the projects' contractors. The latter actually determine and implement all the planning, control and scheduling procedures for the corresponding individual building projects in order to amend the project's situation.

It can be well-recognized [8, 11] that to-day a building company does not determine neither any on-line control nor scheduling techniques for the subordinated projects; neither does the company undertake even quasi-optimal resource reallocation among the projects. This is because those techniques do not exist as yet. Each contractor undertakes individual decision-making in order to optimise (or, better to say, to refine) his own project's parameters, independently on other company's projects. Such actions, being useful for a single project, may result in heavy financial losses for a building company as a whole. This is because building resources are usually restricted and, thus, projects are not independent. For those projects the unification of local optimums may be very far from a global one.

The goal of our paper is to determine both planning and control procedures (including resource reallocation) for the company level. Those actions are input parameters for the lower level, where only scheduling procedures are left at the contractors' disposal.

In our opinion, such a two-level model, being a novel one, will help the building companies to avoid financial losses. Since building resources are usually restricted, a clever heuristic resource manoeuvring has to be introduced. All this makes the developed paper truly urgent.

2. The Problem's Description

A building company, which simultaneously monitors several contractors, is considered. Each contractor operates a building project (house, factory, hospital, etc.) consisting of a chain of operations to be processed in an individual definite technological sequence.

Each project's operation utilizes qualified resources of various specialties, i.e., several non-consumable resources with fixed capacities (manpower, scrappers, etc.). For any operation in progress, all the resources remain unchanged until the operation terminates.

Each type of resources at the company's disposal is in limited supply, is predetermined and the resource limit remains unchanged at the same level throughout the project's realization, i.e., until the last project is actually completed. Thus, due to the limited resource levels, project's operations may have to wait in lines for resource supply, in order to proceed functioning. Since for each operation its duration is a random variable with given density function, a deterministic schedule of the moments when operations actually start cannot be pre-determined. Note that such simultaneously realized projects with consecutive operations cover a broad variety of different management structures, especially aggregated building projects [8].

The system under consideration is based on a single storehouse where all the resources are stored and, if necessary, send to a certain contractor. After finishing an operation all the resources undertaking that operation are returned to the storehouse. Assume that all building projects start functioning at $t = 0$. Assume, further, that the company externally receives from the customers in advance, i.e. before moment $t = 0$, the cost of all finished building projects. This cost covers the following expenses:

I. The cost of hiring and maintaining all the resources within all the projects' realization, i.e. starting from $t = 0$ and finishing at the moment the last project will be finished.

II. Delay penalties. The company has to pay for each i-th project a certain penalty C_i per time unit within the project's duration, i.e. from $t = 0$ until the finishing time F_i, when the project is finished and is delivered to the customer.

The problem is as follows:

- to determine beforehand the optimal total resource capacities of all types of resources at the building company's disposal within the projects' realization and
- to determine random values of the moments the projects' operations actually start (in the course of the projects' realization, conditioned on our decision rules and based on the total predefined resource values),
- in order to minimize the average of the company's expenses (including the penalties to the customers). We introduce average values since the durations of the projects' realizations are random values.

The problem is solved via a heuristic algorithm by a combination of the cyclic coordinate descent method [6] (at the upper level) and a simulation scheduling model (at the lower level). Resource allocation between the projects waiting in lines is carried out via an embedded newly developed decision rule. This rule enables to support projects with high delay penalties at the expense of projects with low penalties in the course of the projects' realization.

3. Notation

Let us introduce the following terms:

n – number of building project BP_i, $1 \le i \le n$, to be realized simultaneously;

$O_{i\ell}$ – the ℓ-th operation of the i-th project in the form of a consecutive chain, $1 \le \ell \le m_i$;

m_i – number of operations in project BP_i;

$t_{i\ell}$ – random duration of operation $O_{i\ell}$;

$\bar{t}_{i\ell}$ – average value of $t_{i\ell}$ (pregiven);

$V_{i\ell}$ – variance of $t_{i\ell}$ (pregiven);

R_k – the total capacity of the k-th type of resources, $1 \le k \le d$, at the disposal of the building company (a deterministic value to be optimised);

d – number of resources;

$r_{i\ell k}$ – the k-th resource capacity required by operation $O_{i\ell}$ (pregiven);

$S_{i\ell}$ – the moment operation $O_{i\ell}$ actually starts (a random value, to be determined by the simulation model via a decision rule in the course of realizing the projects);

$F_{i\ell} = S_{i\ell} + t_{i\ell}$ – the moment operation $O_{i\ell}$ terminates (a random value);

C_i – penalty the building company pays per time unit within the BP_i's duration (pregiven, a constant value);
$F_{i\ell}$ – the moment operation $O_{i\ell}$ terminates (a random value);
F_i – the moment project BP_i terminates, $F_i = S_{im_i} + t_{im_i}$ (a random value);
F – the moment the last project terminates, $F = \underset{i}{Max}\, F_i$;
$W_k\{S_{i\ell}, t\}$ – the summarized capacity of the k-th resource assigned to operations at moment t, on condition that operations $O_{i\ell}$ starts at moments $S_{i\ell}$, $1 \le k \le d$;
$R_k(t) = R_k - W_k(S_{i\ell}, t)$ – free available resources of k-th type at moment t;
$\vec{R}_k^*(t) \subset \vec{R}_k(t)$ – a part of free available resources to be set aside for the tense project;
S_k – the cost of hiring, maintaining and utilizing the k-th resource unit at the time unit $1 \le k \le d$, (pregiven, a constant value);
ΔR_k – the positive search step value to optimise variable R_k, $1 \le k \le d$ (pregiven);
ε – the relative accuracy value to obtain an optimal solution (pregiven);
$R_{k\ \min}$ – the minimal possible level for the total capacity R_k, $1 \le k \le d$ (pregiven by experts);
$R_{k\ \max}$ – the maximal possible level for value R_k, $1 \le k \le d$ (pregiven);
$Q^{(sim)}$ – simulated system's expenses by one simulation run;
$\overline{Q}$ – the system's average total expenses.

Note that the following relations hold:

$$R_{k\ \min} \ge \underset{i}{Max}\ \underset{\ell}{Max}\ r_{i\ell k}\,, \tag{1}$$

$$R_{k\ \max} \le \sum_i \left\{ \underset{1 \le \ell \le m_i}{Max}\ r_{i\ell k} \right\}, \tag{2}$$

$$R_{k\ \min} \le R_k \le R_{k\ \max}\,,\ 1 \le i \le n\,,\ 1 \le \ell \le m_i\,,\ 1 \le k \le d\,. \tag{3}$$

Restriction (1) is evident since otherwise some of the projects cannot be realized at all. If (2) does not hold a certain part of resources will not participate in the projects' realization.

4. The Problem's Formulation

The problem is to determine both optimal deterministic values R_k, $1 \le k \le d$, (before the projects' realization) and random values $S_{i\ell}$ (in the course of the projects' realization and conditioned on our decisions), $1 \le i \le n$, $1 \le \ell \le m_i$, to minimize the average of the total expenses:

$$\underset{[R_k, S_{i\ell}]}{Min}\ \overline{Q} = Min\ E\left\{ \sum_{i=1}^{n} C_i F_i + F \cdot \sum_{k=1}^{d} S_k R_k \right\}. \tag{4}$$

It can be well-recognized that the first summand denotes the total amount of penalties paid to the customers while the second one denotes the total expenses of hiring and maintaining building resources. Note that both summands are random values since F, F_i, $1 \le i \le n$, are random as well.

5. The Problem's Solution

Problem (4) is an extremely complicated problem, which cannot be solved by using regular methods. Thus, we will use heuristic approaches.

The suggested heuristic algorithm to solve the problem comprises two levels. At the lower level (the internal cycle) the simulation model undertakes numerous simulation runs in order to manage the project's realization. At the upper level (the external cycle) the heuristic search sub-algorithm undertakes cycle coordinate optimisation in order to obtain the optimal vector $\vec{R}_k$. The procedure of the optimisation is based on optimising objectives cyclically with respect to coordinate variables $R_1, R_2, ..., R_d$. Coordinate R_1 is optimised first, then R_2, and so forth through R_d. The cyclic coordinate search algorithm (CCSA) [6] is widely known and is very efficient in various optimisation problems with complicated, mostly non-linear restrictions.

At the lower level a decision-making simulation model has to be implemented. The input data of the simulation model is the vector of total resource capacities $\vec{R}_k$, $1 \le k \le d$, which is determined in the course of the coordinate descent algorithm's work. Thus, in the course of a routine simulation run, vector $\{R_k\}$ is fixed and remains unchanged. It goes without saying that vector $\vec{R}_k$ satisfies (1–3).

The main task of the simulation model is to determine (in the course of a simulation run) random starting moments $S_{i\ell}$ of all operations $O_{i\ell}$, $1 \le i \le n$, $1 \le \ell \le m_i$, entering the model.

A routine simulation run starts functioning at $t = 0$ and terminates with the completion of the last project. The simulation model comprises three sub-models as follows:

Sub-model I actually governs most of the procedures to be undertaken in the course of the projects' realization, namely:

- determines essential moments (decision points) when projects may be supplied with free available resources. A routine essential moment usually coincides either with the moment $F_{i\ell}$ an operation is finished and additional resources become available, or when a subset of new operations $O_{i\ell}$ becomes ready to be processed;
- singles out (at a routine decision point) all the operations that are ready to be processed;
- returns the utilized non-consumable resources to the company's store (at the moment an operation is finished);
- determines the remaining projects at each routine decision point;
- determines the completion moment for each project.

Sub-model II comprises decision rules to reallocate free available resources at each decision moment t among operations waiting for resources. In order to determine decision rules penalty values C_i have to be taken into account.

We have developed an entirely new decision rule based on a combination of forecasting models, classical zero-one programming problems and "tense" scheduling models [1–5, 7, 9–10].

Sub-model III supplies the chosen operations $O_{i\ell}$ with resources by means of Sub-model II and later on simulates the corresponding durations $t_{i\ell}$ (for projects, which are waiting in lines to be provided with resources).

Note that realizing Sub-models II and III results in complicated procedures with new sophisticated logistics.

The enlarged procedure of the problem's solution is presented in Figure 1.

6. Decision-Making in the Simulation Model

The basic idea of decision-making within the simulation model's realization is to choose projects' operations $O_{i\ell}$ to be supplied with resource from the line of projects ready to be operated. Determining values $S_{i\ell}$ is carried out at essential moments t (see Section 5) via a newly developed heuristic decision-making rule.

Given at a routine decision point $t \ge 0$:

- f project – operations $O_{i_1\ell_1}$, $O_{i_2\ell_2}, \cdots, O_{i_f\ell_f}$ ready to be processed, $1 \le i_g \le n$, $1 \le \ell_g \le m_{ig}$, $1 \le g \le f$; call henceforth subset $\{O_{i_g\ell_g}\}$ subset B.
- $\{R_k\}$–total resource capacities $R_1, \cdots, R_d$ determined in the course of coordinate optimisation at the upper level. Vector $\vec{R}_k$ remains unchanged within a routine simulation run;
- $r_{i\ell_k}$ – the k-th resource capacity required by $O_{i\ell}$ (pregiven and unchanged in the course of the problem's solution);
- $\bar{t}_{i\ell}, V_{i\ell}$ – parameters of $O_{i\ell}$, $1 \le i \le n$, $1 \le \ell \le m_i$, (pregiven and unchanged within the problem's solution);
- $R_k(t)$ – free available resources from the storehouse, $1 \le k \le d$, at decision point t (a random vector conditioned on our decisions);
- cost values C_i, $1 \le i \le n$,

– the decision rule boils down to determine integer values $\xi_{i_g\ell_g}$, $1 \le g \le f$, where

$$\xi_{i_g\ell_g} = \begin{cases} 0 & \text{if} \quad \text{project's operation } O_{i_g\ell_g} \text{ will not obtain resources at moment } t; \\ 1 & \qquad \text{otherwise}. \end{cases} \tag{5}$$

We will develop the decision-making rule by integrating together tense heuristic decision rules [3–5], forecasting heuristic rules [5] and the classical zero-one programming model [10].

In order to undertake decision-making we need to solve a subsidiary problem to be outlined below.

7. Subsidiary Problem (Problem A)

Problem A, which has to be solved at any decision point t, is as follows:

For all project's operations $O_{j_h\ell_h} \subset \{O_{i\ell}\} \setminus \{O_{i_g\ell_g}\}$, which at the moment t are under way, calculate the mean values of their termination moments $F_{j_h\ell_h}$ on condition that the latter exceed value t. To solve that problem, one has to determine for a pregiven random value $t_{j_h\ell_h}$ and the actually determined value $S_{j_h\ell_h}$ (conditioned on our past decision making) the mean value of the termination moment $F_{j_h\ell_h}$ on condition that $F_{j_h\ell_h} > t$.

Note, that in the general case, we deal with a classical statistical problem of calculating the conditional mean value

$$E\{\alpha/\alpha > \Delta\} = \frac{1}{1 - F_\alpha(\Delta)} \int_\Delta^\alpha x\, f_\alpha(x) dx, \tag{6}$$

where $F_\alpha(x)$ is the cumulative probability function

$$F_\alpha(x) = \int_{-\infty}^x f_\alpha(y) dy. \tag{7}$$

We have determined values $E(\alpha/\alpha > \Delta)$ analytically for three distributions of random processing time of the operations [4]:

a) normal distribution with mean $\bar{t}_{i\ell}$ and variance $V_{i\ell}$;

b) uniform distribution in the interval $\left[\bar{t}_{i\ell} - 3\sqrt{V_{i\ell}},\ \bar{t}_{i\ell} + 3\sqrt{V_{i\ell}}\right]$;

c) exponential distribution with value $\lambda = 1/\bar{t}_{i\ell}$.

For the experimental distribution with the p.d.f. $f_\alpha(x) = \lambda e^{-\lambda x}$ using (6–7) results in

$$E(\alpha/\alpha > \Delta) = \Delta + \frac{1}{\lambda}. \tag{8}$$

In the case of a uniform distribution in [a, b], i.e. for p.d.f. $f_\alpha(x) = \frac{1}{b-a}$,

$$E(\alpha/\alpha > \Delta) = \frac{b + \Delta}{2}. \tag{9}$$

For the normal distribution with parameters (a, σ^2), i.e., for p.d.f. $f_\alpha(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(x-a^2)}{2\sigma^2}}$, we obtain

$$E(\alpha/\alpha > \Delta) = a + \frac{\sigma e^{-(\Delta-a)^2/2\sigma^2}}{\sqrt{2\pi}\left[1 - \phi\left(\frac{\Delta - a}{\sigma}\right)\right]}, \tag{10}$$

where $\phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{y^2}{2}} dy$.

Thus, to obtain value

$$E\left(F_{j_h b_h} / S_{j_h b_h}, \bar{F}_{j_h b_h} > t\right), \tag{11}$$

we need to substitute in (6) values Δ for $t - S_{j_h b_h}$ and $F_{j_h b_h}$ for $t_{j_h b_h}$, while the p.d.f. $f_\alpha(x)$ depends on the probability laws (8–10).

8. Step-Wise Decision-Making Heuristic Procedure

Determining values $\xi_{i_g \ell_g}$ (see Section 4) can be realized by means of the following step-wise procedure:

Step 1. Determine the indices of the building projects BP_i to be realized at moment t in the descending order of their penalty values C_i.

Project PB_1 is called the tense project since it defines often the bottleneck of the system. Subset B has to be reordered in the same manner.

Step 2. At a routine decision moment t carries out a check: does the tense project enter subset $\widehat{B}$ or not? If yes, apply the next step. Otherwise go to *Step 13*.

Step 3. Carry out a check: is it possible to supply at moment t the tense project with needed resources from the company store or not? In other words, do relations

$$R_k(t) \ge r_{1\ell_1 k}, \qquad 1 \le k \le d \tag{12}$$

hold, where ℓ_1 denotes the index of operation the tense project has to undergo at moment t? If (12) holds, apply the next step. Otherwise go to *Step 7*.

Step 4. Exclude the tense project form subset B and update vector $\vec{R}_k(t)$ of free available resources

$$R_k(t) - r_{1\ell_1 k} \Rightarrow R_k(t), \qquad 1 \le k \le m. \tag{13}$$

Step 5. Solve the zero-one programming problem to be formulated as follows: determine integer values $\xi_{i_g \ell_g}$, $1 \le g \le f-1$, to maximize the objective

$$\underset{\{\xi_{i_g \ell_g}\}}{Max} \left\{ \sum_{g=1}^{f-1} \left[C_{i_g} \cdot \bar{t}_{i_g l_g} \cdot \xi_{i_g \ell_g} \right] \right\} \tag{14}$$

subject to

$$\sum_{g=1}^{f-1} \left\{ \xi_{i_g \ell_g} \cdot r_{i_g \ell_g k} \right\} \le R_k(t), \qquad 1 \le k \le m, \tag{15}$$

where $\xi_{i_g \ell_g}$ is defined by (5).

Problem (5, 14–15) is a classical zero-one integer programming problem. Its solution is outlined in many books on operation research, e.g. in [10]. Note that maximizing objective (14) results in the policy as follows: the project management takes all measures to operate first projects, which being realized, decrease more essentially the total penalty the building company has to pay for the projects' prolongation. Only afterwards does the management take care of projects with smaller penalties.

Step 6. After feeding-in-resources for the chosen building projects go to *Sub-model I* (see *Section 5*), and the projects' realization proceeds until the next decision point will be reached.

Step 7. Examine all projects' operations $O_{j_h b_h}$, which at moment t are under way. Let the number of those operations be q.

For each operation $O_{j_h b_h}$, $1 \le h \le q$, solve subsidiary *Problem A* in order to calculate the conditional mean values of the operations' termination moments. Denote those mean values by $\{\overline{F}_{j_h b_h}\}$.

Step 8. Choose value $\overline{F}_{j_\gamma b_\gamma} = \min_{1 \le h \le q} \overline{F}_{j_h b_h}$.

Step 9. Carry out a check: is the amount of available resources from the company's store $\vec{R}_k(t)$ together with additional resources $\vec{r}_{j_\gamma b_\gamma k}$, which will become available from $O_{j_\gamma b_\gamma}$ at moment $t^* = \overline{F}_{j_\gamma b_\gamma} > t$, be enough for operating the tense project BP_1 at moment t^*? In other words, will relations

$$R_k(t) + r_{j_\gamma b_\gamma k} > r_{1\ell_1 k}, \quad 1 \le k \le d, \tag{16}$$

hold?
If yes, apply the next step. Otherwise go to *Step 12*.

Step 10. Determine resource vector

$$R_k^*(t) = r_{1\ell_1 k} - r_{j_\gamma b_\gamma k}, \quad 1 \le k \le d, \tag{17}$$

to be stored and set aside for the tense project.

Step 11. Update free available resources

$$R_k^*(t) - R_k^*(t) \Rightarrow R_k(t), \quad 1 \le k \le d. \tag{18}$$

Go to *Step 5*. Later on apply *Sub-model I.*
Note that applying *Step 5* from *Step 11* differs essentially from applying *Step 5* from *Step 4*. In the latter case the tense project is supplied with resources and starts processing at moment t. If (16) does not hold, the tense project remains in the line until operation $O_{j_\gamma b_\gamma}$ terminates.

Step 12. Applying this step means that, as it stands now, it is impossible to proceed functioning the building projects from sub-set B. Therefore we suggest not supplying resources for any project operation $\{O_{j_g \ell_g}\}$ until the next decision moment. Go to *Sub-model I.*

Step 13. Applying this step means that the tense project BP_1 is under way and is realized in the course of processing operation O_{1b_h}. Examine the results of *Step 7* in order to determine the mean value $\overline{F}_{1b_h}$ of the operation's finishing time. Since value $\overline{F}_{1b_h}$ is calculated at moment t, we will denote this value by $\mathrm{T}_1(t) > t$.

Step 14. Using the results of *Step 7* for all other building projects (besides the tense one), enumerate all time values $\overline{F}_{j_h b_h}$ in descending order.

Step 15. Carry out a check: does at least one project exist with the corresponding conditional mean value $\overline{F}_{j_h b_h}$ satisfying

$$t < \overline{F}_{j_h b_h} < \mathrm{T}_1(t). \tag{19}$$

If yes, then the forthcoming tense building project has to be examined not at moment t, but at the closest next decision moment $F_{j_h b_h}$. If (19) holds *Step 16* has to be applied. Otherwise go to *Step 17*.

Step 16 is similar to *Step 5* with only one exception: integer values $\xi_{i_g \ell_g}$ in zero-one programming model are determined for all f projects' operations $O_{i_g \ell_g}$ with non-updated free available resources $\vec{R}_k(t)$. After solving the modified problem (5, 14, 15) go to *Step 6*.

Step 17 is applied in case when the tense project terminates (according to the conditional forecasting) before all other projects, which are under way. Here a check has to be carried out as follows: does at least one project exist in subset B (i.e., among projects ready to be operated and seeking for resources), which after starting at moment t, will terminate before the moment $\mathrm{T}_1(t)$, which has been calculated at *Step 13*. Thus, inequalities

$$t + \bar{t}_{i_g \ell_g} < \mathrm{T}_1(t), \quad 1 \le g \le f \tag{20}$$

have to be checked for all f projects entering subset B.
If at least one project satisfying (20) does exist, apply the next step. Otherwise go to *Step 24*.

<u>Step 18</u>. Single out all projects entering B and satisfying (20) and enumerate them anew. Let them be projects-operations

$$O_{v_s w_s}, \quad 1 \le s \le f^* \le f, \tag{21}$$

where f^* is the number of projects satisfying (20).

<u>Step 19</u>. Solve zero-one programming model as follows: determine integer values $\xi_{v_s w_s}$, $1 \le s \le f^*$, to maximize the objective

$$\underset{\{\xi_{v_s w_s}\}}{Max} \left\{ \sum_{s=1}^{f*} \left[C_{v_s} \cdot \bar{t}_{v_s w_s} \cdot \xi_{v_s w_s} \right] \right\} \tag{22}$$

subject to

$$\sum_{s=1}^{f*} \left\{ \xi_{v_s w_s} \cdot r_{v_s w_s k} \right\} \le R_k(t), \tag{23}$$

$\xi_{v_s w_s}$ being defined by (5).

<u>Step 20</u>. If problem (5, 22–23) has at least one non-zero solution, supply the corresponding projects' operations with needed resources. Projects' operations $O_{v_s w_s}$, which failed to obtain resources, are sent back to subset B .

<u>Step 21</u>. Update the free available resources $R_k(t)$, $1 \le k \le d$, as follows:

$$R_k(t) - \sum_{s=1}^{f*} \left[\xi_{v_s w_s} \cdot r_{v s w_s k} \right] \Rightarrow R_k(t), \quad 1 \le k \le d \ . \tag{24}$$

<u>Step 22</u>. Enumerate the remaining projects' operations in subset B anew, i.e., in decreasing order of their penalties C_i . Define those operations by $O_{x_s z_s}$, $1 \le s \le f^{**}$.

<u>Step 23</u>. Solve one-zero programming problem (5, 22–23) for f^{**} remaining operations $O_{x_s z_s}$ and updated free resources (24). If the problem's solution includes non-zero integer values, supply the corresponding operations with needed resources. Go to *Step 6*, i.e., proceed with the building system's functioning at moment t until the next decision moment.

<u>Step 24</u>. Applying this step means that, according to our "look ahead" forecasting, the tense project's termination moment will be the next adjacent decision moment, i.e., the closest one to moment t . That means that even at moment $\mathrm{T}_1(t)$ the tense project cannot be supplied with resources.

Take all the conditional mean values of termination moments for all operations of the project, which are under way. Supplement this list with mean values of termination moments for all operations of the project waiting in the line for resources at moment t , (i.e. entering subset B) <u>in case that they will be supplied with resources at that moment</u>. Thus, the joint list includes q mean values $\bar{F}_{j_h b_h}$, $1 \le h \le q$, and f mean values $t + \bar{t}_{i_g \ell_g}$, $1 \le g \le h$. Enumerate the joint list in descending order. To simplify the terminology, define the operations entering the list by O_η, $1 \le \eta \le q + f$, their corresponding penalty values – by C_η , resource vectors – by $\vec{r}_\eta$, the mean values of the operations' termination moments – by $\bar{\mathrm{T}}_\eta$ (where the minimal value $\bar{\mathrm{T}}_{q+f} = \mathrm{T}_1(t)$ refers to the tense project).

<u>Step 25</u>. Analyse sequence $\{\bar{\mathrm{T}}_\eta\}$, element after element, starting from $\eta = f + q - 1$, <u>in the reverse direction</u>, i.e. by diminishing η by one consecutively. Undertake a check: is the operation O_η under way or does it enter subset B . If O_η is under way, apply the next step. Otherwise go to *Step 27*.

Step 26 is similar to *Step 5* and results in solving the zero-one programming problem as follows: determine integer values $\xi_{i_g \ell_g}$, $1 \le g \le f$, to maximize the objective

$$\underset{\{\xi_{i_g \ell_g}\}}{Max} \left\{ \sum_{g=1}^{f} C_{i_g} \cdot \bar{t}_{i_g l_g} \cdot \xi_{i_g \ell_g} \right\}$$

subject to

$$\sum_{g=1}^{f-1} \left\{ \xi_{i_g \ell_g} \cdot r_{i_g \ell_g k} \right\} \le R_k(t), \quad 1 \le k \le m , \tag{25}$$

$\xi_{i_g \ell_g}$ being defined by (5).

Supply the corresponding operations with resources (in case of non-zero solutions) and go to *Step 6*.

Step 27. This step is applied in the case when O_η enters subset B and is waiting for required resources. If relation

$$\vec{R}_k(t) > \vec{r}_\eta \tag{26}$$

holds, i.e., operation O_η can be supplied at moment t with available resources, apply the next step. Otherwise go to *Step 29*.

Step 28. Update the free available resources $\vec{R}_k(t)$

$$\vec{R}_k(t) - \vec{r}_\eta \Rightarrow R_k(t). \tag{27}$$

Step 29. Update

$$B \equiv \left\{ O_{i_g \ell_g} \right\} \setminus O_\eta \Rightarrow B , \tag{28}$$

$$f - 1 \Rightarrow f , \tag{29}$$

and the counter η

$$\eta - 1 \Rightarrow \eta , \tag{30}$$

if $\eta = 0$ go to *Step 6*. Otherwise go to *Step 24*, i.e., proceed examining $\{O_\eta\}$ in the reverse direction.

It can be well recognized that the main purpose of Steps 24–29 is to bring the decision moment, which happens next after moment $\mathrm{T}_1(t)$, as close as possible to that moment. That is because at moment $\mathrm{T}_1(t)$ the tense project's operation terminates and the project cannot be supplied with resources at that moment. Thus, the next decision moment is needed as soon as possible. To conclude, the general goal of our heuristic is to push the tense project through the building process. After the tense project terminates, another remaining project with the maximal penalty value C_i will take his place.

9. Cyclic Coordinate Search Algorithm (CCSA)

As mentioned above, the suggested heuristic algorithm to solve the problem comprises two levels. At the lower level (the internal cycle) the simulation model undertakes numerous simulation runs in order to manage the projects' realization. At the upper level (the external cycle) the heuristic search sub-algorithm undertakes cyclic coordinate optimisation in order to obtain the optimal vector $\vec{R}_k$. The procedure of the optimisation is based on optimising objective (4) cyclically with respect to coordinate variables $R_1, R_2, \cdots, R_d$. Coordinate R_1 is optimised first, then R_2, and so forth through R_d. The coordinate descent method is widely known [6] and is very efficient in various optimisation problems with complicated, mostly non-linear, objectives.

10. Conclusions

The following conclusions can be drawn from the study:

1. The construction industry is very large, complex, and different from other industries. The industry needs much investment and involves various types of stakeholders and participants. A construction process is a continuous one, usually spread over a number of years. Modern construction projects are usually monitored by two-level PM companies.
   It can be well-recognized that to-day a building company does determine neither any on-line control nor scheduling techniques for the subordinated projects; neither does the company undertake even quasi-optimal resource reallocation among the projects. This is because those techniques do not exist as yet. Each contractor undertakes individual decision-making in order to optimise (or, better to say, to refine) his own project's parameters, independently on other company's projects. Such actions, being useful for a single project, may result in heavy financial losses for a building company as a whole. This is because building resources are usually restricted and, thus, projects are not independent. For those projects the unification of local optimums may be very far from a global one.
2. The goal of the paper is to determine both planning, control and scheduling procedures, including resource reallocation, at the company level. Those actions are input parameters for the lower level, where only scheduling procedures are left at the contractor's disposal. The objective is to minimize the average of the building company's expenses.
3. The problem is solved by means of a heuristic algorithm through a combination of a cyclic coordinate descent method at the upper level and a decision-making simulation model at the lower level.
4. Resource reallocation between the projects waiting in lines is carried out via a newly developed decision rule.
5. The novelty of the paper can be defined by:
   - the problem's formulation, which is actually a generalization of formerly developed decision-making simulation models, and
   - by introducing a more effective decision-making rule than the existing ones. The latter are based on one performance rule while our approach is based on a combination of several most effective preference rules together with forecasting models and a classical zero-one programming problem.
6. The efficiency of the developed model has been verified by means of numerical examples and by comparison with other existing heuristics.
7. In our opinion, the results obtained can be used in future by a variety of large building and construction companies, as well as by governmental agencies.

References

1. Barker, J. R. and Graham, B. M. Scheduling the General Job-Shop, *Mgmt. Sci*., Vol. 31, No 5, 1985, pp. 594–598.
2. Coffman, E. G. *Computer and Job-Shop Scheduling Theory*. New York: Wiley, 1976.
3. Gere, W. S. Heuristics in Job Shop Scheduling, *Mgmt. Sci*., Vol. 13, No 3, 1966, pp. 167–190.
4. Golenko-Ginzburg, D. and Gonik, A. Using "Look Ahead" Techniques in Job-Shop Scheduling with Random Operations, *International Journal of Production Economics*, Vol. 50, 2005, pp. 13–22.
5. Golenko-Ginzburg, D., Ben-Yair, A. and Greenberg, D. Comparative Efficiency of Preference Rules in Large Industrial Scheduling, *Communications in Dependability and Quality Management*, Vol. 8, No 2, 2005, pp. 37–52.
6. Luenberger, D. G. *Linear and Non-Linear Programming*, 2nd ed. Massachusetts: Addison-Wesley, 1989.
7. Panwalker, R. and Iskander, W. A Survey of Scheduling Rules, *Operations Research*, Vol. 25, No 1, 1977, pp. 45–59.
8. Ritz, G. J. *Total Construction Project Management*. New-York: McGraw Hill, 1994.
9. Sculli, D. Priority Dispatching Rules in an Assembly Shop, *Omega*, Vol. 15, No 1, 1987, pp. 49–57.
10. Taha, H. A. *Operations Research: AN Introduction*. New-York: Collier Macmillan, 1997.
11. Voropajev, V. I. *Project Management in Russia*. Pennsylvania: Project Management Institute, 1997.

Received on the 23rd of October, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 37–48
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

WEB SYSTEMS AVAILABILITY ANALYSIS BY MONTE-CARLO SIMULATION

T. Walkowiak

Institute of Computer Engineering, Control and Robotics
Wroclaw University of Technology
ul. Janiszewskiego 11/17, 50-372 Wroclaw, Poland
E-mail: Tomasz.Walkowiak@pwr.wroc.pl

The paper describes an availability analysis of Web systems. The analysed system is modelled as a set of tasks that use data, obtained in an interaction with other tasks, to produce responses. System reliability is described by a failure and repair process of system elements. Whereas repair time model takes into account working hours and weekends of the maintain crew. The reliability is measured by a system availability calculated by a Monte-Carlo based simulator. Due to maintain crew working hour model the achieved availability function is periodic (with one week period). Next, functional aspects of a web system are measured by a functional availability, i.e. the probability that a client's will receive response within a given time limit. The metric is calculated by simulation software developed by authors. The web system simulation takes into account the consumption of computational resources (host processing power) and input system load changing in time. Finally, the service availability is defined, which compromises the reliability and functional parameters as well as an input load of the system. Simulation results for a testbed system are given.

Keywords: *web system, reliability, availability, Monte-Carlo simulation*

1. Introduction

The Web systems are currently becoming the core infrastructure of almost all business activities. They belong to a class of complex systems as a result of the large number of components and their complicated interactions. As more and more web systems are being designed and implemented it's vital to have means for analysis the system reliability and ways of selecting the best (according to some criteria) configuration of the system components and system maintenance.

Reliability is mostly understood as the ability of a system to perform its required functions for a specified period of time [1]. It is mostly defined as a probability that a system will perform its function during a given period of time.

The classical web system reliability analysis [5] is based on Markov or Semi-Markov processes [1]. The typical structures with reliability focused analysis are not complicated and are based on serial-parallel or *k* of *n* systems. It is mostly assumed that a system is stationary and therefore one could calculate stationary reliability as the asymptotic value of reliability. Therefore, the method is based on a definition of system operational states. Next, the calculation of the probability that the system is being in a given state is performed. Assessing the reliability states as operational or failed one could calculate the reliability as the expected value of the system being in operational states. The main drawback of the classical approach is the fact that it is based on very strict assumptions related to the life or repair time and random variables.

The assumed distributions of the analysed system elements are idealized and it is hard to reconcile them with practice. Such reliability approach is not able to support the time-depending analysis, which seems to be very important in some practical applications. Therefore, we propose to weaken the assumptions of exponential distribution of repair time and take into account more practical situations like working hours and weekends. Moreover, we focus on a business service realized by web-system [4] and functional aspects of the system, i.e. performance aspects of business service realized by a web system. We assume that the main goal, taken into consideration during design and operation of the web-system, is to fulfil the user's requirements, which could be seen as some requirements to perform user's tasks within a given time limit.

To deal with reliability and functional aspects of web systems we propose a common approach [2] based on modelling and simulation. Modelling is focussed on a process of execution of a user's request, understood as a sequence of task realised on technical services provided by the system [10], whereas, the simulation is responsible for reliability and functional analysis. It is based on a time event simulation with Monte Carlo analysis [3].

The organisation of the paper is as follows. We start with modelling of the web system on the task level (section 2). Next, reliability analysis of a web system is given section 3. It is followed by a functional analysis performed by a simulator tool. The tool allows calculating the user's request time and therefore to calculate the functional availability. Finally, the client's availability is defined by compromising reliability (failures and repairs), functional aspects (probability that a user's will receive a request within a given time limit for a given system input load) and input load (the number of users changing in time during a week). We conclude with a short summary and plans for future works.

2. Web System Model

As it was mentioned in the introduction we decided to analyse web systems from the business service point of view. Therefore, we model a process of execution of a user's request, understand as a sequence of task realised on technical services provided by the system.

Generally speaking, users of the system are generating tasks, which are being realized by a web system. The task to be realized requires some services presented in the system. A realization of the system service needs a defined set of technical resources. Moreover, the services have to be allocated on a given host. Therefore, we can model a web system (*WS*) as a 4-tuple [8, 10]:

$$WS = \langle Client, BS, TI, Conf \rangle, \qquad (1)$$

Client – finite set of clients,
BS – business service, a finite set of service components,
TS – technical infrastructure,
Conf – information system configuration.

During modelling of the technical infrastructure we have to take into consideration functional and reliability aspects of web systems. Therefore, the technical infrastructure of the web system could be modelled as a pair:

$$TI = \langle H, N \rangle, \qquad (2)$$

where
H – set of hosts (computers); *N* – computer network.

The *N* is a function, which gives a value of time of sending a packet form one host (v_i) to another (v_i). The main technical infrastructure of the web systems are hosts. Each host is described by its reliability parameter (mean time to failure and mean time of repair) and functional parameters:

- server name (unique in the system),
- host performance parameter – the real value which is a base for calculating the task processing time (described later),
- set of technical services (i.e. apache web server, tomcat, MySQL database), each technical service is described by a name and a limit of tasks concurrently being executed.

The *BS* is a set of services based on business logic, that can be loaded and repeatedly used for concrete business handling process (i.e. ticketing service, banking, VoIP, etc.). Business service can be seen as a set of service components and tasks that are used to provide service in accordance with business logic for this process [12]. Therefore, *BS* is modelled a set of business service components (*BSC*), (i.e. authentication, data base service, web service, etc.), where each business service component is described a name, reference to a technical service and host describing allocation of business service component on the technical infrastructure and a set of tasks. Tasks are the lowest level observable entities in the modelled system.

It can be seen as a request and response from one service component to another. Each task is described by its name, task processing time parameter and optionally by a sequence of task calls. Each task call is defined by a name of business service component and task name within this business service component and time-out parameter. System configuration (*Conf*) is a function that gives the assignments of each service components to a technical service and therefore to hosts since a technical set is placed on a given host.

In case of service component assigned in a configuration to a load balancing technical service the tasks included in a given service component are being realised on one of technical services (and therefore hosts) defined in the load balancer configuration. The client's model (*Client*) consists of a set of users where each user is defined by its allocation (host name), replicate parameter (number of concurrently ruing users of given type), set of activities (name and a sequence of task calls) and inter-activity delay time (modelled by a Gaussian distribution).

Summarising, a user initiate the communication requesting some tasks on a host, it could require a request to another host or hosts, after the task execution hosts respond to requesting server, and finally the user receives the respond. Requests and responds of each task give a sequence of a user's task execution (choreography) as presented on exemplar Figure 1.

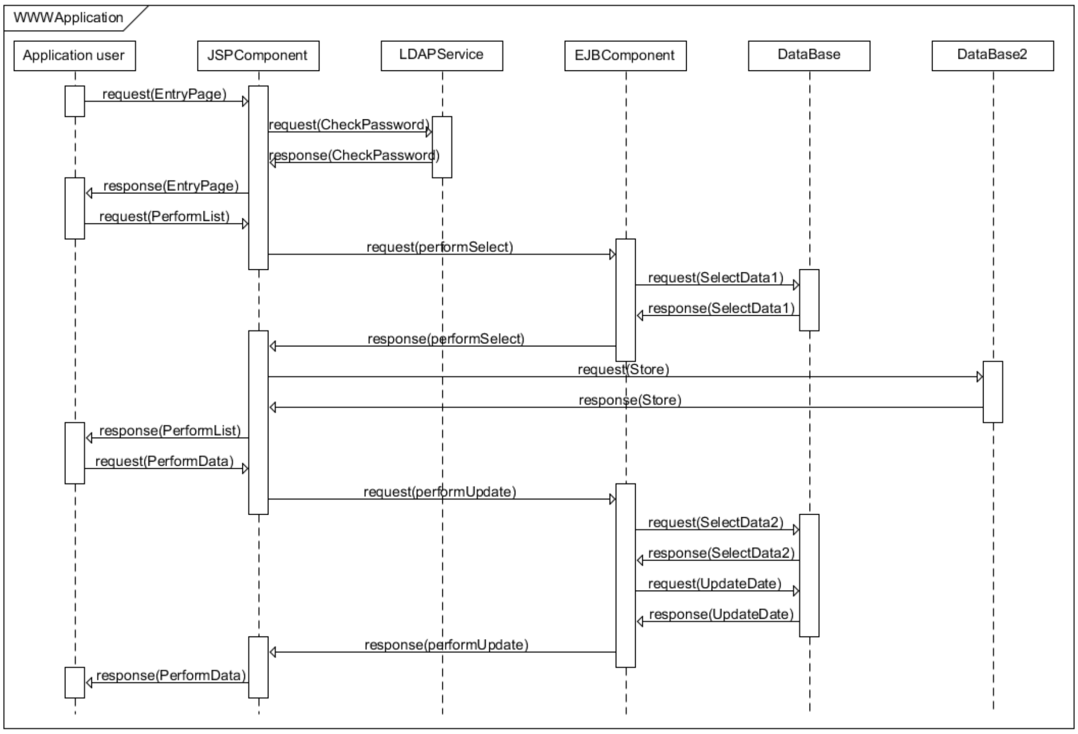

Figure 1. Testbed choreography

The request is understood as correctly answered if answers for each requests in a sequence of a user's task execution were given within defined time limit (parameter of each request in *BS* model) and if a number of tasks executed on a given technical service is not exceeding the limit parameter (parameter of *TI* model).

The user's request execution time in the system is calculated as a sum of times required for TCP/IP communication and times of tasks processing on a given host. The task processing time is equal to the task processing time parameter multiplied by a number of other task processed on the same host in the same time and divided by a the host performance parameter. Since the number of tasks is changing in simulation time, the processing time is updated each time a task finish the execution or a new task is starting to be processed.

3. Reliability Analysis of Web System

3.1. Reliability Model

There are numerous sources of faults in Web systems. These encompass hardware malfunctions (transient and persistent), software bugs, human mistakes, viruses, exploitation of software vulnerabilities, malware proliferation, drainage type attacks on system and its infrastructure (such as ping flooding, DDOS). We propose to model all of them from the point of view of a resulting failure. Looking at the model presented in the previous section it means that a host is not working. If a host is taking part in the choreography (a given business service component is placed on this host) the whole business service is not responding, therefore the web system is not in a ready state.

We assume that system failures could be modelled by a set of failures. Each failure is assigned to one of hosts and represents a separate and independent working-failure stochastic process. The occurrence of failures is described by a random process. The time to failure is modelled by the exponential distribution like in the Markov approach. But in case of repair time a more sophisticated assumption are taken into consideration.

As it has been mentioned in the introduction the classical reliability analysis is assuming the stationary of the process. However, the experience of the author shows that the most probable day that there is a need to repair a web system is Monday. It is mainly due to a fact that during weekends nobody is maintaining the system but failures could happen. To consider this fact we propose to model in detail maintaining crew working hours.

Therefore, we assume that working hours of system maintainer are from 8 am to 4 pm, from Monday to Friday. And only during these days any failure could be discovered and any repair operation could be performed. Of course, any other system of working hours (like for example two shifts) could be analysed in a similar way. Moreover, we assume that new elements (to replace failed one) needs to be delivered from external localization by a post courier. Therefore, the element to be replaced will be available on the next working day at 8 am.

Taking into account all these assumptions we could distinguish the following elements of repair time:

- failure discover time – equal to zero if a failure happens during working hour, in other cases it is equal to a time period to a beginning of next working day (8 am);
- failure analysis time – a time needed to discover the failure reason, it is model by a random variable with a truncated normal distribution, if the failure analysis will be overlapping with not working hours, it is enlarge by a time period to next working day (by 16 hours or even 66 hours in case of Friday);
- element delivery time – with a given probability it is equal to zero (it allows to model an operating system or software component failure), in other cases equal to a time period to next working day (modelling the delivery of the element be a courier);
- element replacement – a time required to replace a failed element or a software reinstallation/ repair in case of software failure, modelled by a random variable with a truncated normal distribution within working hours (like in failure analysis time).

3.2. System Availability

We propose to measure reliability aspects of web systems by system availability metric. It is defined as the probability that the system is ready (provides responses) at a specific time:

$$A_S(t) = \Pr(ready(t)) . \tag{3}$$

The typical approach to analyse reliability is based on Markov processes [1], which encompass the following stages:

- set of reliability states definition;
- states-transition matrix definition;
- proper system of linear equations construction.

For two elements it will give 4 states (as presented on Figure 1): S_0 – both element working, S_1 the first failed, S_2 – the second failed, S_2 – both failed.

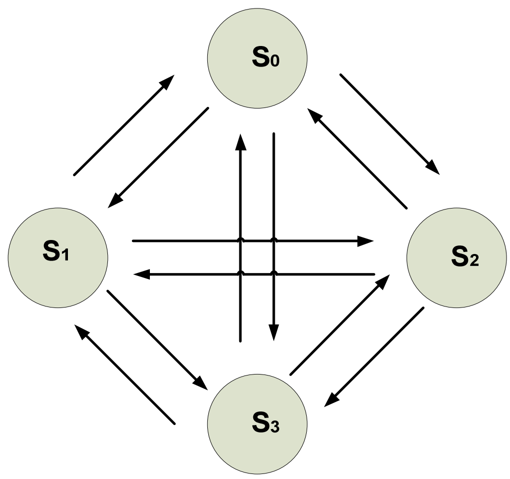

Figure 2. The reliability states for a system with two failures

Markov based methodology supports satisfactory results if the system isn't very complicated and if one uses exponential distribution for the state transition times. Both requirements are not fulfilled in the analysed case. Therefore, we have had to modify it. We've used event-driven simulation.

3.3. Event-Driven Simulation

A common way of analysing systems presented in section 3.1 is a computer simulation. To analyse the system we must first build a simulation model, which was done based on the formal model presented above, and then operate the model. The system model needed for simulation has to encourage the system elements behaviour and interaction between elements.

Once a model has been developed, it is executed on a computer. It is done by a computer program which steps through time. One way of doing it is so called event-driven simulation. Which is based on an idea of event, which could is described by time of event occurring and type of an event. The simulation is done by analysing a queue of event (sorted by time of event occurring) while updating the states of system elements according to rules related to a proper type of event. Due to a presence of randomness in the reliability model of web system the analysis of it has to be done based on Monte-Carlo approach[3]. What requires a large number of repeated simulations?

Summarizing, the event-driven simulator repeats *N*-times the following loop:

- beginning state of a web system initialisation,
- event state initialisation, set time $t = 0$,
- repeat until $t < T$:
- take first event from event list,
- set time equals time of event,
- realize the event – change state of web system according to rules related to proper type of event: change objects attributes describing system state, generate new events and put them into event list, write data into output file.

The simulator was implemented in C++ within the Scalable Simulation Framework (SSF) [6]. SSF is an object-oriented API – a collection of class interfaces with prototype implementations. For the purpose of simulating reliability sates we have used Parallel Real-time Immersive Modelling Environment (PRIME) [7] implementation of SSF due to much better documentation then available for original SSF and additional methods of synchronization between processes. The main reason of using SSF was the fact that it was also used by authors for a development of functional simulator of Web system (section 4.1).

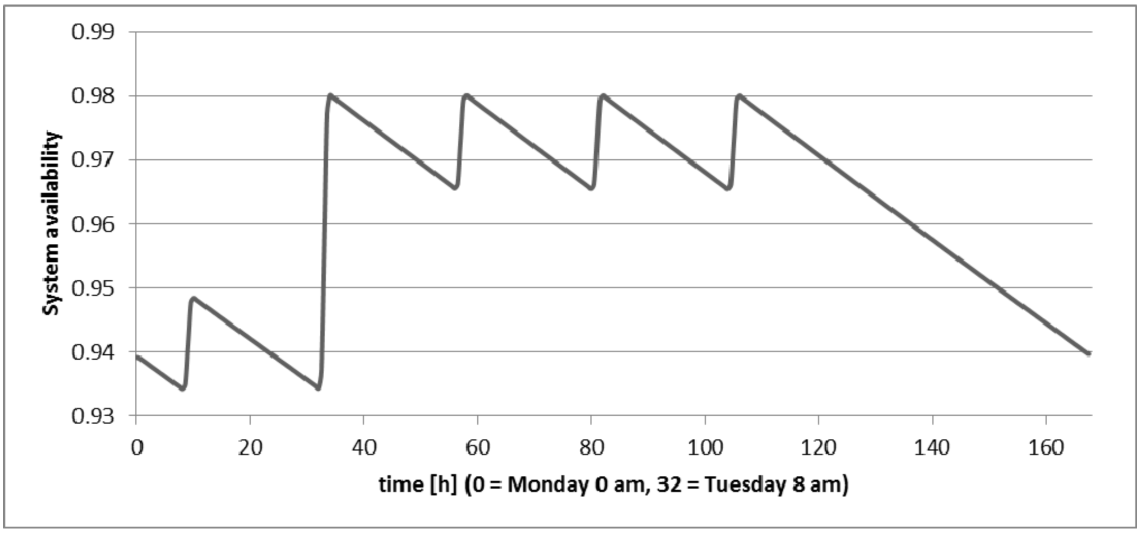

Figure 3. System availability for a testbed system

Simulation experiments were performed on a testbed web system consisting of six hosts. There were five computers with business components communicating according to the choreography presented on Figure 1 and one router with a firewall. Since, today's computer devices are not failing very often, the intensity of failures was set to one year per year. Whereas repair parameters were set as follows:

- mean failure analysis time – 3 hours,
- mean element replacement time – 1 hour,
- probability of hardware failure – 0.9.

The achieved results for simulation of simulating 10,000 weeks 10,000 times are presented on Figure 3.

4. Functional Analysis of Web System

4.1. Functional Simulation [10, 11]

4.1.1. User's request execution model

As it was mentioned in the introduction the presented approach is focused on a process of execution of a user's request, understand as a sequence of task realised on technical services provided by the system.

Therefore, the main aim of simulation was to allow calculation service response time. The user initiate the communication requesting some tasks on a host, it could require a request to another host or hosts, after the task execution a host responds to requesting server, and finally the user receives the respond. Requests and responds of each task give a sequence of a user's task execution – choreography (see Figure 1).

Assume that the choreography for some user c_i is given as a sequence of requests:

$$choregraphy(c_i) = \left(c(task_{b_1}), c(task_{b_2}), ..., c(task_{b_n})\right), \tag{4}$$

where $c(task_{b_i})$ could be a request ($\Rightarrow$) to $task_{b_i}$ or a response from a given task ($\Leftarrow$).

Some tasks are executed on a given host a request is returned to a sender. However, other tasks could require execution of other tasks. Therefore, the task could be described by a sequence of requests, i.e. list of tasks to be called.

For example, some choreography could be written as:

$$choregraphy(c_1) = c_1 \Rightarrow task_1 \Rightarrow task_2 \Leftarrow task_1 \Rightarrow task_3 \Leftarrow task_1 \Leftarrow c_1 \, . \tag{5}$$

The user's request execution time in the system is calculated as a sum of times required for TCP/IP communication (modelled by a random value) and task processing times on hosts according to some choreography.

Therefore, service response time for a single user performing some choreography c (consisting of a sequence of n-tasks) could be calculated as:

$$urpt(c) = \sum_{i=1}^{n} \left(delay\left(al\left(task_{i-1}\right), al\left(task_i\right)\right) + pt(task) + delay\left(al\left(task_i\right), al\left(task_{i-1}\right)\right)\right), \tag{6}$$

where:

- $delay\left(h_i, h_j\right)$ is a time of task request transmission from host h_i to host h_j.
- $al\left(task_0\right)$ is understood as a location of a user.

It is important to mention that *urpt*() that could be seen as a random value since it has different values for each user interaction with the system.

4.1.2. Network transmission time

One of key element of the formula (6) which allows calculating the user's request processing time is the time of transmission the task data over the network.

There is a large number of event driven computer network simulations which are focused on modelling and simulation of network traffic.

TCP/IP packets level simulation results in a large number of events during simulation and therefore in a long simulation time. Therefore, we have proposed the approach [8, 10] based on assumption that task network transmission time could be modelled by independent random values:

$$delay\left(h_i, h_j\right) = TNormal(mean, mean \cdot 0.1) \,, \tag{7}$$

where *TNormal*() denotes the truncated Gaussian distribution (bounded below 0).

We assume, that the local network throughout is high enough so there is no relation between the number of tasks being processed in the system and the network delayed. We think that this assumption is acceptable since in almost all modern information systems high speed local networks are used. In a result, for a large number of Web systems (except media streaming ones) the local network traffic influence on the whole system performance is negligible.

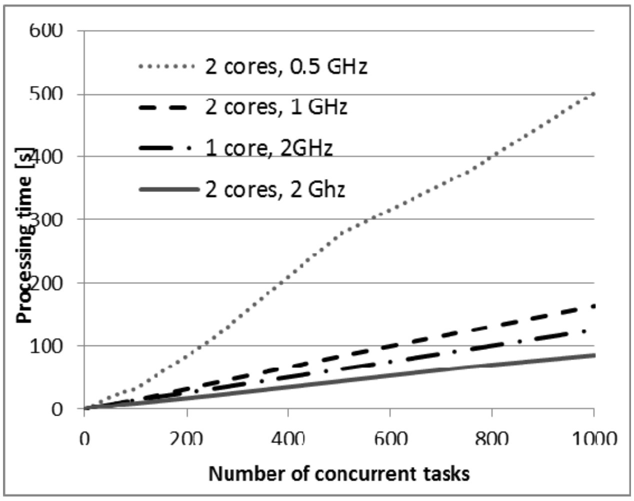

Figure 4. Processing time of an example task on IBM DB2 server in a function of concurrent task number for different types of hosts

4.1.3. Resource consumption model

The key feature for formula (6) is the calculation of the task processing time. It has to take into account the consumption of computational resources (mainly host processing power). Therefore, the algorithm will be called: the resource consumption model (RCM).

Most of web servers work in a multithread environment. Generally speaking, it occurs by time-division multiplexing. In case of a single processor it is achieved by switching the processor between different threads. Example results for IBM DB2 server is presented on Figure 4.

For a case when only one task is executed on a given host the processing time is constant and it depends on the host type described by performance parameter (*performance*()) and execution time parameter (*executiontime*()) of a given task. The execution time of a task is given in seconds. It is a time of processing a task measured on a reference host (host with a performance parameter equal to 1). The time of executing a task on a single processor is given by a simple formula:

$$pt(task_j) = \frac{executiontime(task_j)}{performance(h)} . \tag{8}$$

The algorithm for more than one task being executed at the same time is more complicated. It is based on the idea of event-time and processed based simulation.

Let $\tau_1, \tau_2, ...$ be a time moments when some tasks are starting their processing on a given host *h*. At each of time events the algorithm updates the processing time of all currently running task and finds tasks that finished its execution, i.e. sum of all allocated time slots is larger than the execution time parameter. Next, the algorithm predicts the time of finishing the task. It is based on an assumption that there will be no new tasks meanwhile. The shortest finished is selected as a time of a new event – a possible finish of some task execution. The algorithm is presented below.

1. $\tau_{previous} = \tau$
2. τ =current time
3. If new task is coming (with index i)

   $et(task_i) = 0$

   $number(h) += 1$

4. For all tasks being processed
$$et(task_j) += (\tau - \tau_{previous})\frac{performance(h)}{number(h)}$$
5. For all tasks being processed
6. If $et(task_j) \geq executiontime(task_j)$
finish execution of task j
$$number(h) -= 1$$
7. Else (estimate the finish time of task *j*)
$$\tau_j^e = \tau + \left(executiontime(task_j) - et(task_j)\right) \cdot \frac{number(h)}{performance(h)}$$
8. Add new event at time equal to minimal value of τ_j^e
9. Goto 1

Algorithm 1. Processor sharing RCM

The above algorithm could be easily extended to deal with multi-core processors just by replacement of *number*(h) parameter in formulas in steps 4 and 6 by:
$\lceil number(h)/n \rceil$, where *n* is a number of processor cores.

The main drawback of above algorithm is the fact that it generates large number of events when large number tasks are being executed on a single task at the same time. It is due to the fact that each new task changes the estimated time of finishing for all tasks being executed at this moment. It could have been solved by withdrawing events representing task finishing time in case when new task would have come meanwhile. But this is impossible in case of used for implementation simulation framework (see next chapter). So we have introduced a heuristic algorithm that prevents the generation of a new event if the previous one (for the same host) was close enough (the time difference is smaller than a threshold).

4.1.4. Simulator

As it is mentioned in the previous chapter we have developed a web system simulator [10, 11, 12] within a SSF framework. The main advantage of SSF in case of simulating Web systems is its process oriented approach. The process in SSF could be seen as independent threads of control. It can be blocked waiting for an event to arrive or for a given period of simulation time. Since the real Web servers are built as multithreaded applications processes available in SSF net simplifies Web server implementation in the simulator. Moreover, the implementation of processes in SSF is very efficient, much faster than a usage of general purpose multithreading library. A small test done by authors comparing Java threads to SSF processes showed that process context switching (which happens frequently in event simulation – at least once per one event) in SSF was more than 10 times shorter [10].

4.2. Performance Analysis

The developed simulation software allows analysing web system performance, i.e. to calculate a metric which could allow comparing different configuration of information system. Let define an average user's response time metric as:

$$EURP = \mathrm{E}\left(urpt(c)\right). \tag{9}$$

This metric is intended to be a numerical representation of client's perception of particular system quality.

The results, the average user's response time in a function of number of users per second, is presented on Figure 5. Two different configurations were considered (hosts with different functional parameters). It is important to state that due to probabilistic character of this metric, the Monte-Carlo [3] technique has been used.

The performance of any web system has a big influence on the web system business service quality. It has been shown [9] that if user will not receive answer from the system in less than 10 seconds he/she will probably resign from active interaction with the system and will be distracted by other ones. And it is a base for availability metric presented in the next chapter.

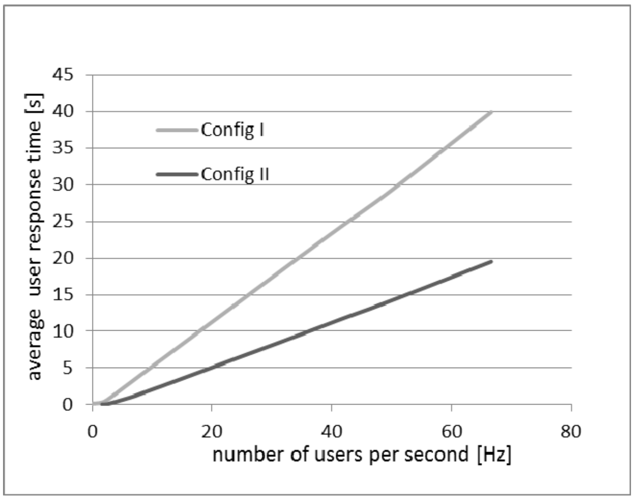

Figure 5. The average user's response time for tetsbed for two configurations

4.3. Functional Availability

To measure functional aspects of web system we propose to use the client's availability metric. It is defined as a probability that service response time will be less than a given time limit ($t_{\max}$) for a given load (number of user's requests per second) of the system:

$$Af(n) = \Pr(urpt(c) \leq t_{\max} \mid nuser = n) \mid . \tag{10}$$

This metric is a numerical representation of clients' perception of particular business service quality. It measures the probability that the user's will not resign from active interaction with the service due too long service response time.

The example results for the testbed system with choreography from Figure 1 with a time-limit set to 10 s and concurrent task limit set to 200 are presented on Figure 6. The mentioned in Chapter 2 time-outs and a maximum number of tasks results in dropping some of requests and therefore in decrease of the availability parameter when number of user's requests enlarges.

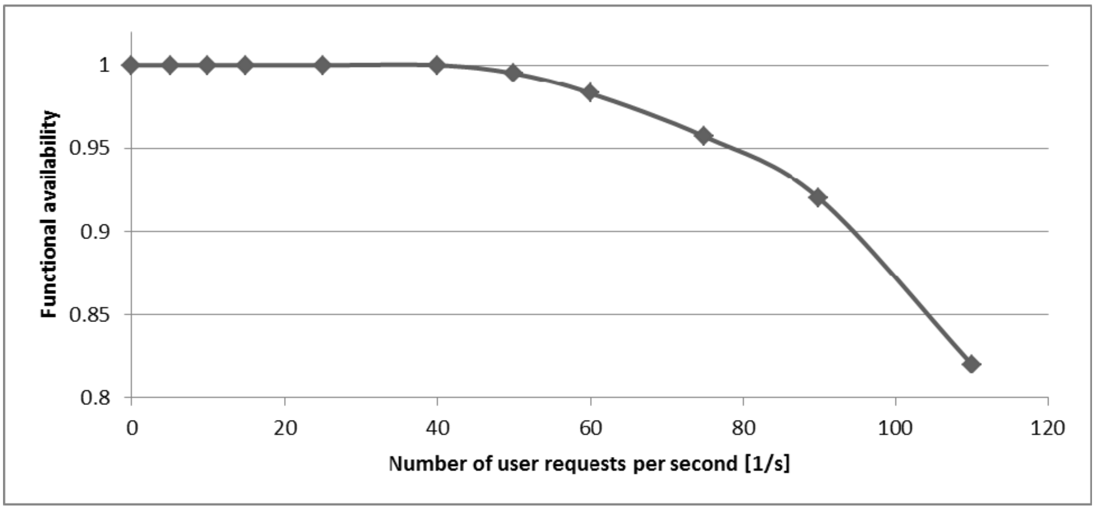

Figure. 6. Functional availability for a testbed system in a function of number of user's requests per second

5. Reliability and Functional Analysis of Web System

5.1. Input Load and Client's Availability

It is obvious that a number of users of a web system changes in time. It depends on a type of provided service. But usually on weekends, there are fewer users then on weekdays. Also one could notice changes in traffic during a day – with a peak load in a middle of day and minimum load at night. Therefore, the input load variations could be described by a function *nuser*(t) similar to that presented on Figure 7.

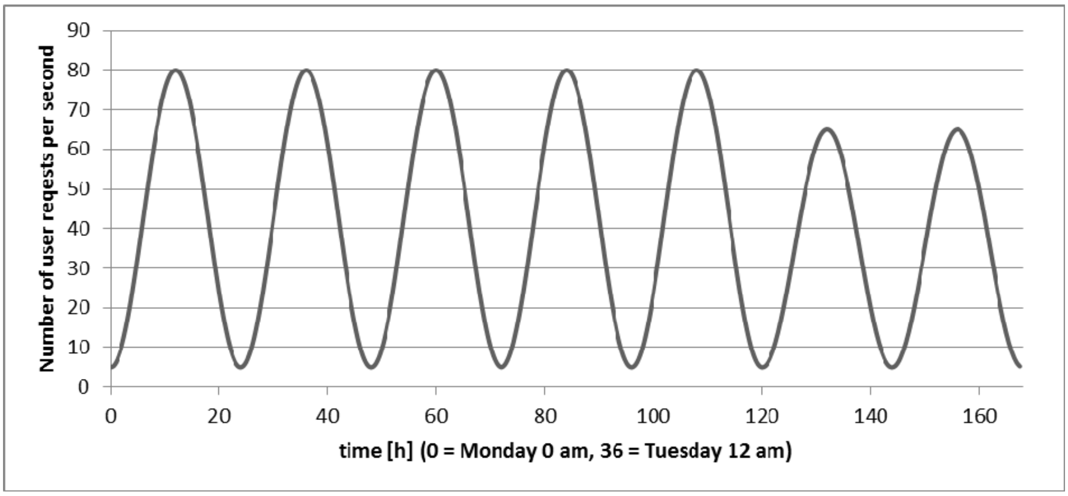

Figure 7. Input load for a tesbed system

Using the function *nuser*(t) the changes of functional availability in time could be easily calculated as

$$A_{ft}(t) = \Pr(urpt(c) \le t_{\max} \mid t) \models A_u\left(nuser(t)\right). \tag{11}$$

The results for a testbed system and assumed input load (from Figure 7) are presented on Figure 8.

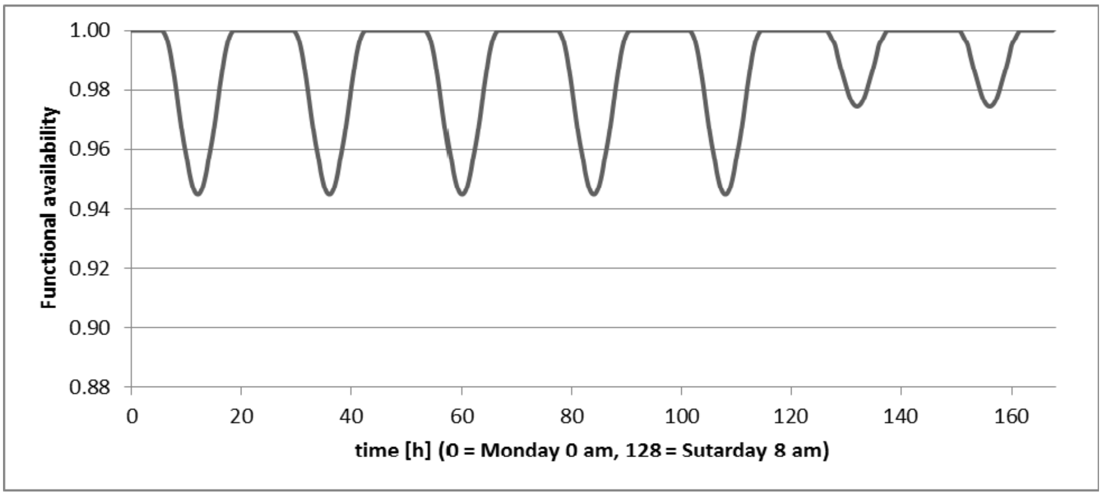

Figure 8. Functional availiabiliy for a tesbed system in afunction of a time (for one week)

5.2. Client's Availability

From the web service client's point of view reliability and functional reasons of getting no answer are undistinguished. Therefore, to measure client's availability we propose to combine system and functional availability as it is given in formula below:

$$A_c(t) = \Pr(operational(t)) = A_S(t) \cdot A_f\left(nuser(t)\right). \tag{12}$$

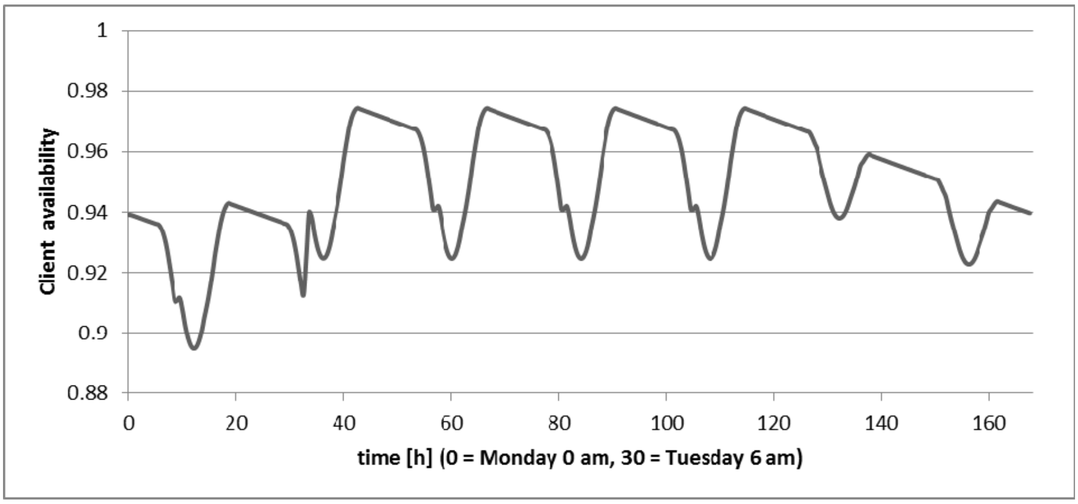

Figure 9. Client's availiabiliy for a tesbed system in afunction of a time (for one week)

The client's availability changes in a week for a testbed system with an input load from Figure 7 are presented on Figure 9. It could be noticed that availability varies in time following changes in input load and system reliability (due to a fact that system maintainer is not working 24 h per day).

6. Conclusions

In this paper we have presented a reliability and functional analysis of Web systems based on modelling and analysis approach. Developed simulation software allows analysing the reliability (understood as the ability of a system to perform its required functions) for a given configuration of a Web system. The following reliability parameters are taken into account as follows: intensity of failures, mean failure analysis time and mean element replacement time. The reliability analysis stresses upon working hours of system maintainers. Functional parameters describe the web system choreography (interaction between tasks), system structure (number of hosts, host performance, service components placement on hosts and each task execution time) and input load (changes of user's requests number in a time during a week).

Using the tool Web-based system configuration and maintenance procedures could be easily verified and different configuration could be compared. It makes the solution a powerful tool for increasing system availability and by that increasing user's satisfaction.

In the future, we plan to extend our solution with other types of failures, which could model viruses, malwares or attack influence on the system performance.

Acknowledgment

The presented work was funded by the Polish National Science Centre under contract no. 4759/B/TO2/2011/40.

References

1. Barlow, R., Proschan, F. *Mathematical Theory of Reliability*. Philadelphia: Society for Industrial and Applied Mathematics, 1996, p. 345.
2. Birta, L., Arbez, G. *Modelling and Simulation: Exploring Dynamic System Behaviour*. London: Springer, 2007, p. 246.
3. Fishman, G. *Monte Carlo: Concepts, Algorithms, and Applications*. Springer-Verlag, 1996, p. 129.
4. Gold, N., Knight, C., Mohan, A. and M. Munro. Understanding service-oriented software, *IEEE Software*, Vol. 21, 2004, pp. 71–77.
5. Lipinski, Z. State Model of Service Reliability. *International Conference on Dependability of Computer Systems* (*DEPCOS-RELCOMEX'06*), *IEEE Computer Society*, 2006, pp. 35–42.
6. Liu, H., Chu, L. and W. Recker. Performance Evaluation of ITS Strategies Using Microscopic Simulation. *Proceedings of the 7th International IEEE Conference on Intelligent Transportation Systems,* 2004, pp. 255–270.

7. Liu, J. *Parallel Real-time Immersive Modelling Environment* (*PRIME*), *Scalable Simulation Framework* (*SSF*), *User's manual*. Colorado School of Mines Department of Mathematical and Computer Sciences, 2006. [Available online: http://prime.mines.edu/]
8. Michalska, K. and T. Walkowiak. Simulation approach to performance analysis information systems with load balancer. In: *Information systems architecture and technology: advances in Web-Age Information Systems,* 2009, pp. 269–278.
9. Nielsen, J. Usability Engineering. San Francisco: Morgan Kaufmann, 1994.
10. Walkowiak, T. *Information systems performance analysis using task-level simulator. DepCoS – RELCOMEX.* IEEE Computer Society Press, 2009, pp. 218−225.
11. Walkowiak, T. Simulation approach to Web system dependability analysis. In: *Summer Safety and Reliability Seminars, SSARS 2011, Gdańsk-Sopot, Poland, 03–09 July 2011 / Ed. by Krzysztof Kołowrocki, Joanna Soszyńska-Budny*. Gdynia: Polish Safety and Reliability Association. Vol. 1, 2011, pp. 197–204.
12. Walkowiak, T. and K. Michalska. Functional based reliability analysis of Web based information systems. In: *Dependable computer systems / Wojciech Zamojski, et al.* (*Eds.*). Berlin; Heidelberg: Springer, 2011, pp. 257–269.

Received on the 22nd of October, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 49–58
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

STATISTICAL LIFE TEST ACCEPTANCE PROCEDURE FOR WEIBULL DISTRIBUTION

K. N. Nechval[1], N. A. Nechval[2], M. Purgailis[2], V. F. Strelchonok[3]
G. Berzins[2], M. Moldovan[4]

[1]Transport Department, Transport and Telecommunication Institute
Lomonosov Street 1, LV-1019, Riga, Latvia
E-mail: konstan@tsi.lv

[2]Statistics Department, EVF Research Institute, University of Latvia
Raina Blvd 19, LV-1050, Riga, Latvia
E-mail: nechval@junik.lv

[3]Informatics Department, Baltic International Academy
Lomonosov Street 4, LV-1019, Riga, Latvia
E-mail: str@apollo.lv

[4]Australian Institute of Health Innovation, University of New South Wales
Level 1 AGSM Building, Sydney NSW 2052, Australia
E-mail: m.moldovan@unsw.edu.au

Products' acceptance models include sampling, inspection, and decision making in determining the acceptable or rejection of a batch of products by experiments for examining the continuous usage time of the products. The most popular lifetime distribution used in the field of product acceptance is either a one-parameter exponential distribution (because it has relatively simple functional forms for both the probability density function and the cumulative distribution function), or a two-parameter Weibull distribution, with the assumption that the shape parameter is known. Such oversimplified assumptions can facilitate the follow-up analyses, but may overlook the fact that the lifetime distribution can significantly affect the estimation of the failure rate of a product. The choice of an appropriate product acceptance model is a crucial decision problem because a good model not only can help producers save testing time and reduce testing cost, but it also can positively affect the image of the product and thus attract more consumers to buy this product. Therefore often the Bayesian approach is used to solve the above problem. Unfortunately, in this case the subjectivity of investigator (a limitation of the Bayesian approach) is introduced through a priori distribution. In order to rule out the subjectivity of investigator and to consider comprehensively the relevant risks, in this paper a frequentist (non-Bayesian) decision analysis is employed.

Keywords: *lifetime, Weibull distribution, parametric uncertainty, product acceptance model*

1. Introduction

A product acceptance model is an inspecting procedure in statistical quality control or reliability tests, which is used to make decisions of accepting or rejecting lots of products to be submitted. This procedure is important for industrial and business purposes of quality management. Product acceptance models have many applications in the field of industries and bio-medical sciences. Due to the highly competitive global market, quality of products definitely plays one of the most important roles for any industry today. For this reason, Statistical Quality Control plays a significant role for the success or failure of an industry. Acceptance sampling plans are an essential tool in Statistical Quality Control. It is very clear that in many situations it may not be possible to perform the inspection of hundred percent. On the other hand, if nothing is tested, desired quality cannot be assured. Acceptance sampling plan is a "middle path" between the inspection of hundred percent and no inspection at all. The acceptance sampling plan requires a decision of accepting or rejecting a lot of products based on a random sample collected from the lot. The main concern in an acceptance model of product is to minimize the cost and time required for the quality control or reliability tests for the decision about the acceptance or rejection of the submitted lot of products. The other purpose of product acceptance models is to provide the desired protection to producers and consumers. Usually, with every product acceptance model, the associated consumer's and producer's risks are also provided. For a given product acceptance model, the consumer's and producer's risks are the probabilities that a bad lot is accepted and a good lot is rejected, respectively. An acceptance model which is used to protect producers and consumers is called a well-designed acceptance model of product. A typical application of product acceptance models is as follows: a company receives a shipment of product from a vendor. This product is often a component or raw material used in the company's manufacturing process. A sample is taken from the lot and the relevant quality characteristic of the units in the sample is inspected. On the basis of the information in this sample, a decision is made regarding lot disposition. Traditionally, when the life test indicates that the mean life of products exceeds the specified one, the lot of products is accepted, otherwise it is rejected. Accepted lots are put into production, while rejected lots may be returned to the vendor or may be subjected to some other lot disposition action. While it is customary to think of acceptance sampling as a receiving inspection activity, there are also other uses. For example, frequently a manufacturer samples and inspects its own product at various stages of production. Lots that are accepted are sent forward for further processing, while rejected lots may be reworked or scrapped. For the purpose of reducing the test time and cost, a truncated life test may be conducted to determine the smallest sample size to ensure a certain mean life of products when the life test is terminated at a pre-assigned time t_0 and the number of failures observed does not exceed a given number.

A sampling inspection plans in the case that the sample observations are lifetimes of products put to test aims at verifying that the actual population mean exceeds a required minimum. The population mean stands for the mean lifetime of the product, say μ. If μ_0 is a specified minimum value, then one would like to verify that $\mu \geq \mu_0$, this means that the true unknown population mean lifetime of the product exceeds the specified value. On the basis of a random sample of size n, the lot is accepted, if by means of a suitable decision criterion, the product acceptance model decides in favour of $\mu \geq \mu_0$. Otherwise the lot is rejected. The decision criterion is naturally based on the number of observed failures in the sample of n products during a specified time t_0 from which a lower bound for the unknown mean lifetime is derived. If the observed number of failures is large, say larger than a number ϑ, the derived lower bound is smaller than μ_0 and the hypothesis $\mu \geq \mu_0$ is not verified. Hence, the lot cannot be accepted. A common practice in life testing is to terminate the life test by a predetermined time t_0 and note the number of failures (assuming that a failure is well defined). One of the objectives of these experiments is to set a lower confidence limit on the mean life. It is then to establish a specified mean life with a given probability of at least p which provides protection to consumers. The decision to accept the specified mean life occurs if and only if the number of observed failures at the end of the fixed time t_0 does not exceed a given number 'η'– called the acceptance number. The test may get terminated before the time t_0 is reached when the number of failures exceeds 'η' in which case the decision is to reject the lot.

Extensive work has been done on product acceptance models since their inception. Several text books and papers are available which provide different acceptance models of product for different probability distribution functions, see, for example, Epstein [1], Sobel and Tischendrof [2], Goode and Kao [3], Gupta and Groll [4], Gupta [5], Fertig and Mann [6], Kantam and Rosaiah [7], Kantam *et. al.* [8], Baklizi [9], Wu and Tsai [10], Rosaiah and Kantam [11], Rosaiah *et. al.* [12], Tsai and Wu [13], Balakrishnan *et. al.* [14], Srinivasa Rao and Kantam [15], and the references cited therein. All these authors considered the design of product acceptance models based on the population mean or median under a truncated life test.

In this paper, the two-parameter Weibull distribution with the probability density function

$$f(x \mid \beta, \delta) = \frac{\delta}{\beta}\left(\frac{x}{\beta}\right)^{\delta-1} \exp\left[-\left(\frac{x}{\beta}\right)^{\delta}\right] \quad (x > 0) \tag{1}$$

indexed by scale and shape parameters β and δ is used as the underlying distribution of a random variable X representing the lifetime of product. In determining (via testing the expected value of X) whether or not a production lot is accepted, one wants the most effective sample size n of observations $X_1, \ldots, X_n$ of the random variable X and the test plan for the specified producer risk (probability of rejecting a lot which is adequate for the real business situation) and consumer risk (probability of accepting a lot which is not adequate for the real business situation). Let μ_1 be the expected value of X in order to accept a production lot, and μ_2 be the expected value of X in order to reject a production lot, where $\mu_1 > \mu_2$, then the test plan has to satisfy the following constraints: (i) Pr{reject a lot | $E\{X\} = \mu_1$} = α_1 (Producer risk), and (ii) Pr{accept a lot | $E\{X\} = \mu_2$} = α_2 (Consumer risk). It is assumed that $\alpha_1 < 0.5$ and $\alpha_2 < 0.5$.

The problem is to find the sample size n of observations of the random variable X and test plan based on $\mathbf{X} = (X_1, \ldots, X_n)$ in order to determine whether or not a lot of product is accepted. The test plan has to satisfy the specified constraints for the associated consumer's and producer's risks, respectively.

The cases of product lifetime testing are considered when the shape parameter δ of the two-parameter Weibull distribution is assumed to be known a priori as well as when it is unknown.

2. Product Acceptance Model when the Shape Parameter is a Priori Known

In determining whether or not a product lot is accepted, we have to use the test plan which satisfies the following conditions:

$$\Pr\{\text{reject a lot} \mid E\{X\} = \mu_1\} = \alpha_1 \text{ (Producer risk)}, \tag{2}$$

$$\Pr\{\text{accept a lot} \mid E\{X\} = \mu_2\} = \alpha_2 \text{ (Consumer risk)}, \tag{3}$$

where

$$E\{X\} = \mu = \int_0^\infty x f(x \mid \beta, \delta) dx = \beta\,\Gamma\left(1 + \frac{1}{\delta}\right) \tag{4}$$

is the expected value of X, $E\{X\}=\mu_1$ is statistically acceptable for product, $E\{X\} = \mu_2$ is statistically rejectable for product, α_1 and α_2 are the specified producer's and consumer's risks, respectively.

To test for assuring μ in the Weibull distribution, we consider life testing with Type II censoring when the shape parameter δ is a priori known. Let us assume that n items of a sample $\mathbf{X}^{(n)} = (X_1, \ldots, X_n)$ drawn at random from a lot are placed on test simultaneously and the test is terminated when ($r \le n$) of them have failed. Let $X_1 \le X_2 \le \ldots \le X_r$ be the r smallest lifetimes, then

$$Q_r = \sum_{i=1}^{r} X_i^{\delta} + (n-r) X_r^{\delta} \tag{5}$$

is sufficient statistic for β^{δ} and it follows that the decision rule may be based on Q_r, i.e., accept the lot of products if Q_r > threshold and reject it otherwise where a threshold is a pre-specified positive constant. Since the test is terminated at the r-th failure time, it can be shown [16] that the expected test time is

$$E\{X_r \mid n, r, \beta, \delta\} = \beta\,\Gamma\left(1 + \frac{1}{\delta}\right) \sum_{k=0}^{r-1} \binom{r-1}{k} (-1)^k \frac{n!}{(r-1)!(n-r)!} (n-r+k+1)^{-(\delta+1)/\delta}. \tag{6}$$

If the shape parameter δ is a priori known, the maximum likelihood estimator of β^{δ} is given by

$$\widehat{\beta}^{\delta} = \frac{Q_r}{r}, \tag{7}$$

and the pivotal quantity

$$V = 2r(\widehat{\beta}^{\delta} / \beta^{\delta}) \tag{8}$$

is χ^2 distributed with $2r$ degrees of freedom. The r and h are determined by

$$\begin{cases} \widehat{\beta}^{\delta} > h, & \text{accept the lot,} \\ \widehat{\beta}^{\delta} \le h, & \text{reject the lot.} \end{cases} \tag{9}$$

To select r and h, we use the equations (2) and (3), which can be presented in the case when the parameter δ is known as

$$\Pr\left\{\widehat{\beta}^{\delta} \le h \mid \mu = \mu_1; \delta\right\} = \Pr\left\{\frac{2r\widehat{\beta}^{\delta}}{\beta_1^{\delta}} \le \frac{2rh}{\beta_1^{\delta}} \mid \mu = \mu_1; \delta\right\} = \Pr\left\{V \le \chi^2_{2r;\alpha_1}\right\} = \alpha_1, \tag{10}$$

$$\Pr\left\{\widehat{\beta}^{\delta} > h \mid \mu = \mu_2; \delta\right\} = \Pr\left\{\frac{2r\widehat{\beta}^{\delta}}{\beta_2^{\delta}} > \frac{2rh}{\beta_2^{\delta}} \mid \mu = \mu_2; \delta\right\} = \Pr\left\{V > \chi^2_{2r;1-\alpha_2}\right\} = \alpha_2, \tag{11}$$

where

$$\beta_j = \frac{\mu_j}{\Gamma\left(1 + \frac{1}{\delta}\right)}, \quad j = 1, 2, \tag{12}$$

$\chi^2_{2r;p}$ is the p-quantile of χ^2 distribution with $2r$ degrees of freedom. It follows from (10) and (11) that

$$\frac{\beta_2^{\delta}}{\beta_1^{\delta}} \le \frac{\chi^2_{2r;\alpha_1}}{\chi^2_{2r;1-\alpha_2}}. \tag{13}$$

Therefore, the required r is the smallest integer satisfying (13), which can be obtained directly from (13). Using r based on (13), we have from (10) and (12) that the h for $\widehat{\beta}^{\delta}$ is given by

$$h=\left(\frac{\mu_1}{\Gamma(1+1/\delta)}\right)^{\delta}\frac{\chi^2_{2r;\alpha_1}}{2r}. \tag{14}$$

Thus, the lot of products is accepted if $\widehat{\beta}^{\delta}$ > h; otherwise, it is rejected.

Based on the required r, the optimal value of n is found as

$$n^{*}=\arg\min_{n\geq r}[c_{\circ}n+c_{\bullet}E\{X_r \mid n,r,\beta_1,\delta\}]$$

$$=\arg\min_{n\geq r}\left[c_{\circ}n+c_{\bullet}\beta_1\,\Gamma\left(1+\frac{1}{\delta}\right)\sum_{k=0}^{r-1}\binom{r-1}{k}(-1)^k\frac{n!}{(r-1)!(n-r)!}(n-r+k+1)^{-(\delta+1)/\delta}\right], \tag{15}$$

where $c_{\circ}$ is the cost of sampling and putting an item on test, $c_{\bullet}$ is the cost per unit of test time.

3. Product Acceptance Model when the Shape Parameter is Unknown

3.1. Preliminaries

In this section, we consider both parameters β, δ to be unknown. We will give here appropriate expressions for the case of complete (uncensored) sampling. Let $\mathbf{X}^{(n)}=(X_1, \ldots, X_n)$ be a random sample from the two-parameter Weibull distribution (1), and let $\widehat{\beta}$, $\widehat{\delta}$ be maximum likelihood estimates of β, δ computed on the basis of a sample $\mathbf{X}^{(n)}=(X_1, \ldots, X_n)$. In terms of the Weibull variates, we have that

$$V_1=\left(\frac{\widehat{\beta}}{\beta}\right)^{\delta},\quad V_2=\frac{\delta}{\widehat{\delta}},\quad V_3=\left(\frac{\widehat{\beta}}{\beta}\right)^{\widehat{\delta}} \tag{16}$$

are pivotal quantities. Further more, let

$$Z_i=\left(\frac{X_i}{\widehat{\beta}}\right)^{\widehat{\delta}},\quad i=1, \ldots, n. \tag{17}$$

It is readily verified that any n–2 of the Z_i's, say Z_i, …, Z_{n-2} form a set of n–2 functionally independent ancillary statistics. The appropriate conditional approach, first suggested by Fisher [17], is to consider the distributions of V_1, V_2, V_3 conditional on the observed value of $\mathbf{Z}^{(n)}=(Z_i, \ldots, Z_n)$. (For purposes of symmetry of notation we include all of Z_i, …, Z_n in expressions stated here; it can be shown that Z_n, Z_{n-1}, can be determined as functions of Z_i, …, Z_{n-2} only).

The marginal distribution of

$$V_2=\frac{\delta}{\widehat{\delta}}, \tag{18}$$

conditional on fixed set of ancillary statistics $\mathbf{z}^{(n)}=(z_i, \ldots, z_n)$ is appropriate for making inference about δ when β is unknown. It can be found (see Corollary 1.1 below with r = n) that the marginal probability density function of V_2, conditional on fixed $\mathbf{z}^{(n)}$**,** is given by

$$g_2(v_2 \mid \mathbf{z}^{(n)})=\vartheta(\mathbf{z}^{(n)})v_2^{n-2}\prod_{i=1}^{n}z_i^{v_2}\left(\sum_{i=1}^{n}z_i^{v_2}\right)^{-n},\quad (v_2>0), \tag{19}$$

where

$$\vartheta(\mathbf{z}^{(n)})=\left[\int_0^{\infty}v_2^{n-2}\prod_{i=1}^{n}z_i^{v_2}\left(\sum_{i=1}^{n}z_i^{v_2}\right)^{-n}dv_2\right]^{-1} \tag{20}$$

is the normalizing constant. The probability statement

$$\Pr\{q_1\leq V_2\leq q_2 \mid \mathbf{z}^{(n)}\}=1-\alpha \tag{21}$$

leads in the usual way to the $(1-\alpha)$ conditional confidence interval

$$q_1\hat{\delta} \le \delta \le q_2\hat{\delta}. \tag{22}$$

The marginal distribution of

$$V_3 = \left(\frac{\hat{\beta}}{\beta}\right)^{\hat{\delta}} \tag{23}$$

is used to make inferences about β, when δ is unknown. It can be found (see Corollary 2.1 below with $r = n$) that the probability distribution function of V_3, conditional on fixed $\mathbf{z}$, can conveniently be expressed as

$$\Pr\{V_3 \le h \mid \mathbf{z}^{(n)}\} = \vartheta(\mathbf{z}^{(n)}) \int_0^\infty \frac{v_2^{n-2}\left(\prod_{i=1}^n z_i^{v_2}\right) G_n\left(h^{v_2}\sum_{i=1}^n z_i^{v_2}\right)}{\left(\sum_{i=1}^n z_i^{v_2}\right)^n} dv_2 \quad (h \ge 0), \tag{24}$$

where $G_n(\tau)$ represents the incomplete gamma integral,

$$G_n(\tau) = \int_0^\tau \frac{t^{n-1}e^{-t}}{\Gamma(n)} dt. \tag{25}$$

For any specified value of h, (21) can be integrated numerically to give conditional probability statements for V_3. Then, for example, the probability statement

$$\Pr\{V_3 \le h \mid \mathbf{z}^{(n)}\} = \alpha \tag{26}$$

leads to an α conditional confidence interval for β,

$$\beta \ge h^{-1/\hat{\delta}}\hat{\beta}. \tag{27}$$

3.2. Main Theorems

The above results can be presented more naturally, however, if we consider the distribution of the logarithm of a Weibull variate, which we denote by Y. The random variate Y follows the first asymptotic distribution of extreme values, with density

$$f(y \mid a,b) = \frac{1}{b}\exp\left(\frac{y-a}{b}\right)\exp\left(-\exp\left(\frac{y-a}{b}\right)\right) \quad (-\infty < y < \infty), \tag{28}$$

where

$$a = \ln\beta, \quad b = \delta^{-1}. \tag{29}$$

Now, (28) is a distribution with location and scale parameters a and b, respectively, and it is well known that if $\hat{a}$, $\hat{b}$ are maximum likelihood estimates for a, b, from a complete (uncensored) sample of size n, then

$$U_1 = \frac{\hat{a}-a}{b}, \quad U_2 = \frac{\hat{b}}{b}, \quad U_3 = \frac{\hat{a}-a}{\hat{b}} \tag{30}$$

are pivotal quantities, whose distributions depend only on n. That is, inferences concerning a and b here may be based on the pivotal quantities (27) as usual; however, the distributions of these pivotals should be considered conditional on the observed values of ancillary statistics. We generalize this situation and allow the original data to be possibly censored. Here the following theorems hold.

Theorem 1. Let $Y_1 \le ... \le Y_r$ be the first r ordered past observations from a sample of size n from the first asymptotic distribution of extreme values (28). Then the marginal probability density function of the pivotal quantity

$$U_2 = \widehat{b}/b, \tag{31}$$

conditional on fixed set of ancillary statistics

$$\mathbf{s}^{(r)} = (s_1, ..., s_r), \tag{32}$$

where

$$S_i = \frac{Y_i - \widehat{a}}{\widehat{b}}, \quad i = 1, ..., r, \tag{33}$$

are ancillary statistics (any r–2 of which form a functionally independent set), $\widehat{a}$ and $\widehat{b}$ are the maximum likelihood estimators of a and b based on the first r ordered past observations ($Y_1 \le ... \le Y_r$) from a sample of size n, which can be found from solution of

$$\widehat{a} = \widehat{b} \ln\left(\left[\sum_{i=1}^{r} e^{y_i/\widehat{b}} + (n-r)e^{y_r/\widehat{b}}\right] \Big/ r\right), \tag{34}$$

and

$$\widehat{b} = \left(\sum_{i=1}^{r} y_i e^{y_i/\widehat{b}} + (n-r) y_r e^{y_r/\widehat{b}}\right)\left(\sum_{i=1}^{r} e^{y_i/\widehat{b}} + (n-r)e^{y_r/\widehat{b}}\right)^{-1} - \frac{1}{r}\sum_{i=1}^{r} y_i, \tag{35}$$

is given by

$$g_2^{\circ}(u_2 \mid \mathbf{s}^{(r)}) = \vartheta^{\circ}(\mathbf{s}^{(r)}) u_2^{r-2} \exp\left(u_2 \sum_{i=1}^{r} s_i\right)\left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r)\exp(s_r u_2)\right]^{-r}, \quad u_2 \in (0, \infty), \tag{36}$$

where

$$\vartheta^{\circ}(\mathbf{s}^{(r)}) = \left(\int_0^{\infty} u_2^{r-2} \exp\left(u_2 \sum_{i=1}^{z} s_i\right)\left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r)\exp(s_r u_2)\right]^{-r} du_2\right)^{-1} \tag{37}$$

is the normalizing constant.

Proof. The joint density of $Y_1 \le ... \le Y_r$ is given by

$$f(y_1, ..., y_r \mid a, b) = \frac{n!}{(n-r)!}\prod_{i=1}^{r} \frac{1}{b}\exp\left(\frac{y_i - a}{b} - \exp\left(\frac{y_i - a}{b}\right)\right) \exp\left(-(n-r)\exp\left(\frac{y_r - a}{b}\right)\right). \tag{38}$$

Using the invariant embedding technique [18–22], we then find in a straightforward manner, that the probability element of the joint density of U_1, U_2, conditional on fixed $\mathbf{s}^{(r)} = (s_1, ..., s_r)$, is

$$f(u_1, u_2 \mid \mathbf{s}^{(r)}) du_1 du_2$$

$$= \vartheta^{\bullet}(\mathbf{s}^{(r)}) u_2^{r-2} \exp\left(u_2 \sum_{i=1}^{r} s_i\right) e^{r u_1} \exp\left(-e^{u_1}\left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r)\exp(s_r u_2)\right]\right) du_1 du_2,$$

$$u_1 \in (-\infty, \infty), \quad u_2 \in (0, \infty), \tag{39}$$

where

$$\vartheta^{\bullet}(\mathbf{s}^{(r)}) = \left(\int_0^{\infty} \Gamma(r) u_2^{r-2} \exp\left(u_2 \sum_{i=1}^{z} s_i\right)\left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r)\exp(s_r u_2)\right]^{-r} du_2\right)^{-1} \tag{40}$$

is the normalizing constant. Now u_1 can be integrated out of (39) in a straightforward way to give (36). This ends the proof.

Corollary 1.1. Let $X_1 \le ... \le X_r$ be the first r ordered past observations from a sample of size n from the two-parameter Weibull distribution (1). Then the marginal probability density function of the pivotal quantity

$$V_2 = \delta / \widehat{\delta}, \tag{41}$$

conditional on fixed set of ancillary statistics

$$\mathbf{z}^{(r)} = (z_i, \ldots, z_r), \tag{42}$$

where

$$Z_i = \left(\frac{X_i}{\widehat{\beta}} \right)^{\widehat{\delta}}, \quad i = 1, ..., r, \tag{43}$$

are ancillary statistics (any r–2 of which form a functionally independent set), $\widehat{\beta}$ and $\widehat{\delta}$ are the maximum likelihood estimators of β and δ based on the first r ordered past observations ($X_1 \le ... \le X_r$) from a sample of size n, which can be found from solution of

$$\widehat{\beta} = \left(\left[\sum_{i=1}^{r} x_i^{\widehat{\delta}} + (n-r) x_r^{\widehat{\delta}} \right] \Big/ r \right)^{1/\widehat{\delta}}, \tag{44}$$

and

$$\widehat{\delta} = \left[\left(\sum_{i=1}^{r} x_i^{\widehat{\delta}} \ln x_i + (n-r) x_r^{\widehat{\delta}} \ln x_r \right) \left(\sum_{i=1}^{r} x_i^{\widehat{\delta}} + (n-r) x_r^{\widehat{\delta}} \right)^{-1} - \frac{1}{r} \sum_{i=1}^{r} \ln x_i \right]^{-1}, \tag{45}$$

is given by

$$g_2(v_2 \mid \mathbf{z}^{(r)}) = \vartheta(\mathbf{z}^{(r)}) v_2^{r-2} \prod_{i=1}^{r} z_i^{v_2} \left(\sum_{i=1}^{r} z_i^{v_2} + (n-r) z_r^{v_2} \right)^{-r}, \quad (v_2 > 0), \tag{46}$$

where

$$\vartheta(\mathbf{z}^{(r)}) = \left[\int_0^\infty v_2^{r-2} \prod_{i=1}^{r} z_i^{v_2} \left(\sum_{i=1}^{r} z_i^{v_2} + (n-r) z_r^{v_2} \right)^{-r} dv_2 \right]^{-1} \tag{47}$$

is the normalizing constant.

Theorem 2. Let $Y_1 \le ... \le Y_r$ be the first r ordered past observations from a sample of size n from the first asymptotic distribution of extreme values (28). Then the probability distribution function of the pivotal quantity

$$U_3 = \frac{\widehat{a} - a}{\widehat{b}}, \tag{48}$$

conditional on fixed set of ancillary statistics $\mathbf{s}^{(r)}$, is given by

$$\Pr(U_3 \le h \mid \mathbf{s}^{(r)})$$

$$= \vartheta^{\circ}(\mathbf{s}^{(r)}) \int_0^\infty \frac{u_2^{r-2} \exp\left(u_2 \sum_{i=1}^{r} s_i \right) G_r \left(\exp(hu_2) \left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r) \exp(s_r u_2) \right] \right)}{\left[\sum_{i=1}^{r} \exp(s_i u_2) + (n-r) \exp(s_r u_2) \right]^r} du_2 \quad (h \ge 0), \tag{49}$$

where

$$G_r(\tau) = \int_0^{\tau} \frac{t^{r-1}e^{-t}}{\Gamma(r)} dt. \tag{50}$$

represents the incomplete gamma integral.

Proof. The proof is similar to that of Theorem 1 and so it is omitted here.

Corollary 2.1. Let $X_1 \le ... \le X_r$ be the first r ordered past observations from a sample of size n from the from the two-parameter Weibull distribution (1). Then the probability distribution function of the pivotal quantity

$$V_3 = \left(\frac{\widehat{\beta}}{\beta}\right)^{\widehat{\delta}} \tag{51}$$

conditional on fixed set of ancillary statistics $\mathbf{z}^{(r)}$, is given by

$$\Pr\{V_3 \le h \mid \mathbf{z}^{(r)}\} = \vartheta(\mathbf{z}^{(r)}) \int_0^{\infty} \frac{v_2^{r-2}\left(\prod_{i=1}^r z_i^{v_2}\right) G_r\left(h^{v_2}\left[\sum_{i=1}^r z_i^{v_2} + (n-r)z_r^{v_2}\right]\right)}{\left(\sum_{i=1}^r z_i^{v_2} + (n-r)z_r^{v_2}\right)^r} dv_2 \quad (h \ge 0). \tag{52}$$

3.3. Test Plan

To test for assuring μ in the Weibull distribution, we consider life testing with Type II censoring when the shape parameter δ is unknown. The r and h are determined by

$$\begin{cases} \widehat{\beta}^{\widehat{\delta}} > h, & \text{accept the lot,} \\ \widehat{\beta}^{\widehat{\delta}} \le h, & \text{reject the lot.} \end{cases} \tag{53}$$

To select r and h, we use the equations (2) and (3), which can be presented in the case when the parameter δ is unknown as

$$\Pr\left\{\widehat{\beta}^{\widehat{\delta}} \le h \mid \mu = \mu_1; \mathbf{z}^{(r)}\right\} = \Pr\left\{\left(\frac{\widehat{\beta}}{\beta_1}\right)^{\widehat{\delta}} \le \frac{h}{\beta_1^{\widehat{\delta}}} \mid \mu = \mu_1; \mathbf{z}^{(r)}\right\} = \Pr\left\{V_3 \le V_{3(\mathbf{z}^{(r)};\alpha_1)}\right\} = \alpha_1, \tag{54}$$

$$\Pr\left\{\widehat{\beta}^{\widehat{\delta}} > h \mid \mu = \mu_2; \mathbf{z}^{(r)}\right\} = \Pr\left\{\left(\frac{\widehat{\beta}}{\beta_2}\right)^{\widehat{\delta}} > \frac{h}{\beta_2^{\widehat{\delta}}} \mid \mu = \mu_2; \mathbf{z}^{(r)}\right\} = \Pr\left\{V_3 > V_{3(\mathbf{z}^{(r)};1-\alpha_2)}\right\} = \alpha_2, \tag{55}$$

where

$$\Pr\{V_3 \le V_{3(\mathbf{z}^{(r)};\alpha)} \mid \mathbf{z}^{(r)}\} = \alpha. \tag{56}$$

From (54) and (55),

$$\left(\frac{\beta_2}{\beta_1}\right)^{\widehat{\delta}} \le \frac{V_{3(\mathbf{z}^{(r)};\alpha_1)}}{V_{3(\mathbf{z}^{(r)};1-\alpha_2)}}. \tag{57}$$

Therefore, the required r is the smallest integer satisfying (57), which can be obtained only via testing n ($n \ge r$) items of the lot of products. Using r based on (57), we have from (54) and (12) that the h for $\widehat{\beta}^{\widehat{\delta}}$ is given by

$$h = \left(\mu_1 / E\left\{\Gamma\left(1 + \frac{1}{\widehat{\delta}V_2}\right)\right\}\right)^{\widehat{\delta}} V_{3(\mathbf{z}^{(r)};\alpha_1)}, \tag{58}$$

where

$$E\left\{\Gamma\left(1+\frac{1}{\widehat{\delta}V_2}\right)\right\}=\int_0^\infty \Gamma\left(1+\frac{1}{\widehat{\delta}v_2}\right)g_2(v_2 \mid \mathbf{z}^{(r)})dv_2. \tag{59}$$

Thus, the lot of products is accepted if $\widehat{\beta}^{\widehat{\delta}} > h$; otherwise, it is rejected.

The optimal value of n may be found in this case as follows. Let us assume that from the past experiences of testing m items of products we have available the marginal probability density function of the pivotal quantity $V_2=\delta/\widehat{\delta}$, conditional on fixed $\mathbf{z}^{(m)}=(z_i, \ldots, z_m)$ with $Z_i=(X_i/\widehat{\beta})^{\widehat{\delta}}$, $i=1,\ldots,m$, which is given by

$$g_2(v_2 \mid \mathbf{z}^{(m)})=\vartheta(\mathbf{z}^{(m)})v_2^{m-2}\prod_{i=1}^m z_i^{v_2}\left(\sum_{i=1}^m z_i^{v_2}\right)^{-m}, \quad (v_2>0), \tag{60}$$

where

$$\vartheta(\mathbf{z}^{(m)})=\left[\int_0^\infty v_2^{m-2}\prod_{i=1}^m z_i^{v_2}\left(\sum_{i=1}^m z_i^{v_2}\right)^{-m}dv_2\right]^{-1}. \tag{61}$$

Assuming that the required $r \le m$ and can be found approximately by using the past experiences of testing m items and (57), we have

$$n^*=\underset{n\ge r}{\operatorname{argmin}}\left[c_{\circ}n+c_{\bullet}\beta_1\int_0^\infty \Gamma\left(1+\frac{1}{\widehat{\delta}v_2}\right)\sum_{k=0}^{r-1}\binom{r-1}{k}(-1)^k\frac{n!}{(r-1)!(n-r)!}(n-r+k+1)^{-\left(1+\frac{1}{\widehat{\delta}v_2}\right)}g_2(v_2 \mid \mathbf{z}^{(m)})dv_2\right]. \tag{62}$$

4. Conclusions

The methodology described here can be extended in several different directions to handle various problems that arise in practice. It will be noted that often the Bayesian approach is used to solve the above problem. Unfortunately, in this case the subjectivity of investigator (a limitation of the Bayesian approach) is introduced through a priori distribution. In order to rule out the subjectivity of investigator and to consider comprehensively the relevant risks, in this paper a frequentist (non-Bayesian) decision analysis is employed. It is based on the invariant embedding technique which allows one to use available statistical information as completely as possible.

Acknowledgments

This research was supported in part by Grant No. 06.1936, Grant No. 07.2036, Grant No. 09.1014, and Grant No. 09.1544 from the Latvian Council of Science and the National Institute of Mathematics and Informatics of Latvia. The authors are thankful to a referee for providing useful comments and suggestions.

References

1. Epstein, B. Truncated Life Tests in the Exponential Case, *Annals of Mathematical Statistics*, Vol. 68, 1954, pp. 555–564.
2. Sobel, M. and J. A. Tischendrof. Acceptance Sampling with Life Test Objective. *Proceedings of Fifth National Symposium on Reliability and Quality Control*. Philadelphia, 1959, pp. 108–118.
3. Goode, H. P., Kao, J. H. K. Sampling Plans Based on the Weibull Distribution. *Proceedings of Seventh National Symposium on Reliability and Quality Control*, Philadelphia, 1961, pp. 24–40.
4. Gupta, S. S. and P. A. Groll. Gamma Distribution in Acceptance Sampling Based on Life Tests, *Journal of the American Statistical Association*, Vol. 56, 1961, pp. 942–970.
5. Gupta, S. S. Life Test Sampling Plans for Normal and Lognormal Distribution, *Technometrics*, Vol. 4, 1962, pp. 151–175.

6. Fertig, F. W. and N. R. Mann. Life-test Sampling Plans for Two-parameter Weibull Populations, *Technometrics*, Vol. 22, 1980, pp. 165–177.
7. Kantam, R. R. L. and K. Rosaiah. Half Logistic Distribution in Acceptance Sampling Based on Life Tests, *IAPQR Transactions*, Vol. 23, 1998, pp. 117–125.
8. Kantam, R. R. L., Rosaiah, K., Srinivasa Rao, G. Acceptance Sampling Based on Life Tests: Log-Logistic Model, *Journal of Applied Statistics*, Vol. 28, 2001, pp. 121–128.
9. Baklizi, A. Acceptance Sampling Based on Truncated Life Tests in the Pareto Distribution of the Second Kind, *Advances and Applications in Statistics*, Vol. 3, 2003, pp. 33–48.
10. Wu, C. J. and T. R. Tsai. Acceptance Sampling Plans for Birnbaum-Saunders Distribution under Truncated Life Tests, *International Journal of Reliability, Quality and Safety Engineering*, Vol. 12, 2005, pp. 507–519.
11. Rosaiah, K., Kantam, R. R. L. Acceptance Sampling Based on the Inverse Rayleigh Distribution, *Economic Quality Control*, Vol. 20, 2005, pp. 277–286.
12. Rosaiah, K., Kantam, R. R. L., Santosh Kumar, Ch. Reliability Test Plans for Exponentiated Log-Logistic Distribution, *Economic Quality Control*, Vol. 21, 2006, pp. 165–175.
13. Tsai, T. R., Wu, S. J. Acceptance Sampling Based on Truncated Life Tests for Generalized Rayleigh Distribution, *Journal of Applied Statistics*, Vol. 33, 2006, pp. 595–600.
14. Balakrishnan, N., Leiva, V., Lopez, J. Acceptance Sampling Plans from Truncated Life Tests Based on the Generalized Birnbaum-Saunders Distribution, *Communications in Statistics-Simulation and Computation,* Vol. 36, 2007, pp. 643–656.
15. Srinivasa, Rao G., Kantam, R .R. L. Acceptance Sampling Plans from Truncated Life Tests Based on the Log-Logistic Distribution for Percentiles, *Economic Quality Control*, Vol. 25, 2010, pp. 153– 167.
16. Lieblein, J. On Moments of Order Statistics from the Weibull Distribution, *Annals of Mathematical Statistics*, Vol. 26, 1955, pp. 330–333.
17. Fisher, R. A. Two New Properties of Mathematical Likelihood, *Proceedings of the Royal Society*, Vol. A 144, 1934, pp. 285–307.
18. Nechval, N. A., Berzins, G., Purgailis, M., Nechval, K. N. Improved Estimation of State of Stochastic Systems via Invariant Embedding Technique, *WSEAS Transactions on Mathematics*, Vol. 7, 2008, pp. 141–159.
19. Nechval, N. A., Purgailis, M. Stochastic Decision Support Models and Optimal Stopping Rules in a New Product Lifetime Testing. *Stochastic Control / Chris Myers (Ed.).* Croatia, India: Sciyo, 2010, pp. 533–558.
20. Nechval, N. A., Purgailis, M., Cikste, K., Berzins, G., Nechval, K. N. Optimization of Statistical Decisions via an Invariant Embedding Technique: Lecture Notes in Engineering and Computer Science. *Proceedings of the World Congress on Engineering, WCE 2010, 30 June-2 July, 2010.* London, U.K., 2010, pp. 1776–1782.
21. Nechval, N. A., Nechval, K. N., Purgailis, M., Rozevskis, U. Improvement of Inventory Control under Parametric Uncertainty and Constraints. *Adaptive and Natural Computing Algorithms / A. Dobnikar, U. Lotric, B. Ster (Eds.). LNCS.* Berlin, Heidelberg, 2011. Vol. 6594. Part II, pp. 136–146.
22. Nechval, N. A., Purgailis, M., Nechval, K. N., Rozevskis, U. Optimization of Prediction Intervals for Order Statistics Based on Censored Data: Lecture Notes in Engineering and Computer Science. *Proceedings of the World Congress on Engineering, WCE 2011, 6–8 July, 2011.* London, U.K., 2011, pp. 63–69.

Received on the 21st of May, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 59–63
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

THE GROUND RADIO TRANSMITTERS DETECTION THROUGH MEASUREMENTS ON SCIENTIFIC SATELLITES

A. Aitmagambetov[1], A. Inchin[2], A. Lozbin[2]

[1]*Kazakh Academy of Transport and Communications*
97, Shevchenko st., 050012, Almaty, Kazakhstan
E-mail: altayzf@mail.ru

[2]*Institute of Space Techniques and Technologies*
34, Kislovodskaya st., 050063, Almaty, Kazakhstan
E-mail: inchinas@mail.ru, lozbin@mail.ru

In the frame of Kazakhstan's Scientific Space System Project the research of hardware and software of French satellite DEMETER was investigated. The data processing Software of DEMETER is based on package SWAN under IDL Virtual machine. For elimination some problem of this software we have developed own Software DeSS with data mapping. This software allows to detect signals from different radio transmitters up to 3,33 MHz. There is a great interest for Radio Communications authority to carry out radio monitoring of ground transmitters by means of scientific satellites.

Keywords: *scientific satellite, radio transmitters, electromagnetic field, software*

1. General

At present satellite systems are widely used for telecommunications and broadcasting. Applications of satellites in spectrum monitoring and location of radio transmitters are of great interest for Radio communications Authority. Special interest for that is application of low-orbit scientific satellites.

The signals from ground low-frequency transmitters are regularly registered on artificial satellites. Channeled magnetosphere signals can be detected also on a ground surface in magneto conjugate points (MCP) of a radiator. By results of such signals measurements it is possible to define a low-frequency wave's propagation and their interaction with magnetosphere-ionosphere plasma. On Figure 1a is showed a schematic drawing of such signals [1] and, on Figure 1b, the real signals from French Satellite DEMETER visualized by our software are shown.

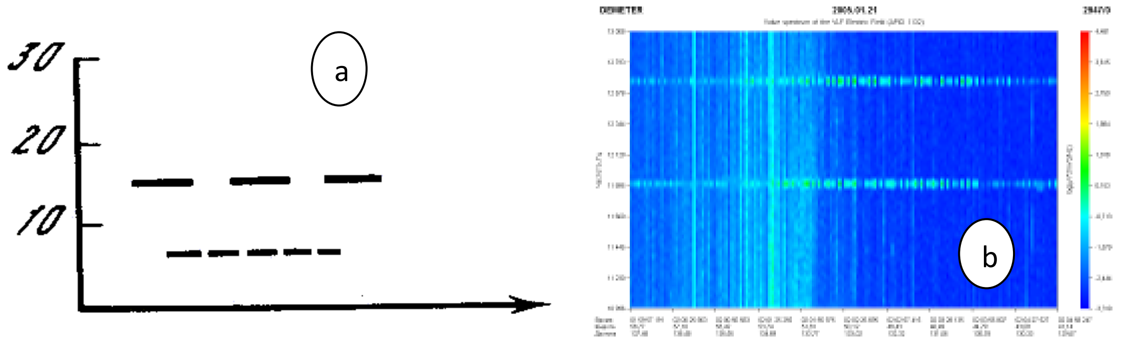

Figure 1. The Signals from VLF Transmitters a) schematic drawing; b) real signals from Russian transmitters "Alfa"

The VLF signals from radio transmitters and whistlers are generate typical individual emissions. These emissions also can have a scientific interest.

Trigger emissions

These radiations (Figure 2) as well as accompanying spectrum widening of low-frequency signals from transmitter, apparently, are resulted from these signals interaction with energetic particles or electrostatic fluctuations around an equatorial plane of magnetosphere. The probable mechanism of trigger emissions occurrence was given by Molchanov [1].

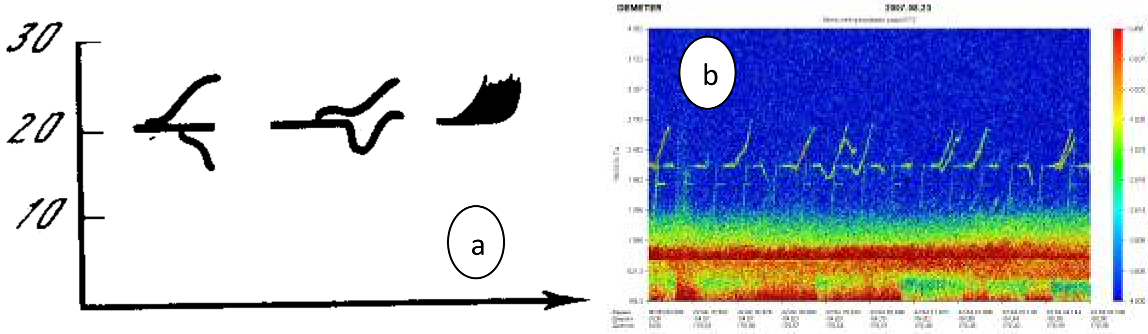

Figure 2. Trigger emissions. a) schematic drawing; b) real signals from American transmitter "HAARP"

Discrete emissions

These emissions (Figure 3) are registered both, on ground surface and on an artificial satellite. According to Molchanov [1], these radiations are generated either signals of transmitters, or electronic whistlers, however, in this case, the initial wave for any reasons is not detected. It can happen because of the big divergence of paths of initial and generated waves and-or because of the high attenuation of an initial wave. Still rather recently discrete radiations considered as own are generated, for instance, by monoenergetic particles beam; however more detailed researches have led the scientists to the conclusion about their induced character [1].

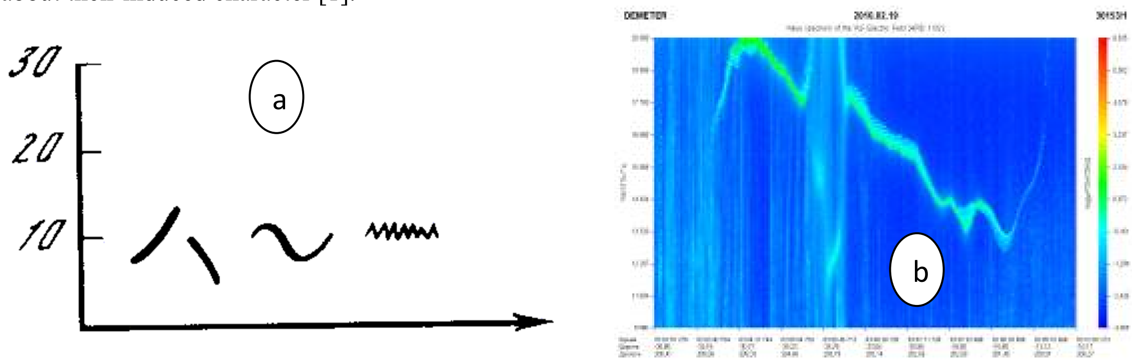

Figure 3. Discrete emissions. a) schematic drawing; b) real signals

Here only the basic known effects from VLF transmitters influence are resulted. There are some more emissions as, for example, *quasinoise emissions from whistlers* or *emissions on modulation frequency of ground transmitters* which also have scientific interest.

Certainly, scientific interest of research of transmitters influence on an ionosphere is a main task, but, here there is also one indirect practical advantage as a detection and localization of radio transmitters.

The software "DIAS" for data processing from scientific satellite "DEMETER" was developed at the Institute of Space Techniques and Technologies (Almaty, Kazakhstan) [2]. This software allows researcher to create the maps of electric and magnetic perturbations of different frequencies in global and regional scale: electrical component – up to 3,33 MHz, magnetic component – up to 20 kHz. This frequency range was caused by electromagnetic sensor's features of the satellite. The mapping of electromagnetic perturbations allows determination of the transmitter's locations and estimating the radiated power.

Because of such frequency range of electric and magnetic devices on DEMETER satellite, the researches of radio transmitters influence on ionosphere are limited only to average, long and super long waves. For radio transmitters influence research there are special functions in Software: "data multiupload" and "signal-noise relation" (SNR).

The caused by action of transmitters ionosphere disturbance's detection and identification technique consists of multiuploading of electric and magnetic spectral and wave data in VLF range and reception of a global or regional picture of disturbances.

On Figure 4a the example of electric field disturbance's detection and on Figure 4b – magnetic field, from ground VLF NWC transmitter located in Australia is presented. In this case it was applied both options – data multiuploading and SNR.

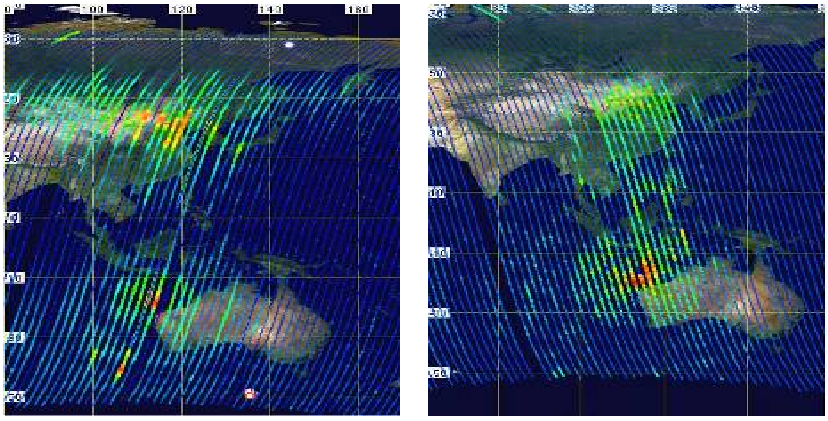

Figure 4. The example of electric (a) and magnetic (b) field disturbances detection under VLF transmitter NWC (Australia)

The electrical and magnetic disturbances were calculated as (1):

$$SNR = \frac{2 \cdot A_{F_0}}{A_{F_+} + A_{F_-}}; \qquad (1)$$

where, $A_{F_0} = 10^{S_{F0}}$, $(\mu V/m)^2/Hz$ – the amplitude on transmitter working frequency F_0; here S_{F_0} – value from spectrogram on transmitter working frequency ($log(\mu V/m)^2/Hz$); $A_{F_+} = 10^{S_{F_0} + \delta F}$, $(\mu V/m)^2/Hz$ – the amplitude on transmitter working frequency $F_0+\delta F$; *here*, δF – ½ of transmitter broadband (special for each transmitter and operator inputted in Software); $A_{F_-} = 10^{S_{F_0} - \delta F}$, $(\mu V/m)^2/Hz$ – the amplitude on transmitter working frequency $F_0-\delta F$.

Similarly it is possible to visualize disturbances for the transmitter with frequency up to 3 MHz (for DEMETER Satellite). On the Figure 5 the Russian broadcasting transmitter and its influence on ionosphere is shown.

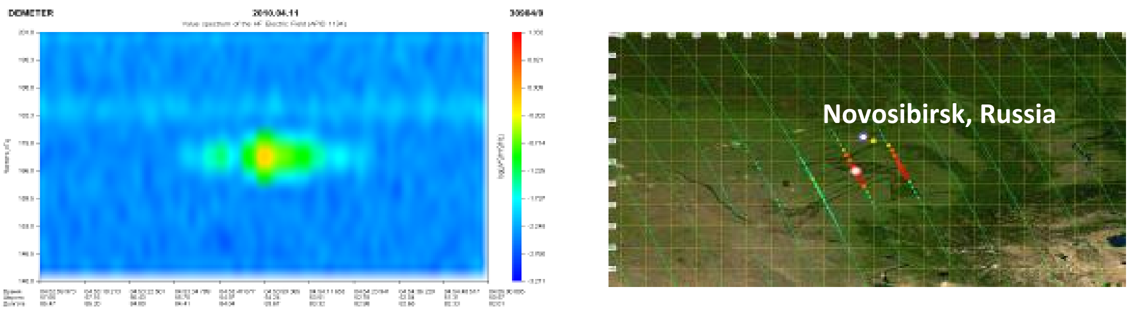

Figure 5. Electrical disturbances on frequency 171 kHz due the Russian broadcasting transmitter in Novosibirsk

As we can see on Figure 5, the electrical part of the electromagnetic field in ionosphere has disturbances on the broadcasting frequency 171 kHz of this transmitter. And, on the right side we can see, that North Magneto-Conjugate Point of the disturbance maximum is mapped to the Novosibirsk city.

Recently in a media the theme the so-called "The Climatic Weapon" which name active heating stands of type "Sura" (Russia) and "HAARP" (USA) is widely shown. As a matter of fact, these heating stands are the same radio transmitters only used in the scientific purposes. Now in the world exists seven similar devices: 1) HAARP (High-frequency Active Auroral Research Program), Alaska, USA; 2) EISCAT, Tromse, Norway; 3) in Peru; 4) SURA in Nizhniy Novgorod, Russia; 5) in Apatite, Murmansk, Russia; 6) Kharkov, Ukraine; 7) Dushanbe, Tajikistan. From these devices only HAARP, SURA and Tromse are active, other – passive. The main differences of the HAARP are its amazing power, which for today makes 1GW (planned – 3.6GW) and closeness to northern magnetic pole.

The HAARP project directs a 3.6 GW signal, in the 2.8–10 MHz region of the HF [High Frequency] band, into the ionosphere. The signal may be pulsed or continuous. Then, effects of the transmission and any recovery period can be examined using associated instrumentation, including VHF and UHF radars, HF receivers, and optical cameras. According to the HAARP team, this will advance the study of basic natural processes that occur in the ionosphere under the natural but much stronger influence of solar interaction, as well as how the natural ionosphere affects radio signals.

Some of the main scientific findings from HAARP include:

1. Generation of very low frequency radio waves by modulated heating of the auroral electro jet, useful because generating VLF waves ordinarily requires gigantic antennas;
2. Production of weak luminous glow (below what can be seen with the naked eye, but measurable) from absorption of HAARP's signal;
3. Production of extremely low frequency waves in the 0.1 Hz range. These are next to impossible to produce any other way, because the length of a transmit antenna is dictated by the wavelength of the signal it is designed to produce;
4. Generation of whistler-mode VLF signals which enter the magnetosphere, and propagate to the other hemisphere, interacting with Van Allen radiation belt particles along the way;
5. VLF remote sensing of the heated ionosphere.

On the Figure 6 we can see the spectrum and spectrogram of the electrical field in ULF range over the HAARP unit in 2007.

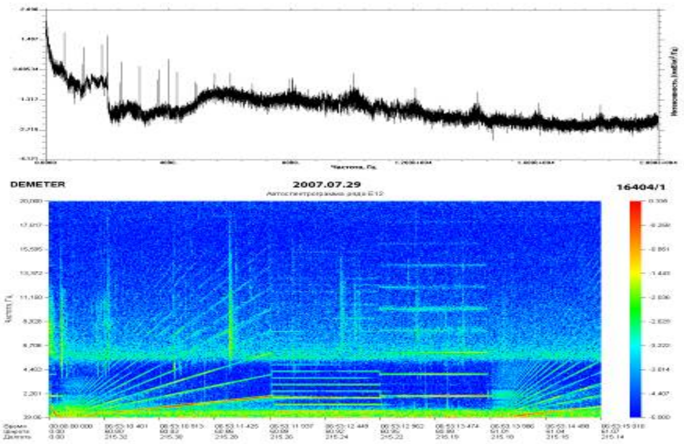

Figure 6. Spectrum and Spectrogram of the electrical field in ULF range over the HAARP

The horizontal lines on the spectrogram are a ULF harmonics of the HAARP transmission. On the spectrum we can see 19 vertical picks with different intensity. The quantitative futures of this picks given in the table on Figure 7. The most intense picks is on the frequency 612,8 and 2011,2 Hz. So it is confirmed that such transmitters as "climatic weapon" also can be observe from the satellite. The special interest attracts the ULF and VLF range of such units.

Table 1. Table of picks quantitative futures for the HAARP transmitter

#	Frequency, Hz	Intensity, $(\mu V/m)^2/Hz$	#	Frequency, Hz	Intensity, $(\mu V/m)^2/Hz$
1	612,8	73,63	***11***	5517,6	0,89
2	1226,4	15,24	***12***	6032,8	0,95
3	1839,2	20,83	***13***	7970,4	0,51
4	2011,2	47,00	***14***	8045,6	0,52
5	2452,8	3,30	***15***	10056,0	0,72
6	3065,6	1,72	***16***	12068,0	0,17
7	3678,4	1,24	***17***	14079,2	0,09
8	4022,4	4,5	***18***	16090,4	0,03
9	4291,2	0,98	***19***	18100,8	0,03
10	4904,8	0,37			

The given approach allows estimating the transmitter's power. Recently, by means of the scientific satellite data, the high power broadcasting transmitters have been detected. However, under certain electromagnetic conditions in atmosphere and in ionosphere, parameters of receivers and antenna systems, the less powerful sources detection is possible.

So in addition to scientific tasks of the satellite it would be carrying out radio monitoring task for both territory of Kazakhstan and global scale. In this case the frequency range of satellite's sensors should be broadening up to tens GHz.

So far as it is known [3], Radio Communications Authority of each country should carry out spectrum monitoring for checking radio transmitter's radiation parameters, for detecting illegal transmitters and interference sources. It is necessary for definition of conformity of parameters of radiation of radio-electronic devices for corresponding norms and conditions of permissions to use radio-frequency spectrum. Besides, radio control services are obliged to find out illegally operating radio transmitters and radio noise sources.

At present, the spectrum monitoring is principally performed by ground fixed and mobile radio monitoring stations. Besides it is known that airplanes and helicopters are occasionally used for spectrum monitoring. For the countries with large territory it is a great interest to carry out radio monitoring of ground transmitters by means of satellites. There is no sufficient information on civil satellite applications for radio monitoring.

In this connection it is very interest the questions of scientific satellite creation with possibility of measurement radio emission source's parameters in a range of frequencies from several kHz to several tens GHz with localization possibility within several kilometres. First of all, this problem is actually for the control of ground satellite stations of the space communication working in a range of frequencies from 4 to 12 GHz (ranges C and Ku) and, also, at introduction of digital broadcasting networks.

Satellite onboard equipment for radio monitoring should contain broadband tuner with antenna system and processing software for direction finding and analysis. The choice of direction finding method and equipment for receiving is necessary to do on the basis of theoretical and experimental researches for the purpose of the onboard device optimisation.

2. Conclusion

Thus, we can see from article materials, the ground radio transmitter's signals detection onboard spacecraft, both directly or indirectly, can be done. One way, transmitters can be observed by electromagnetic field measurements for radio spectrum up to several MHz. Other way – broadband tuner for upper part of radio spectrum can be used.

Besides scientific goals of scientific spacecraft with electromagnetic equipment, the goal of radio frequency monitoring over the Republic of Kazakhstan and other countries can be implemented. Scientific satellite based radio monitoring implementation will provide useful information on new telecommunications and broadcasting network planning for The Radio Communications Authority of the country and, also, to participate in International programs on Global Radio monitoring.

References

1. Molchanov, O. *Low-frequency waves and induced emissions in near Earth plasma*. M.: Science, 1985. 224 p.
2. Certificate of authorship №1585 RK. VS 0005712. The Software for Spectrum analysis "DeSS" (Software) / A. Inchin, Yu. Shpadi, A. Lozbin, M. Shpadi (RK). – declare10.10.10; printed: 20.10.10.
3. *Spectrum Monitoring. Handbook*. Geneva: ITU, 2002.

Received on the 20th of September, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 64–67
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

RADIATION-INDUCED DEFECTS IN THE IONIC SOLID SURFACES

E. P. Britavskaya

South Ukrainian National Pedagogical University
Department of Physical and Mathematical Modelling
26 Staroportofrankovskaya, 65020, Odessa, Ukraine

The dynamics of ions and atoms in the ionic solid surfaces under the influence low-energy radiation has been studied. The Coulomb, Pauli, exchange and Van der Waals potentials have been used. In the case of alkali halide surfaces it is shown that if recharge of an anion $(X^- \to X^+)$ occurs in two surface layers, it may initiate the ejection of positive metal ions M^+ and, due to the capture of an electron by positive ions M^+, also of neutral atoms M°. Besides the Coulomb repulsion the Pauli shock is shown to play an essential role in the ejection process. The last mechanism has large efficiency when the excitation of a core electron occurs and depends strongly on the crystal ionicity.

Keywords: *ionization-induced defect formation, electro-ion emission*

1. Introduction

As has been shown [1] the recharge of surface atoms leads to ejection of anion with a single positive charge or of alkali ions.

In [2] it was demonstrated that the participation of valence electrons of adatoms in the Auger transition causes their desorption. To understand better the behaviour of alkali halide surface ions in condition of irradiation a computer simulation of the surface atoms dynamics was carried out in [6–8]. In [5] a semi-empirical quantum-chemical approximation was used to solve the analogous problem. All these radiation-induced processes are known as sub-threshold radiation effects (SRE). These effects are defined as atomic displacements that occur at low energies of radiation as a result of ionisation or excitation of electron. SRE on surface and in the bulk of non-metallic solids were discussed in [9–11, 18, 19]. So far many experimental results cannot de fully explained [14–17], [20–24]. The aim of this paper is to give a detailed explanation of sub-threshold mechanisms of electron-ion emission from the ionic surfaces.

2. Simulation Method

The computer program based on molecular dynamic (MD) approximation was used. This is a quite good approximation for a wide range of materials and conditions. The quantum effect becomes significant only when one considers electron motion or translation and rotational motion of light atoms or molecules. Here quantum effects are accounted in independent calculations.

In the standard MD method the atoms` motion is described by classic equations with interaction potential *U (r)*. For the system with *N* particles the following system has to be integrated:

$$m\frac{d^2\vec{r}_i(t)}{dt^2} = \sum_{\substack{i=1 \\ i\neq j}}^{N} \vec{F}(r_{ij}), \tag{1}$$

$$\vec{F}(r_{ij}) = -\nabla U(r_{ij}). \tag{2}$$

Here *m* is a mass of atom, r_{ij} is the distance between atoms *i* and *j*, $\vec{F}(r_{ij})$ is a force acting on *i*-atom from *j*-atom, $\vec{r}_i(t)$ is a radius-vector of *i*-atom.

To solve this problem, a set of algorithms are proposed. We used the Verlet algorithm [25]. The initial velocities that correspond to given temperature are introduced using the Maxwell-Boltzmann distribution.

After each time step computer calculates the temperature, the current potential energy and the total energy that should be conserved.

3. Sub-Threshold Mechanisms of Defect Formation in the Ionic Surface Layers

A modelling of the atomic processes accompanied by the relaxation of the ionized states demands to take into account the real lifetime of the electron excitation τ_e. The theoretical and experimental data, for ionisation state were used. We inserted a distribution of electron excitations lifetime into the algorithm of computer modelling of atomic displacements.

Two conditions were satisfied for the escape of the ion from the surface:

– ion kinetic energy E_k exceeds the energy necessary for the exit of nuclear particles from the lattice site in elastic collision E_d :

$$E_k > E_d \;;$$

– distance R between the emitted ion and crystal surface exceeds the mean free path $\mathbf{\Lambda}$ in the gas phase:

$$R > \Lambda \,.$$

Below the results of computer simulation of ionisation-stimulated emission of atoms and ions from the ionic crystals surface are demonstrated. The compounds of *LiCl, LiBr,LiI, NaI, KCl*, *KI* were studied. The calculations were performed for (100) plane.

In figures 1–5 the kinetic dependences of the ions emission from the surface of the researched crystals are shown. In all cases the crystallographic area was examined.

The ionisation of the 1s-level of the ion Cl^- in *LiCl* and subsequent Auger transitions lead to transformation $Cl^- \to Cl^+$. As a result the recharged ion Cl^+ is surrounded by 5 ions Li^+. An unstable configuration arises and an ion Cl^+ is emitted. Such mechanism of ionisation-stimulated displacement of ions is known as a Coulomb explosion (Figure 1).

In case with the crystal *KCl* similar kinetics was observed.

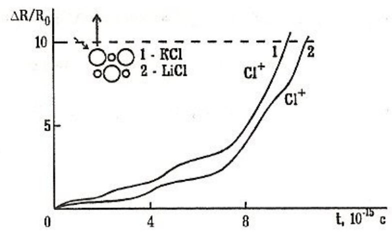

Figure1. Kinetics of Cl^+ emission in the case of Coulomb explosion

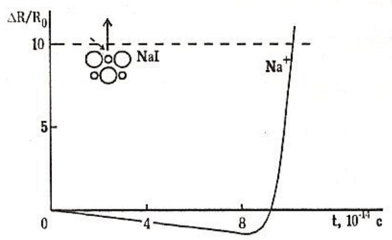

Figure 2. Kinetics of Na^+ emission in the case of Pauli shock

Special interest is in kinetic dependences shown on Figure 2. In this case at first the ionisation of the 1s-level of Na^+ with subsequent Auger transition occurs. The attraction force increases between cation and anion and the distance between them becomes considerably less than in the similar system $Na^+ - I^-$. After recombination of cation Na^+ we observe the Pauli shock.

Thus, the conditions, which influence the effective emission of atoms and ions from the ionic surfaces as a result of the activity of sub-threshold mechanisms of defect creation, were detected. As mentioned above, the calculation algorithm included the enumeration of different values of the electron excitation τ_e, which are usual for this level. As each combination of τ_e corresponds to its value of accumulated impulse P, the program at the same time calculated the energy distribution of the emitted particles. It turned out that these distributions illustrate the correlation of different mechanisms of sub-threshold defect creation. Besides, the correlation of mechanisms is determined by the parameter of crystal ionicity, and also by peculiarities of ionised atoms' positions.

4. Conclusions

1. The kinetic curves of the ionisation stimulated emission of atoms and ions from the surface of ionic crystals have been obtained. In the process of sub-threshold emission different mechanisms of sub-threshold defect creation are revealed (Coulomb explosion, Pauli shock).
2. It was found that the correlation between different mechanisms of sub-threshold defect creation depends on the lifetime of the excited electron states, peculiarities of inter-atomic interaction (crystal ionicity), and the starting position of the ionised atom.
3. Two types of Pauli shock have been detected. The conditions of their realization were determined.
4. The calculation method allows getting the energy distribution of emitted atoms and ions. Its of sub-threshold defect creation features are determined by the correlation of sub-threshold mechanisms that are realized.

References

1. Kiv, A. E., Malkin, A. M. *Sov.Phys.Solid. State*, Vol. 18, 1976, p. 857.
2. Knotek, M. L., Feibelman, P. J. *Phys. Rev. Lett*., Vol. 40, 1978, p. 964.
3. Kiv, A. E., Soloviev, V. N., Maximova, T. I. Microstructure of the Relaxed (001) Si structure, *Semicond. Phys. & Optoelectonics*, Vol. 3, 2000, pp. 157–161.
4. Iskanderova, Z. A., Kiv, A. E., Soloviev, V. N. About the Mechanism of E-centre formation in Si, *Phys. and Techniques of Semicond*, Vol. 11, 1977, pp. 199–201.
5. Kiv, A. E., Elango, M. A., Britavskaya, E. P., Zakharchenko, I. G. Mechanisms of subthreshold atomic emission from solids surface, *Nucl.Instrum. & Methods*, *B*, Vol. 90, 1994, pp. 257–260.
6. Britavskaya, E. P., Chislov, V. V., Shakhovtsov, V. I., Zakharchenko, I. G. New mechanisms of radiation defect creation in space conditions / Ed. R. C. Tennyson and A. E. Kiv, *NATO ASI Series-3. High Technology*, Vol. 22, 1996, pp. 1–5.
7. Britavskaya, E. P., Kiv, A. E., Kovalchuk, V. V., Urum, G. D. Surface Disordered Phase in Semiconductors, *Ukr. Phys. Journ*., Vol. **7**, 1995, pp. 698–701.
8. Britavskaya, E. P., Urum, G. D., Chislov, V. V. The model of photo stimulated structure transformations in amorphous materials, *Photoelectronics*, 1996, pp. 44–46.
9. Shakhovtsov, V. I., Britavskaya, E. P., Urum, G. D. Dozymetry of low intensive laser radiation on the basis of subthreshold mechanisms of radiation-induced defect creation, *Proc. of Polish-Ukrainian Seminar on optoelectronic metrology*, 1994, pp. 51–54.
10. Britavskaya, E. P., Chislov, V. V., Urum, G. D., Zakharchenko, I. G. The model of high sensitive detector of ionizing radiation, *Proc. of Pecar's Intern. Conf.*, 1994, pp. 7–11.
11. Kiv, A. E., Britavskaya, E. P., Urum, G. D. Electron-lattice relaxation in radiation physics, *Proc. of Intern. Conf. on Dielectric and Related Phenomena*, 1994, pp. 59–61.
12. Ageev, V. N., Kuznetsov, Yu. A., Yakshinskiia, B. V., Madey, T. E. Stimulated desorption of alkali metal ions and atoms: Local surface field relaxation, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, Vol. 101, 1999, pp. 69–72.
13. Madey, T. E. Adsorption of oxygen on W(100): Adsorption kinetics and electron stimulated desorption, *Surface Science*, Vol. 33, 1972, pp. 355–376.
14. Ptasińska, S., Sanche, L. Low energy electron stimulated desorption of ions from surface, *International Journal of Mass Spectrometry*, Vol. 263, 2007, pp. 179–184.
15. Ageev, V. N., Burmistrova, O. P., Kuznetsov, Yu. A. Desorption stimulated by electronic excitations, *SovPhysUspehi*, Vol. 32 (7), 1989, pp. 588–604.
16. Ageev, V. N., Kuznetsov, Yu. A., Madey, T. E. Electron-stimulated desorption of sodium atoms from an oxidized molybdenum surface, *Phys. Rev. B*, Vol. 58, 1998, pp. 2248–2252.
17. Abell, G. C. Empirical chemical pseudopotential theory of molecular and metallic bonding, *Phys. Rev*., Vol. B31, 1985, pp. 6184–6196.

18. Barthès, M.-G., Pariset, C. A low energy electron diffraction-Auger electron spectroscopy study of alloy formation during the adsorption of tin on (100) and (111) Au, *Thin Solid Films*, Vol. 77, Issue 4, 1981, pp. 305–312.
19. Park, Ch., Kramer, M., Bauer, E. Thresholds of electron stimulated desorption of F+ ions, *Surface science letters*, Vol. 109, Issue 3, 2002, pp. 533–538.
20. Devine, R. A. B., Arndt, J. Correlated defect creation and dose-dependent radiation sensitivity in amorphous SiO2, *Phys. Rev*., Vol. B 39, 1989, pp. 5132–5138.
21. Mase, K., Nagasono, M., Tanaka, S. Ion desorption induced by core-electron transitions studied with electron–ion coincidence spectroscopy, *Surface Science,* Vol. 451, Issues 1–3, 2000, pp. 143–152.
22. Ishii, M., Hayashi, T., Matsumoto, S. Adsorption, desorption and decomposition of nitrogen monoxide on Rh(100) studied by electron-stimulated desorption, Auger electron spectroscopy and temperature-programmed desorption, *Applied Catalysis*, Vol. 225, 2002, pp. 207–213.
23. Morigaki, K., Hikita, H, Takeda, T, Roca, C. The kinetics of light-induced defect creation in hydrogenated polymorphous silicon – stretched exponential relaxation, *Physica status solidi (c),* Vol. 7, 2010, pp. 692–695.
24. Lushchik, A., Baimakhanuly, A., Kotlov, A., Nagirnyi, V., Shablonin, E., Vasil'chenko, E. Defect creation via hot carriers recombination or decay of cationexcitons in NaCl and MgO at 6–12 K, *Science & Research Jobs*, DOI: 15816, 2010
25. *Computer Simulation in Chemical Physics / M. P. Allen, D. J. Tildesley (Eds.).* Kluwer Academic Publishers, 1993.

Received on the 12th of September, 2011

Computer Modelling and New Technologies, 2011, Vol.15, No.3, 68–71
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

DEPENDENCE OF RETENTION PROPERTIES OF MEMORY TRANSISTORS ON THE TEMPERATURE OF INJECTED ELECTRONS

S. Zyryn, I. Tolkach

South Ukrainian National Pedagogical University
Department of Physical and Mathematical Modelling
26 Staroportofrankovskaya, 65020, Odessa, Ukraine

Computer modelling of retention characteristics of memory transistor was performed. The case of the gate dielectric with nanoparticles as trapping centres (TC) is considered. The approach is based on the study of the life time of trapped electrons, τ_{TE}^{i} in TC that is proportional to the number of computer simulation steps. It was found that the value τ_{TE}^{i} depends significantly on the temperature of injected charge carriers. The interpretation of results is based on the consideration of the radiationless energy loss by injected charges.

Keywords: *computer modelling, memory transistors, Coulomb blockade, retention characteristics*

1. Introduction

The gate dielectric of a wide class of memory transistors is a so called ONO (oxide-silicon nitride-oxide) structure. The aim of the bottom oxide (BOX) film, which is grown thermally on the silicon substrate, is to provide a good interface to the semiconductor and prevent back-tunnelling of the injected electrons (IE) for better charge retention. The second layer of the ONO structure in this transistor is the silicon nitride which is also grown thermally. This layer is the trapping media for the charge and functions as the storage media of the device.

The thickness of the silicon nitride has to be balanced between programming voltage and charge retention – the thickness has to be not so thin that the stored charge leaks to the gate and not so thick that it causes excessive programming voltage. Furthermore, there is an additional blocking oxide layer placed between the gate and the nitride layer as it is shown on Figure 1. The top oxide (TOX) layer is usually thicker than the BOX layer. The function of the blocking oxide is to prevent electron injection from the metal to the nitride layer during erase operation. As a result, a thicker nitride layer can be used, leading to lower programming voltage as well as better charge retention [1].

Since in the programmed state of memory transistors, electrons are stored in silicon nitride layer, the data can be lost if electrons leak away from the injected region (IR) [2]. In the case when the traps of electrons, IR are nanoparticles embedded into nitride it happens due to escape of trapped electrons from these trapping centres. The instability of the erase state is observed due to accumulation of positive charge in the BOX [3]. As a result, the programmed state Vt decreases, and the erased state Vt increases with the increasing retention time.

Retention of memory transistors is characterized by the stability of the programmed and erased state V_t. The V_t shift of the programmed state of the device after cycling (a series of programming/erase (P/E) operations) is experimentally controlled after high temperature bakes. The V_t shift of the programmed state is called HT V_t shift. The second type of V_t shift characterizes the erased state of the device after cycling. This shift has weak temperature dependence and is called RT V_t shift. HT and RT V_t shifts determine the operating margins of the memory cell [4].

The V_t shift depends on one side on the quality of device and on the other side on the conditions of P/E operations, in particular on the energy (temperature) of injected carriers. The aim of this research is to study an influence of the temperature of injected electrons on the retention properties of memory transistor.

2. Research Approach and Results

In this work we used the model and programs developed by authors of [5–9]. The research is aimed to study an influence of the temperature (or kinetic energy) of IE on the intrinsic Coulomb blockades (ICB) [10].

In nanocrystal memory devices two ways of programming operations are possible:

1. In the first case hot electrons are injected into the injection region of the gate dielectric. In simulation procedure we determine the value of injected charge that spreads away from IR.
2. In the second case the positive voltage at the gate is causes the tunnelling of electrons into the dot. In this last case the energy of IE is small.

We study the first case, i.e. the situation when hot electrons are injected into nanoparticles.

In computer experiment different numbers of electrons were placed into the nanoparticle potential well (PW). The number of simulation steps, n_s, is fixed when i^{th}-electron leaves the PW. This number of steps is proportional to the life time of the trapped electron inside a nanoparticle τ_{TE}^{i}. The dependence of τ_{TE}^{i} on the temperature is described by Arrhenius exponent:

$$\tau_{TE}^{i} = \tau_0 \cdot \exp\left(\frac{U_{eff}}{k_B T}\right). \qquad (1)$$

In (1) τ_0 is a frequency of the own oscillations of the particle, U_{eff} is the effective barrier for a particle in PW and $k_B T$ is an energy that corresponds to the temperature T. Note that U_{eff} is a potential barrier for ionisation of i-th electron (assuming that i electrons are located in the nanoparticle). Naturally the effective barrier changes with the number of injected electrons.

Figure 1 demonstrates the dependence of τ_{TE}^{i} on the number of electrons inside the nanoparticle. Three factors influence on the value of U_{eff} [9]:

1. The intrinsic Coulomb blockade;
2. The quantum confinement of trapped charges;
3. The superposition of the electron wave functions.

Figure 1 reflects the contribution of the first factor in the retention of nanodevice with nanoparticles in the gate dielectric.

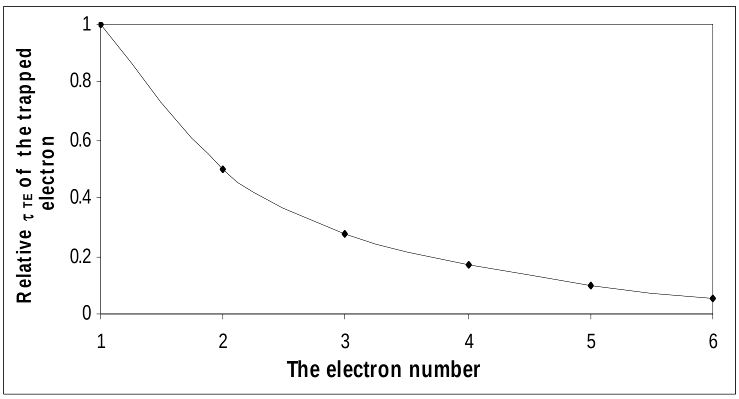

Figure 1. Dependence of τ_{TE}^{i} on the number of trapped electrons

As it follows from Figure 1 the effective potential barrier decreases with increasing of the number of TE.

Further we studied an influence of the temperature of injected hot electrons on the intrinsic Coulomb blockade [10]. The temperature of electrons was varied in the interval from 0.01 to 0.11 eV. For each temperature the value $n_s \sim \tau_{TE}^{i}$ was determined for the case when i = 3. U_{eff} = 2 eV for the third electron. The obtained results are shown on Figure 2.

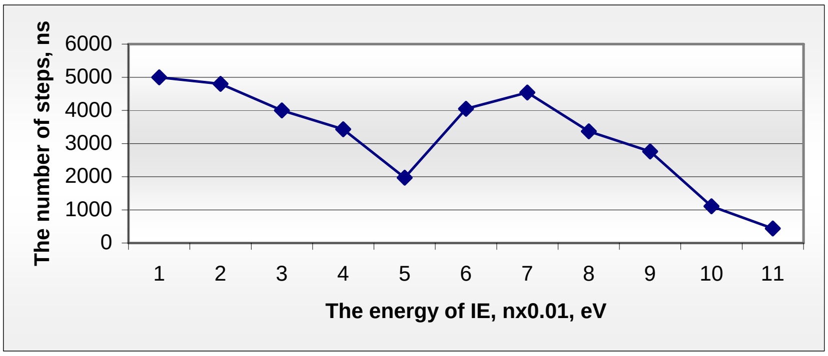

Figure 2. The dependence of the life time ($n_s \sim \tau^i_{TE}$) of the trapped electrons on their energy (kT) in the interval (0. 01 – 0. 11) eV

Figure 2 shows that the energy of IE influences on the retention characteristics of memory device. The correlation between parameters $n_s \sim \tau^i_{TE}$ and kT is complex and can be understood if to assume that a Coulomb interaction of injected electrons is influenced by their initial velocities at once after injection. Drooping part of the curve shown on Figure 2 is linked to the radiationless energy loss by hot electrons that leads to an additional heating of atomic system. According to (1) we observe a decrease of τ^i_{TE} . The further increase of kT causes a decrease of the probability of radiationless energy loss. It means that an additional heating is stopped and the life time of trapping electrons grows. The situation changes when the energy of injected electrons becomes so large that they can overcome the potential barrier without thermal activation or with help of very small thermal activation.

The obtained results indicate the optimal voltage conditions that can provide the best retention characteristics of memory transistors with nanoparticles as trapping centres.

3. Conclusions

Computer simulation of the behaviour of charge carriers placed into nanoparticles as trapping centres in memory transistors is performed. The effective potential barrier for the electron ionisation from the trapping centre depends on the number of trapped electrons. It has been found that this dependence is influenced by the temperature (the kinetic energy) of injected electrons. Thus the additional way for an optimisation of the programming operation is proposed.

References

1. NG, K. K. Complete Guide to Semiconductor Devices. N.Y., USA: IEEE Press, 2002, pp. 666–670.
2. Tsai, W. J., Zous, N. K., Liu, C. J., Liu, C. C., Chen, C. H., Wang, T., Pan, S. and C. Y. Lu. Data Retention Behavior of a SONOS type Twobit Storage FLASH Memory Cell, *International Electron Device Meeting (IEDM), Technical Digest.* Dec. 2001, pp. 32.6.1–32.6.4.
3. Manzini, S. and A. Modelli. Tunneling discharge of trapped holes in silicon dioxide. In: *Insulation Films of Semiconductors / J. F. Verweis and D. R. Wolters, (Eds.).* Amsterdam, The Netherlands: Elsevier, 1983, pp.112–115.
4. Yen, C. C., Tsai, W. J., Lu, T. C., Chen, H. Y., Zous, N. K., Liao, Y. Y., You, G. D., Cho, S. K., Liu, C. C., Hsu, F. S., Huang, L. T., Chiang, W. S., Liu, C. J., Cheng, C. F., Chou, M. H., Chen, C. H., Wang, T., Ting, W., Pan, S., Ku J. and C. Y. Lu. Novel Operation Schemes to Improve Device Reliability in a Localized Trapping Storage SONOStype FLASH Memory. In: *International Electron Devices Meeting (IEDM -03), Technical Digest.* Dec. 2003, pp. 7.5.1–7.5.4.
5. Fuks, D., Kiv, A., Maximova, T., Bibi, R., Roizin, Ya., Gutman, M. Computer model of the trapping media in *micro*FLASH memory cells, *Journal of Computer-Aided Materials Design*, Vol. 9, 2002, pp. 21–32.
6. The Nature of HT Vt Shift in NROM Memory Transistors / David Fuks, Arnold Kiv, Yakov Roizin, Micha Gutman, Rachel Avichail-Bibi, and Tatyana Maximova, *IEEE Trans. Electron Dev.,* Vol. 53, No 2, 2006, pp. 304–313.

7. Avichail-Bibi, R., Fuks, D., Kiv, A., Maximova, T., Roizin, Ya. and M. Gutman. A model of the trapping media in *micro*FLASH memory cells, *J. of Materials Processing and Technology*, 153–154, 2004, pp. 179–184
8. Fuks, D., Kiv, A., Roizin, Ya., Gutman, M. Computer simulation and experimental study of retention of SONOS device, *Journal of Computational Electronics*, Vol. 5, 2006, pp. 49–52.
9. Kiv, A., Fuks, D., Maximova, T., Rudnikov, T. Molecular Dynamics Simulation of Low-Dimensional Structures. In: *Information Technologies, Management and Society: Proceedings of the 2nd International Conference 'Information Technologies and Management'*, 2004, pp. 43–53.
10. Britavska, O., Zyryn, S., Tolkach, I. Nanoparticles in gate dielectric of memory transistors. In: *Nanomaterials and nanodevices for ecological security / Yu. Shunin and A. Kiv (Eds.). NATO Series.* Springer, 2011.

Received on the 1st of September, 2011

Computer Modelling & New Technologies, 2011, Volume 15, No. 3
Transport and Telecommunication Institute, Lomonosov Str.1, Riga, LV-1019, Latvia

Authors' index

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

- Vice-Rector on Academic Issues (Information Systems Management Institute), professor, Dr.Sc.Habil., Member of International Academy of Refrigeration
- Director of Professional Study Programme Information Systems (Information Systems Management Institute)
- Director of Master Study Programme Computer systems (Information Systems Management Institute)
- **University studies**: Moscow physical and technical institute (1968–1974).
- Ph.D. (physics & mathematics) on solid state physics (1982, Physics Institute of Latvian Academy of Sciences), Dr.Sc.Habil (physics & mathematics) on solid state physics (1992, Ioffe Physical Institute of Russian Academy of Sciences)
- **Publications:** 430 publications, 1 patent
- **Scientific activities**: solid state physics, physics of disordered condensed media, amorphous semiconductors and glassy metals, semiconductor technologies, heavy ion induced excitations in solids, mathematical and computer modelling, system analysis

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

- Vice-rector for Research and Development Affairs of Transport and Telecommunication Institute, Professor, Director of Telematics and Logistics Institute
- PhD in Aviation (1981, Moscow Institute of Civil Aviation Engineering) Dr.Sc.Habil. in Aviation (1992, Riga Aviation University), Member of the International Telecommunication Academy, Member of IEEE, Corresponding Member of Latvian Academy of Sciences (1998)
- **Publications:** 445 scientific papers and 67 patents
- **Research activities:** information technology applications, operations research, electronics and telecommunication, analysis and modelling of complex systems, transport telematics and logistics

Dimitri Golenko-Ginzburg (born in Moscow, November 24, 1932)

- Professor, Industrial Engineering and Management Department, Ariel University Center of Samaria, Ariel, Israel
- Professor, Industrial Engineering and Management Department, Ben-Gurion University of the Negev, Beer-Sheva, Israel (1988–2004)
- Full Professor (tenured position), Institute of National Economics, Uzbekistan Ministry of Higher Education, Tashkent (1977–1979)
- Full Professor (tenured position), Moscow Economico-Statistical Institute, USSR Ministry of Higher Education, Moscow (1967–1977)
- **University study**: Moscow State University, Department of Mathematics (1954-1958)
- **University study**: Moscow Institute of National Economics, Department of Economics (1950–1954)
- Ph.D. (Applied Mathematics) on simulating probability processes on computers (1962, Moscow Physico-Technical Institute)
- **Publications:** 15 books, about 500 refereed articles and refereed letters in scientific journals
- **Scientific activities**: production planning and control, planning and controlling network projects, industrial scheduling, managing reliability and safety

Nicholas A. Nechval

- University of Latvia, Professor
- **University study:** Riga Civil Aviation Engineers Institute (Faculty of Electrical Engineering) cum laude, 1965
- Ph.D. degree in automatic control and systems engineering, Riga Aviation University, Riga, Latvia, 1969**;** Dr.habil.sc.ing. (radio engineering), Riga Aviation University (RAU), 1993
- **Research activities:** Mathematics,Stochastic Processes, Pattern Recognition, Digital Radar Signal Processing, Operations Research, Statistical Decision Theory, Adaptive Control
- **Professional Activities and Memberships:** Scientific Society (on problem of Protection from Biodeterioration), Russian Academy of Sciences, (since 1987); Latvian Association of Professors, (since 1997)

Konstantin Nechval (born in March 5, 1975)

- Mg.sc.ing., Lecturer at Transport and Telecommunication Institute
- **University study:** Bachelor of Science in engineering (RAU, 1996). Engineer qualification in maintenance of aircraft and engines (RAU,1998); Master degree in engineering (RAU,1999), PhD studies in Riga Technical University (2000)
- **Research interests:** Operation Systems: Dos, Linux, Windows; Programming: Delphi, BASIC, HTML, PHP; LISP, C#; Aplications: MatLab, MatCad, Matematica, StatGraphics, Derive, AutoCad, MS Office, Open Office

Svetlana Zyryn

- **University study:** received the MSc degree in physics from South-Ukrainian National Pedagogical University, Odessa, Ukraine, 2009
- From 2010 she is a post-graduate student at the Department of Physical and Mathematical Modelling in the same university
- **Scientific interests:** physical processes in electronic devices, especially in memory transistors
- **Publications:** 10 scientific papers in the field of charge carriers migration in dielectric fields and information technologies application in natural and humanitarian sciences

Irina Tolkach

- **University study:** received the MSc degree in physics from South-Ukrainian National Pedagogical University, Odessa, Ukraine, 2009
- From 2010 she is a post-graduate student at the Department of Physical and Mathematical Modelling in the same university
- **Scientific interests:** dielectric properties of thin films as components of transistors
- **Publications:** 10 scientific papers in the field of dielectric relaxation after injection of local charges

Elena Britavskaya

- **University study:** received PhD degree in physics of elements and systems (1999, Odessa)
- From 2000 to 2005 she was a Senior lecturer at the Department of Theoretical Physics (South-Ukrainian National Pedagogical University)
- From 2006 she is an Associate Professor at the Department of Physical and Mathematical Modelling (South-Ukrainian National Pedagogical University)
- **Scientific interests:** radiation physics of ionic crystals and sub-threshold radiation effects
- **Publications:** 25 scientific papers

Dmitry N. Chabanenko (born in Kriviy Rih, January 19, 1984)

- Post-graduate student (Cherkassy National University named after Bogdan Khmelnitsky)
- **University study:** Krivy Rig State Pedagogical University (2001–2006)
- **Scientific interests:** Complex systems, econophysics, mathematical and computer modelling, system analysis, parallel programming, agent-based modeling
- **Publications:** 30 publications

Vladimir M. Saptsin (born in Kremenchug, March 28, 1951)

- Associate Professor (Kremenchug National University named after M. Ostrogradsky)
- **University study:** Moscow State University (1968–1974)
- Ph.D. (physics & mathematics) on solid state physics (1981, Department of Semiconductor Physics, Moscow State University), prepared the dissertation of Doctor of physics and mathematical sciences (physics & mathematics) on solid state physics (1995, Lykov ITMO in Minsk)
- **Scientific activities:** complex systems modeling, econo-physics, solid state physics, physics of disordered condensed media, amorphous semiconductors and glassy metals, semiconductor technologies, heavy ion induced excitations in solids, mathematical and computer modelling, system analysis
- **Publications:** 70 publications

Vladimir N. Soloviev (born in Kriviy Rih, September 15, 1952)

- Chairman of the Economic Cybernetics Department, Professor
- **University study:** Kriviy Rih State Pedagogical University (1970–1975)
- Ph.D. (physics & mathematics) on solid state physics (1981, Leningrad Politechnical Institute named after M. Kalinin), Doctor (physics & mathematics) on solid state physics (1993, Physics Institute of Ukrainian Academy of Sciences)
- **Scientific activities:** complex systems modeling, econo-physics, solid state physics, physics of disordered condensed media, amorphous semiconductors and glassy metals, semiconductor technologies, heavy ion induced excitations in solids, mathematical and computer modelling, system analysis
- **Publications:** 295 publications

CUMULATIVE INDEX

COMPUTER MODELLING and NEW TECHNOLOGIES, volume 15, No. 3, 2011

(Abstracts)

D. Golenko-Ginzburg, D. Greenberg. Long-Term Innovative Construction Projects with Alternative Outcomes and Branching Nodes, *Computer Modelling and New Technologies*, vol. 15, No 3, 2011, pp. 7–15.

We will consider a new financial account policy for long-term construction projects with stochastic alternative multivariant outcomes. The policy is based on the optimal subproject which is singled out from the initial stochastic alternative network.

Keywords: *Stochastic alternative networks; Controlled alternative networks; Joint variant; Outcome tree; Consecutive financial agreements*

V. Soloviev, V. Saptsin, D. Chabanenko. Markov Chains Application to the Financial-Economic Time Series Prediction, *Computer Modelling and New Technologies*, vol. 15, No 3, 2011, pp. 16–20.

In this research the technology of complex Markov chains is applied to predict financial time series. The main distinction of complex or high-order Markov Chains and simple first-order ones is the existing of after-effect or memory. The technology proposes prediction with the hierarchy of time discretization intervals and splicing procedure for the prediction results at the different frequency levels to the single prediction output time series. The hierarchy of time discretizations gives a possibility to use fractal properties of the given time series to make prediction on the different frequencies of the series. The prediction results for world's stock market indices are presented.

Keywords: *Prediction, time series, complex Markov chains, discrete time, fractal properties*

V. Soloviev, V. Saptsin. Heisenberg Uncertainty Principle and Economic Analogues of Basic Physical Quantities, *Computer Modelling and New Technologies*, vol. 15, No 3, 2011, pp. 21–26.

From positions, attained by modern theoretical physics in understanding of the universe bases, the methodological and philosophical analysis of fundamental physical concepts and their formal and informal connections with the real economic measuring is carried out. Procedures for heterogeneous economic time determination, normalized economic coordinates and economic mass are offered, based on the analysis of time series, the concept of economic Plank's constant has been proposed. The theory has been approved on the real economic dynamic's time series, including stock indices, Forex and spot prices, the achieved results are open for discussion

Keywords: *quantum econophysics, uncertainty principle, economic dynamics time series, economic time*

D. Golenko-Ginzburg, D. Greenberg. On-Line Control Models for Multi-Level Construction Systems, *Computer Modelling and New Technologies*, vol. 15, No 3, 2011, pp. 27–36.

A building company, which simultaneously monitors several contractors, is considered. Each contractor operates a building project (house, factory, hospital, etc.) consisting of a chain of operations to be processed in an individual definite technological sequence. Each project's operation utilizes qualified resources of various specialties, i.e., several non-consumable resources with fixed capacities (manpower, scrappers, etc.). For any operation in progress, all the resources remain unchanged until the operation terminates. Each type of resources at the company's disposal is in limited supply, is predetermined and the resource limit remains unchanged at the same level throughout the project's realization, i.e., until the last project is actually completed. Thus, due to the limited resource levels, project's operations may have to wait in lines for resource supply, in order to proceed functioning.

The problem is solved by means of a heuristic algorithm by a combination of the cyclic coordinate descent method (at the upper level) and a simulation scheduling model (at the lower level). Resource allocation between the projects waiting in lines is carried out via an embedded newly developed decision rule. This rule enables to support projects with high delay penalties at the expense of projects with low penalties in the process of the projects' realization.

Keywords: *Building projects; Decision-making rule; Renewable resources; Resource allocation; Simulation model*

S. Zyryn, I. Tolkach. Dependence of Retention Properties of Memory Transistors on the Temperature of Injected Electrons, *Computer Modelling and New Technologies*, vol. 15, No 3, 2011, pp. 68–71.

Computer modelling of retention characteristics of memory transistor was performed. The case of the gate dielectric with nanoparticles as trapping centres (TC) is considered. The approach is based on the study of the life time of trapped electrons, τ_{TE}^{i} in TC that is proportional to the number of computer simulation steps. It was found that the value τ_{TE}^{i} depends significantly on the temperature of injected charge carriers. The interpretation of results is based on the consideration of the radiationless energy loss by injected charges.

Keywords: *computer modelling, memory transistors, Coulomb blockade, retention characteristics*

COMPUTER MODELLING and NEW TECHNOLOGIES, 15.sējums, Nr. 3, 2011 (Anotācijas)

D. Golenko-Ginzburgs, D. Grīnbergs. Ilgtermiņa inovatīvie būvniecības projekti ar alternatīviem rezultātiem un filiāļu punktiem, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 7.–15. lpp.

Rakstā autori izskata jaunu finansiālās atskaites politiku ilgtermiņa būvniecības projektiem ar stohastiskiem alternatīviem multivariantu rezultātiem. Minētā politika ir balstīta uz optimālu apakšprojektu, kurš tiek izvirzīts no sākotnējā stohastiskā alternatīvas tīkla.

Atslēgvārdi: *stohastiskie alternatīvas tīkli, kontrolētie alternatīvas tīkli, saistītais variants, rezultāta koks, secīgas finanšu vienošanās*

V. Solovjovs, V. Sapcins, D. Čabaņenko. Markova ķēžu pielietošana finanšu-ekonomisko laikrindu prognozēšanai, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 16.–20. lpp.

Šajā pētījumā tiek pielietotas komplekso Markova ķēžu tehnoloģijas, lai prognozētu finansiālās laikrindas. Komplekso jeb augstas kārtas un pirmās kārtas Markova ķēžu atšķirība ir pēc-efekta vai atmiņas esamība. Tehnoloģija piedāvā prognozi ar laika diskretizācijas intervālu hierarhiju un savienošanas procedūru prognozes rezultātiem no dažādiem frekvenču līmeņiem līdz vienkāršām prognozes izejas laikrindām. Laika diskretizāciju hierarhija dod iespēju lietot laikrindu fraktālās īpašības, lai veidotu prognozi sēriju dažādām frekvencēm. Rakstā tiek doti prognožu rezultāti pasaules akciju tirgus indeksiem.

Atslēgvārdi: *prognoze, laikrindas, kompleksās Markova ķēdes, diskrēts laiks, fraktālās īpašības*

V. Solovjovs, V. Sapcins. Pamata fizikālo kvantitāšu heisenberga nenoteiktības princips un ekonomiskie analogi, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 21.–26. lpp.

No pozīcijas, kas sasniegta ar modernas teorētiskās fizikas palīdzību universa pamatu izpratnē, metodoloģiskas un fundamentālās fizikas konceptu filozofiskas analīze un to formālā un neformālā saikne ar reālo ekonomikas mērīšanu tiek pētīta dotajā darbā. Kārtība heterogēna ekonomiska laika noteikšanai, normalizētas ekonomiskas koordinātes un ekonomiskā masa tiek izskatīta, pamatojoties uz laika rindu analīzi, un ekonomiskas Planka konstantes jēdziens ir ierosināts dotajā rakstā. Teorija ir apstiprināta ar reālām ekonomiskām dinamiskā laika rindām, tostarp akciju indeksiem, *Forex* un vietu cenām, un iegūtie rezultāti ir atklāti diskusijām.

Atslēgvārdi: *kvantu ekono-fizika, nenoteiktības princips, ekonomiskas dinamiskā laika rindas, ekonomisks laiks*

D. Golenko-Ginzburgs, D. Grīnbergs. Tiešsaistes kontroles modeļi daudzlīmeņu būvniecības sistēmām, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 27.–36. lpp.

Rakstā tiek apskatīta celtniecības firma, kas vienlaicīgi kontrolē vairākus līgumslēdzējus. Katrs līgumslēdzējs strādā ar vienu celtniecības projektu (māja, rūpnīca, slimnīca, u.c.), kas sastāv no darbību ķēdes, kas, savukārt, jāveic noteiktā tehnoloģiskā secībā. Katra projekta veikšanai izmanto dažādu specialitāšu kvalificētus resursus, piem., dažus neizmantojamus resursus ar fiksētām jaudām (darbaspēks, gružu aizvācējs, u.c.). Attiecībā uz jebkuru darāmo darbību, visi resursi paliek nemainīgi līdz procesa beigām. Katrs resursu veids, kas ir kompānijas rīcībā, ir ierobežotā krājumā, ir iepriekš paredzēts un resursu limits paliek nemainīgs vienādā līmenī projekta realizācijas laikā, t.i., kāmēt pēdējais projekts ir faktiski pabeigts. Tādējādi, ņemot vērā ierobežoto resursu līmeni, projekta darbībām varētu būt jāgaida rindā resursu sagādei, lai turpinātu darbību.

Problēma tiek risināta ar heiristiska algoritma līdzekļiem, ar cikliskās koordinātu samazināšanas metodes kombināciju (augšējā līmenī) un imitācijas plānošanas modeli (zemākajā līmenī).

Resursu sadalījums starp projektiem, kas gaida rindā, tiek veikts ar iegulto tikko izstrādāto lēmuma noteikumu. Šis noteikums ļauj atbalstīt projektus ar augstiem kavējumu sodiem pie projekta ar zemiem sodiem izdevumiem to realizācijas laikā.

Atslēgvārdi: *celtniecības projekti, lēmumu pieņemšanas noteikums, atjaunojamie resursi, resursu piešķiršana, imitācijas modelis*

T. Valkovjaks. Web sistēmu pieejamības analīze ar Monte Karlo imitāciju, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 37.–48. lpp.

Rakstā tiek aplūkota web sistēmas analīzes pieejamība. Analizētā sistēma ir modelēta kā uzdevumu rinda, kas lieto datus, iegūtus mijiedarbībā ar citiem uzdevumiem, lai radītu atbildes. Sistēmas uzticamību raksturo ar neveiksmi un sistēmas elementu remonta procesu. Tā kā novēršanas laika modelis ņem vērā darba stundas un uzturamās apkalpes nedēļas nogales. Uzticamība tiek mērīta ar sistēmas pieejamību aprēķinātu ar stimulatoru, balstītu uz Monte-Karlo pieeju. Sakarā ar saglabātu apkalpes darba stundu modeli sasniegtā pieejamības funkcija ir periodiska (ar vienas nedēļas laiku). Tālāk, funkcionālie aspekti web sistēmu mēra ar funkcionālu pieejamību, t.i., varbūtība, ka klients saņems atbildi attiecīgajā termiņā. Rādītājs ir aprēķināts, izmantojot simulācijas programmatūru, ko izstrādājuši autori. Web sistēmas modelēšana ņem vērā skaitļošanas resursu patēriņu (uzņēmēja apstrādes jaudu) un ieejas sistēmas slodzi, mainoties laikā. Visbeidzot, pakalpojuma pieejamība ir definēta, kas kompromitē uzticamību un funkcionālos parametrus, kā arī sistēmas ieejas slodzi. Rakstā tiek parādīti simulācijas rezultāti.

Atslēgvārdi: *web sistēma, uzticamība, pieejamība, Monte-Karlo simulācija*

K. Nečvals, N. Nečvals, M. Purgailis, V. Strelčonoks, G. Bērziņš, M. Moldovans. Statistiskā dzīves testa akceptēšanas procedūra Veibula sadalījumam, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 49.–58. lpp.

Produktu akceptēšanas modeļi ietver paraugu ņemšanu, pārbaudes un lēmumu pieņemšanu, lai noteiktu pieņemšanu vai produktu partijas noraidīšanu ar eksperimentu, kas noteiktu produktu nepārtrauktas lietošanas laiku. Vispopulārākais dzīves ilguma sadalījums, kas tiek lietots produktu pieņemšanas jomā ir vai nu viena parametra eksponenciālais sadalījums vai div-parametru Veibula sadalījums, ar pieņēmumu, ka formas parametrs ir zināms. Šādi pārspīlēti pieņēmumi var veicināt pēcpārbaudes analīzes, bet var neievērot faktu, ka dzīves laika sadalījums var nozīmīgi ietekmēt produkta sagraušanas ātruma novērtēšanu. Atbilstoša produkta pieņemšanas modeļa izvēle ir būtisks problēmas risinājums, jo labs modelis ne tikai var palīdzēt ražotājiem ietaupīt pārbaudes laiku un samazināt testēšanas izmaksas, bet tā arī var pozitīvi ietekmēt tēlu produktiem, un tādējādi piesaistītu vairāk patērētājus iegādāties šo produktu. Tāpēc bieži tiek izmantota *Bayesian* pieeja, lai risinātu minēto problēmu. Diemžēl šajā gadījumā pētnieka subjektivitāte (*Bayesian* pieejas ierobežošana) ir pieteikta ar *apriori* sadali. Lai izslēgtu pētnieka subjektivitāti un vispusīgi izvērtētu attiecīgos riskus, šajā rakstā tiek izmantota *frequentist (non-Bayesian)* lēmumu analīze.

Atslēgvārdi: *dzīves laiks, Veibula sadale, parametriska nenoteiktība, produkta akceptēšanas modelis*

A. Aitmagambetovs, A. Inčins, A. Lozbins. Zemes radio raidītāju uztveršana ar zinātnisko satelītu mērījumu sistēmas palīdzību, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 59.–63. lpp.

Kazahstānas Zinātniskās Kosmosa sistēmas projekta ietvaros tika veikti aparatūras un franču satelīta DEMETER programmatūras pētījumi. DEMETER programmatūras datu apstrāde ir balstīta uz SWAN paketi saskaņā ar IDL Virtuālo mašīnu. Šīs programmatūras dažu problēmu novēršanai autori ir izstrādājuši savu programmatūru DeSS ar datu kartēšanu. Šī programmatūra ļauj detektēt signālus no dažādiem radioraidītājiem līdz pat 3,33 MHz. Radio sakaru iestādēm ir liela interese veikt zemes raidītāju radio monitoringu, izmantojot zinātnisko satelītu iekārtas.

Atslēgvārdi: *zinātniskais satelīts, radio raidītājs, elektromagnētiskais lauks, programmatūra*

E. Britavskaja. Radiācijas izraisītie defekti jonizētās cietās virsmās, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 64.–67. lpp.

Rakstā tiek pētīta jonu un atomu dinamika jonizētās cietās virsmās zemas enerģijas radiācijas ietekmē. Tiek izmantoti Kulomba, Pauli, apmaiņas un Van der Vāla potenciāli. Attiecībā uz sārmu halogēna virsmām ir pierādīts, ka, ja anjonu $(X^- \rightarrow X^+)$ pārlādēšana parādās divos virsmas slāņos, tā var uzsākt pozitīvo metāla jonu M^+ izmešanu un līdz ar elektronu sagūstīšanu ar pozitīviem joniem M^+, arī neitrālo atomu M°. Bez Kulomba atgrūšanās ir parādīts Pauli trieciens, lai spēlētu pamata lomu izmešanas procesā. Pēdējam mehānismam ir liela efektivitāte, ja parādās galvenā elektrona ierosināšana un stingri ir atkarīgs no kristāla jonizācijas.

Atslēgvārdi: *jonizācijas izraisīto defektu veidošanās, elektro-jonu emisija*

S. Zirins, I. Tolkačs. Atmiņas tranzistoru saglabāšanas īpašības atkarība no inžekcijas elektronu temperatūras, *Computer Modelling and New Technologies,* 15.sēj., Nr.3, 2011, 68.–71. lpp.

Rakstā tika veikta atmiņas tranzistoru aiztures īpašību datormodelēšana Tiek izskatīts gadījums par vārtu dielektriķi ar nanodaļiņām, kā lamatu centru. Pieeja tiek balstīta uz notverto elektronu dzīves ilguma izpēti, τ_{TE}^{i} lamatu centrā, kas ir proporcionāls datormodelēšanas soļu skaitam. Ir atklāts, ka τ_{TE}^{i} vērtība galvenokārt ir atkarīga no injicēto lādiņu temperatūras. Rezultātu interpretācija ir balstīta uz bez-radiācijas enerģijas zudumu, ko injicē lādiņš, apsvērumiem.

Atslēgvārdi: *datormodelēšana, atmiņas tranzistori, Kulomba blokāde, aiztures īpašības*

COMPUTER MODELLING & NEW TECHNOLOGIES

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

Host Organization:
Transport and Telecommunication Institute

Supporting Organizations:
Latvian Transport Development and Education Association
Latvian Academy of Sciences
Latvian Operations Research Society

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

- mathematical and computer modelling
- mathematical methods in natural and engineering sciences
- physical and technical sciences
- computer sciences and technologies
- material science, solid state physics and chemistry
- nanomaterials, nanodevices and nanotechnologies
- aviation and aerospace technologies
- electronics and telecommunication
- transport and logistics
- economics and management
- innovative education
- social sciences

In journal articles can be presented in English. All articles are reviewed.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371) 67100593. Fax: (+371) 67100535
E-mail: journal@tsi.lv, www.tsi.lv

COMPUTER MODELLING AND NEW TECHNOLOGIES, 2011, Vol. 15, No.3
ISSN 1407-5806, **ISSN** 1407-5814 (on-line: www.tsi.lv)
Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

The papers published in Journal "Computer Modelling and New Technologies" are included in
INSPEC (since 2010), **VINITI** (since 2011)
www.theiet.org/resources/inspec/
http://www2.viniti.ru/

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

1. In order to format your manuscript correctly, see the Page Layout Guideline for A4 (21 cm x 29,7 cm) paper size. Page Layout should be as follows: Top – 3 cm, Bottom – 3 cm, Left – 3 cm, Right – 3 cm.
2. Maximum length for the article is 10 pages.
3. **Application of other Styles with the exception of Normal is impossible!**
4. ***Articles*** should be Times New Roman typeface, single-spaced.
5. The article should include:
   - title;
   - author's name(s) and information (organisation, city, country, present address, phones, and e-mail addresses);
   - abstract (100–150 words);
   - keywords (max. about six);
   - introduction – clearly explaining the nature of the problem, previous work, purpose and contribution of the research;
   - description of proper research;
   - conclusion section (this is mandatory) which should clearly indicate advantages, limitations and possible applications;
   - references.

   Attention! First name, last name, the title of the article, abstract and keywords must be submitted in the English and Latvian languages (in Latvian it is only for Latvian authors) as well as in the language of the original (when an article is written in different language).
6. The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (***British English***), headings and the style of referencing.
7. ***The title of the article*** – 14 point, UPPERCASE, style Bold and centered.
8. ***Author's names*** – centered, type size 12 point, Upper and lower case, style Bold Italic.
9. ***Author's information*** – 10 point, Upper and lower case, style Italic, centered.
10. ***Abstract and keywords*** – 8 point size, style Normal, alignment Justify.
11. ***The first level Headings*** – 11 point, Upper and lower case, style Bold, alignment Left. Use one line space before the first level Heading and one line space after the first level Heading.
12. ***The second level Headings*** – 10 point, Upper and lower case, style Bold, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the second level Heading.
13. ***The third level Headings*** – 10 point, Upper and lower case, style Italic, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the third level Heading.
14. ***Text*** of the article – 10 point, single-spaced, alignment Justify.
15. The set of ***formulas*** on application of fonts, signs and a way of design should be uniform throughout the text. The set of formulas is carried out with use of editors of formulas MS Equation 3.0 or MathType. The formula with a number – the formula itself should be located on the left edge of the text, but a number – on the right. Font sizes for equations are: 11pt – full, 7pt – subscripts/superscripts, 5pt – sub- subscripts/superscripts, 16pt – symbols, 11pt – subsymbols.
16. All ***Figures*** – must be centered. Figure number and caption always appear below the Figure, type size 8 point.

Figure 1. This is figure caption

Diagrams, Figures and Photographs – must be of high quality, в in format *.TIFF, *.JPG, *.BMP with resolution not less than 300 dpi. Also formats *.CDR, *.PSD are possible. Combination of Figures in format, for instance, *.TIFF with elements of the in-built Figure Editor in MS Word is prohibited.

17. ***Table Number and Title*** – always appear above the Table. Alignment Left. Type size 8 point. Use one line space before the Table Title, one line space after the Table Title and 1/2 line space after the Table.

Table 1. This is an example of a Table

Heading	**Heading**	**Heading**
Text	Text	Text
Text	Text	Text

18. ***References*** in the text should be indicated by a number in square brackets, e.g. [1].
References should be numbered in the order cited in the manuscript. The correct format for references is the following:

Article: author, title, journal (in italics), volume and issue number, year, inclusive pages
Example: 1. Amrahamsson, M., Wandel, S. A Model of Tearing in Third – Party Logistics with a Service Parts Distribution Case Study, *Transport Logistics*, Vol. 1, No 3, 1998, pp. 181-194.

Book: author, title (in Italics), location of publishers, publishers, year
Example: 2. Kayston, M. and Fried, W. R. *Avionic Navigation Systems.* New York: John Wiley and Sons Inc, 1969.

Conference Proceedings: author; title of an article; proceedings (in italics); title of a conference, date and place of a conference; publishing house, year, pages.
Example: 3. Canales Romero J. A First Step to Consolidate the European Association of Aerospace Students in Latvia (Presented by the Munich Local Group). In: *Research and Technology – Step into the Future: Program and Abstracts. Research and Academic Conference, Riga, Latvia, April 7-11, 2003, Transport and Telecommunication Institute.* Riga: TTI, 2003, p. 20.

19. ***Authors Index***
Editors form the author's index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.
20. ***Acknowledgements***
Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper. The first page of the contribution should start on page 1 (right-hand, upper, without computer page numbering). Please paginate the contributions, in the order in which they are to be published. Use simple pencil only.
21. **Articles poorly produced or incorrectly formatted may not be included in the proceedings**.