Galina Setlak, Mikhail Alexandrov, Krassimir Markov
(editors)

Artificial Intelligence Driven Solutions to Business and Engineering Problems

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Artificial Intelligence Driven Solutions to Business and Engineering Problems

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This issue contains a collection of papers that concern actual problems of research and application of information technologies, especially the new approaches, models, algorithms and methods of artificial intelligence to be used in business and engineering applications.

It is represented that book articles will be interesting for experts in the field of information technologies as well as for practical users.

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PREFACE

This issue contains a collection of papers that concern actual problems of research and application of information technologies, especially the new approaches, models, algorithms and methods of artificial intelligence to be used in business and engineering applications.

Main topics which are covered in the issue are:

- Business Intelligence Systems
- Decision Making Support and Expert Systems
- Natural Language Procassing and Social Network Analysis
- Software Engineering Information Systems
- Computer Aided Engineering and Simulation

We express our thanks to all authors of this collection as well as to all who support its publishing.

Rzeszow – Sofia *G. Setlak, M.Alexandrov, K. Markov*
September 2012

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ANALYSIS OF THE THROUGHPUT OF THE PROCESS OF DISTANCE LEARNING

Sergey Maruev, Evgeniya Gorbunova

Abstract: *We consider queuing systems as models of distance learning system we analyze how characteristics of business process in the system affect on throughput and on learning outcomes. The processes of executing tasks and tasks validation process are the key processes in the distance learning. A model of the process performed by a student is a queuing system with refusals. A model of the process performed by the teacher is a multi-channel queuing system with limited queue. We present a structure of one of the courses of the University, where the authors work to form individual trajectory of learning. for students with different levels of knowledge. Such an approach allow to increase the throughput of distance learning system.*

Keywords: *distance learning, process modeling, queuing system analysis*

ACM Classification Keywords: *K.3.1 Computer Uses in Education, Distance Learning*

Introduction

The term throughput is used at different levels of detail to describe the various characteristics of educational systems. In the analysis at the macro level, throughput refers to the number of people who have got education by age and grade level [35 R, 2007; Hugjen_en, http]. According to some surveys [Bowen, 2011; DL, http], the development of information technology and distance learning leads to increased throughput of educational systems. At the micro level of throughput depends on the resources of education institution, used in the learning process. The throughput analysis helps to identify key resources and to determine a number of students in the system [Maruev, 2012]. A lot of research is devoted to evaluation of throughput of hardware and software in distance learning systems. But the characteristics of the business process in the system also affect on a throughput and learning outcomes. This aspect of distance learning is analyzed in this paper. In this case, we assume that there are sufficient resources and technical capacity to process performance.

Process modeling and description

As an example, we consider processes in the system of distance learning of the Russian Presidential Academy of National Economy and Public Administration. The Academy is located in Moscow and has 67 branches in different regions of Russia. Considered a distance learning program is an additional training for students to prepare them for their education in graduate programs in Moscow. The training in our case adds to fulltime learning. The following processes are performed in the system: the teacher puts on a platform of educational materials, the student work with them and do a task, the teacher checks the result of the task and make comments. At any time a student applies for and receives the recommendation via its internal e-mail. On-line

discussions carried out periodically on schedule. The process of executing tasks and tasks validation process are the key processes in the system (Fig.1). They provide the main channel of feedback between a student and a teacher. These processes determine the time of the working cycle of the system as a whole.

A complete course is divided to pieces - didactic units. Every didactic unit is related with the activities and learning outcomes. The special task is used to estimate of these learning outcomes. Task flows circulate in the system: 1- flow from distance learning platform (DLP) to student, 2 – flow from student to DLP to estimate an executed task, 3- flow with assessment result from DLP to student.

A student executes many tasks for many courses. We accept that the student does not choose a task and he start working on a task, obtained at the time when he is not busy. This allows us to accept the flow 1 as a Poisson flow without consequences. If a student makes a mistake, he makes a task again after a teacher recommendation. A mistake is a random event, remaking tasks add to the flow 1.

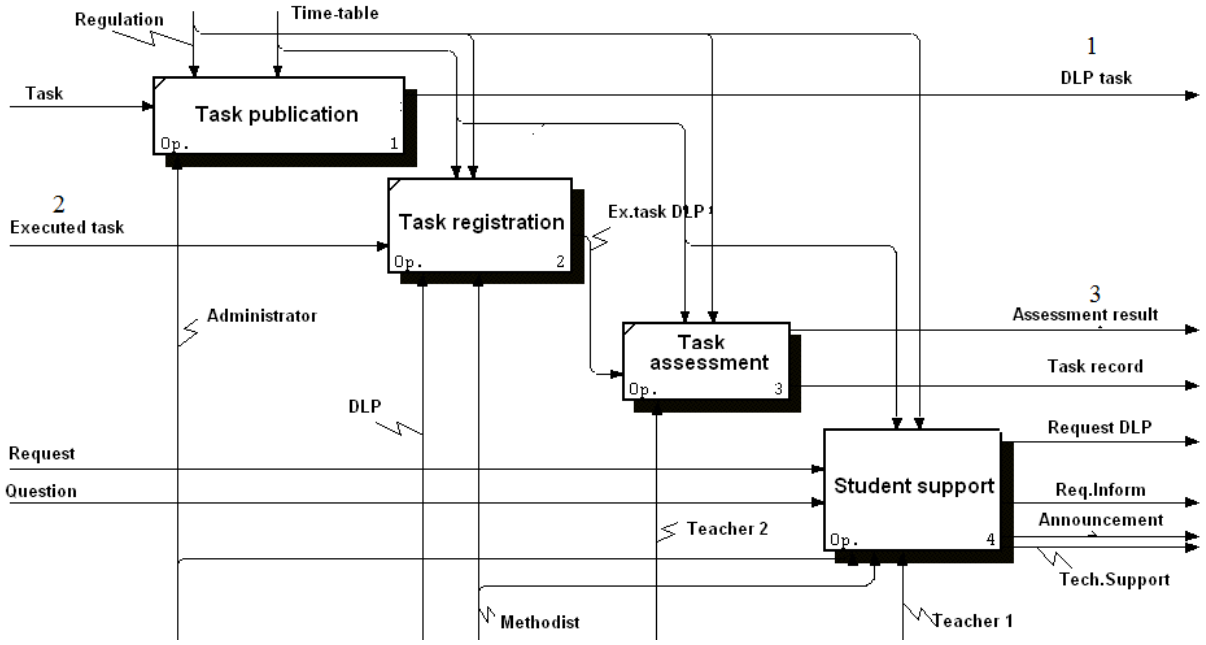

Fig. 1. A functional model of the process "Tasks validation and student support"

Executed tasks came to the system independently, each task from one student. The probability of receiving a new task does not connected with previous receiving task. A number of tasks in any disjoint time period do not depend on a number of tasks in another disjoint time period. So the flow 2 is a Poisson flow.

Approach

3.1. Problem definition

The quality of education depends on the quality of all processes in the system of distance learning (DLS). The quality of the process "Tasks validation and student support" depends on the consistency of the intensity of flows between the student and the system. The student receives a flow of tasks from the system, executes them and sends them for assessment to DLS. He gets the assessment and comments from DLS. Student also sends to the system requests for additional information, and receives it from DLS.

The intensity of the flows in the system depends on the number of tasks, the speed of their implementation and verification. Inconsistency of the intensities of flows leads to non-fulfillment of tasks and to default of students'

knowledge. The problem is to determine the appropriate flow parameters for each recipient, and to harmonize the parameters of flows between the actors.

The throughput of the system evaluated both in terms of student actions, and actions of the teacher. A model of the process performed by a student is a queuing system with refusals. A refusal means that a student is busy (is working with a previous task) and can not start to perform a new task. The probability of it depends on the number and complexity of the tasks and the time available for a student.

A model of the process performed by the teacher is a multi-channel queuing system with limited queue. A time of stay the executed task in the system shall not exceed the time allotted to the study of the didactic unit.

The processes are balanced if they do not interrupt each other.

3.2. Individual trajectory of learning

Different initial level of knowledge gives students a possibility to pass same topics and tasks, it means to design individual trajectory of learning. Individual trajectory of learning could be only in case of an assessment of passing topics. A graph of logical structure of knowledge of the training program is used for it. Didactic units are nodes of the graph and edges show a direct following between didactic units [Maruev, 2003].

The graph of logical structure of knowledge is used for training program design and learning outcomes validation [Maruev, 2006a; Maruev 2006b]. An algorithm of the graph construction includes the following steps. After Step 1 we have a complete list of didactic units. In step 2, the experts determined the immediate predecessors of each didactic unit. In step 3, a sensitivity of the model to individual estimates is evaluated. On step 4 we construct the levels of didactic units, eliminate cycles and check the connectivity of the graph. Fig.2 illustrates the graph of logical structure for “Microeconomics”. It includes 8 levels of didactic units. Same units have more than one incoming arrow, call them “gathering points”. A way of individual trajectory of learning design is to test students' knowledge in gathering points and avoid paths leading to points with a reasonable knowledge. For example a successful test of knowledge at a point 223 will reduce the number of didactic units from 41 to 27.

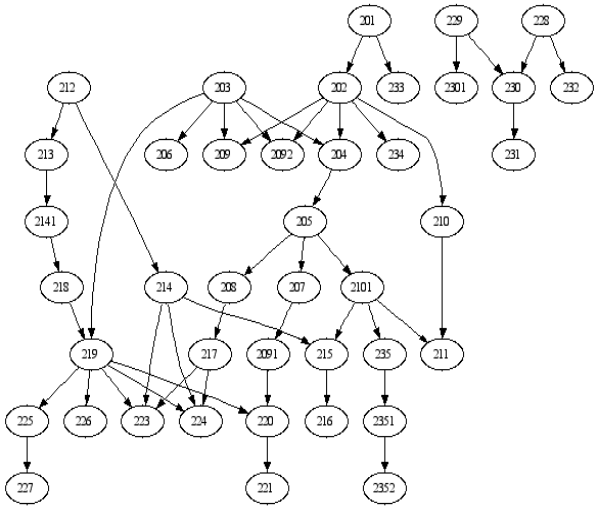

Fig.2. The graph of logical structure of knowledge for “Microeconomics”

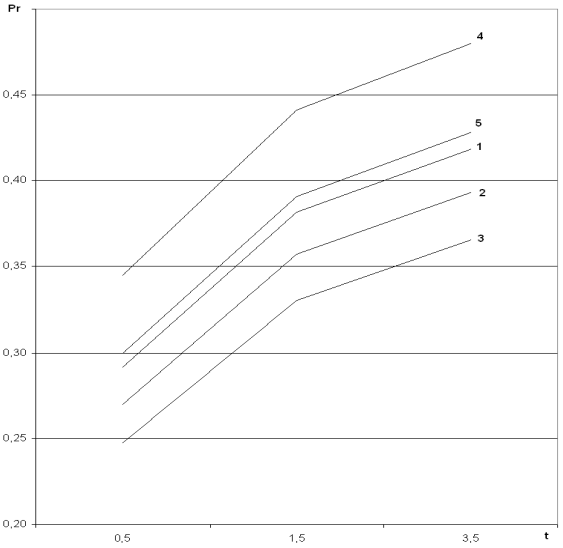

Fig.3. Probability of refusal in DLS

Modeling

The aim of modeling is to show how the structure of the learning materials influences on the throughput of the process. We accepted the standard parameters of learning at Russian university: student work with tasks 27 hours a week, working period proceeds 36 weeks and include 10 courses in different subjects. A course consists of ***N*** topics and has a task for each topic. A teacher can divide a complete course into different number of topics. Obviously to decrease time of the every task processing ***t*** it is necessary to execute more tasks ***N*** . Also a probability of mistake and repeated implementation of small task is less than large. A refusal in the system take place if a student receive new task before he finish previous task. Fig.3 illustrates a dependence between a probability of refusal ***Pr*** and ***t***. Average number of repeated tasks are 1 for line 1, 0.8 for line 2 and 0.6 for line 3. The additional distance courses increase labour intensiveness of students and probability of refusal (line 4). To decrease work of students looking after examinations in former years we eliminate same topics and tasks (line 5).

To assess the capacity of the process performed by the teacher, we take the intensity of the flow of requests received in the first step of modeling. A criterion for the balanced of processes is a time of stay the executed task in the system (waiting in the queue and task assessment) less than 10 hours. The simulation showed that this ratio will be observed if one teacher works with 5 students. Table 1 below examines characteristics of the queue system in the case of 64 tasks per student, assessment time 1 hour and teacher time 10 hours a week.

Table 1. Characteristics of the system performed by the teachers

Number of students	Number of teachers	λ	μ	ρ	P_0	Number of tasks in the queue	Number of tasks in the system	Time in the queue	Time in the system
3	1	0,533	1	0,533	0,467	0,676	1,143	1,268	2,143
4	1	0,711	1	0,711	0,289	2,173	2,462	3,055	3,462
5	1	0,889	1	0,889	0,111	7,889	8,000	8,875	9,000
3	2	0,533	1	0,533	0,538	0,038	0,571	0,071	1,071
4	2	0,711	1	0,711	0,446	0,097	0,808	0,136	1,136
5	2	0,889	1	0,889	0,373	0,212	1,101	0,238	1,238
6	2	1,067	1	1,067	0,312	0,434	1,501	0,407	1,407
7	2	1,244	1	1,244	0,260	0,879	2,123	0,706	1,706
8	2	1,422	1	1,422	0,214	1,848	3,270	1,299	2,299
9	2	1,600	1	1,600	0,170	4,354	5,954	2,721	3,721
10	2	1,778	1	1,778	0,120	13,613	15,391	7,657	8,657
11	2	1,956	1	1,956	0,037	140,911	142,867	72,057	73,057

We do not take into account the psychological factors of distance learning. Students need time for reflect new knowledge, to find creative solutions, the transition to a new job. These activities increase the time of processing tasks.

Conclusion

The paper proposes the solution of problem of consistency of processes in the system of distance learning. The throughput of the system evaluated both in terms of student actions, and actions of the teacher. A model of the process performed by a student is a queuing system with refusals. A model of the process performed by the teacher is a multi-channel queuing system with limited queue. The processes are balanced if they do not interrupt

each other. Matching capacities of the processes is obtained as a result of simulation for different parameters of flows and using education technology. An individual trajectory of learning for students with different levels of knowledge is formed to increase the throughput of the system. Simulation of the system was performed for the distance learning system of the Russian Presidential Academy of National Economy and Public Administration.

We suppose that modeling of distance learning systems in terms of Queuing Theory could be useful for planning educational process under limited resources of an educational institution.

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Author's Information

Evgeniya Gorbunova *– Bachelor of business intelligence, The Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia;*

e-mail: egorbunova@gmail.com

Major Fields of Scientific Research: business process modeling, computer uses in education.

Sergey Maruev *– Professor, The Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia;*

e-mail: maruev@gmail.com

Major Fields of Scientific Research: mathemetical modeling, economics of education, busines process modeling.

CONSTRUCTING DECISION TREE BASED ON QUESTIONNAIRES TO DETECT A POSSIBLE CORRUPTION IN LOGISTICS

Dmitry Stefanovskiy, Sergey Maruev, Xavier Tejada

Abstract: *Decision trees are the well-known a popular tool in the areas where non-numerical data are used. In the paper we demonstrate the application of decision trees for analysis of International logistics. First of all we cluster data to reduce the number of variants for comparison. Then the regression analysis is completed and the significant parameters combinations are determined. The logical function and decision tree could be useful for revealing possible corruption schemes in logistics. Finally we complete experiments with this decision tree. The suggested method can be used for constructing a decision tree based on a large amount of similar data.*

ACM Classification Keywords: *1.2 Artificial Intelligence*

Keywords: *decision trees, logistics, corruption*

Introduction

The activity of one of the authors is related with a product transportation from West Europe to East Europe. It was detected the essential changes in transportation flows during recent yeas and this fact caused our interest to the topic. Our goal is to construct a classifier for testing hypothesis about possible corruption in logistics.

There are many newspaper and journal articles and books discussing various aspects of corruption. But only few of them contain its formal models. That is due to the lack of numeric date to be processed.

Typical approaches to revealing hidden corruption use analysis of numerical characteristics reflecting prices of goods, taxes, etc. [Levin, 2011; Rose-Ackerman, 1978] Same works discuss the behavior of private and state agents in different macroeconomic conditions [Shleifer, 1993; Olimpieva, 2007]. Our approach is based on qualitative information we get from the companies dealing with product transportation from West Europe to East Europe. In the paper this information is presented in the form of questionnaires. After processing the information is transformed to a decision tree. This decision tree can be a detector for revealing simple cases related to corruption.

In section 2 we describe a questionnaire. In section 3 we form and analyze a decision table. Here we construct a decision tree itself. In section 4 we discuss the experiment. Section 5 contains the conclusion

Questionnaire and data preprocessing

A questionnaire was developed. The questions were offered to managers of transportation companies on conditions of anonymity. In 3 months about 5 thousands records in a database were received. Each record stores combinations of parameters (answers) corresponding to one transportation. The questionnaire includes the following questions:

1) Is the cargo intended for the Russian Federation? (1-Yes, 0-No)
2) Is the date of sale of the cargo the same as the date it crossed the border? (1-Yes, 0-No)
3) Do you face corruption at the customs on the borderline? (1-Yes, 0-No)
4) Have any companies registered in Byelorussia become your clients since January, 1, 2012? (1-Yes, 0-No)

5) Is the recipient registered in the Russian Federation? (1-Yes, 0-No)
6) Do you participate in the corruption at the customs of the Russian Federation? (1-Yes, 0-No)
7) Do you participate in the corruption in case herbal and veterinary control of the Russian Federation? (1-Yes, 0-No)
8) Do you participate in the corruption at the customs of the EU? (1-Yes, 0-No)
9) Do you participate in the corruption in case herbal and veterinary control of the EU? (1-Yes, 0-No)
10) Where was the border crossed? (Poland-1, Baltic States-0)
11) Do you think that the official salary of customs officials in the Russian Federation should be higher? (1-Yes, 0-No)
12) Do you think that the official salary of customs officials in the EU should be higher? (1-Yes, 0-No)
13) Do you think you will lose more if you participate in corruption activities at the EU customs? (1-Yes, 0-No)
14) Do you think you will lose more if you participate in corruption activities at the Russian customs? (1-Yes, 0-No)
15) Do you think you will lose more if you participate in corruption activities in case herbal and veterinary control of the Russian Federation? (1-Yes, 0-No)
16) Do you think you will lose more if you participate in corruption activities in case herbal and veterinary control of the EU? (1-Yes, 0-No)

The preliminary analysis showed that many records had similar sets of values of parameters. To group them we used k-means method with the selection of the best k on the basis of Dunn index

Having determined the cluster centers it proved that there were parameters with the almost identical values in all the centers. Excluding these parameters let us simplify further analysis of the data. Sets of parameters of the cluster centers are shown in Table 1. Here each parameter xi is related with the question-i from the questionnaire.

Table 1. Sets of parameters of the cluster centers

Claster	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}
1	1	1	1	1	0	1	0	1	0	0	1	1	0	0	0	0
2	0	1	1	1	0	1	0	1	0	0	1	1	0	0	0	0
3	0	1	1	1	0	1	1	1	0	0	1	1	0	0	1	0
4	1	0	0	1	0	1	0	0	0	1	1	1	0	0	0	0
5	1	0	0	1	0	1	0	0	0	1	1	1	0	0	0	1
6	1	1	1	1	0	1	0	1	0	0	1	1	0	0	1	0
7	1	1	1	1	0	1	0	1	1	0	1	1	0	0	0	0
8	1	1	1	0	1	1	0	1	0	0	1	1	0	0	0	0
9	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	0
10	0	0	1	1	0	1	1	0	0	1	1	1	0	0	0	0
11	1	1	1	1	0	1	0	1	1	0	1	1	0	0	0	0
12	1	0	0	1	0	1	0	1	0	0	1	1	0	0	0	0
13	1	1	1	1	1	1	0	0	0	0	1	1	0	1	0	0
14	0	1	1	1	0	1	1	0	0	1	1	1	0	0	0	0
15	1	1	1	1	0	1	1	1	0	1	1	1	0	0	0	1

For the further analysis the parameters x2, x7, x8 and x10 are chosen.

Constructing decision tree

Let's take x_{10} as a dependent variable. The regression analysis including the individual variables and their pair productions allowed to construct the following formula:

$$x_{10} = a_0 + a_1x_2 + a_2x_7 + a_3x_8 + a_4x_2x_8 + a_5x_2x_7 + a_6x_8x_7$$

Coefficients and estimators are shown in table 2.

Table 2.Coefficients of the regression equation

		Estimate	Std. Error	t value
a_0	(Intercept)	1.00E+00	1.754E-16	5.700E+15
a_1	clust_data[, 2]	-1.00E+00	2.481E-16	-4.031E+15
a_2	clust_data[, 8]	3.694E-16	3.038E-16	-3.291E+15
a_3	clust_data[, 7]	1.00E+00	3.038E-16	1.216E+00
a_4	clust_data[, 2]:clust_data[, 8]	1.00E+00	3.652E-16	2.738E+15
a_5	clust_data[, 2]:clust_data[, 7]	1.00E+00	4.297E-16	2.327E+15
a_6	clust_data[, 2]:clust_data[, 7]	-1.00E+00	4.051E-16	-2.468E+15

According the regression equation a logical function is constructing in the form:

$$X_{10} = \text{xor}(\text{xor}(\text{xor}(\text{xor}(x_2,!x_8),(x_2\&x_8)),(x_2\&x_7)),!(x_7\&x_8)),$$

xor, &, ! - the logical operations: exclusive disjunction, conjunction and negation.

Fig.1 illustrates the decision tree related with the logical function

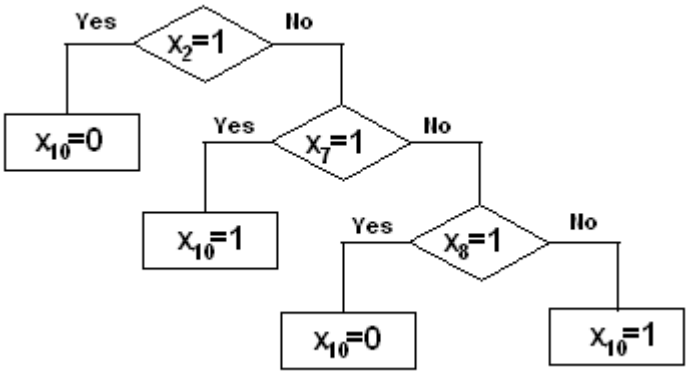

Fig.1. Logical tree

This study argues that the choice of a route can indicate a possibility to participate in a corruption scheme. Statistical verification confirms this statement.

Conclusion

In the paper the decision tree based on questionnaire was constructed. The clustering allowed to reveal the significant combinations of parameters and to reduce the number of variants for comparison. The regression analysis determined the significant combinations of parameters for construction of logic function and the decision tree.

This decision tree was used for analysis of transportation flows of goods from West Europe to East Europe. The experiment with the decision tree was completed and the results showed good coincidence with statistical data. The proposed method can be used for constructing a decision tree based on a large amount of similar data.

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Authors' Information

Dmitry Stefanovskiy - *Assoc. Prof., Ph.D, the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571,*

e-mail: dstefanovskiy@gmail.com

Major Fields of Scientific Research: mathematical modelling, world economy

Sergey Maruev *– Professor, The Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia;*

e-mail: maruev@gmail.com

Major Fields of Scientific Research: mathemetical modeling, economics of education, busines process modeling

Javier Tejada Cárcamo *– Professor of Computer Science Department, San Pablo Catholic University; Research and Software Development Center of San Agustin National University (Cátedra Concytec);*

e-mail: jawitejada@hotmail.com

Major Fields of Scientific Research: text mining, business intelligence, classification

PROGRAM WORLD-DYN BASED ON FORRESTER MODEL OF WORLD DYNAMICS

Olga Proncheva

Abstract: *Forrester model is a system of differential equations reflecting dynamics of 5 macro-economical variables (population, resources, etc.) . Such a model were developed more then 40 year ago and it proved to be an effective tool for qualitative analysis of world dynamics. By the moment there is no an accessible end-user program based on this model and our goal was the development of such a program with a comfortable graphical interface. In the paper we describe the program World-Dyn, which allows to set initial data and noise level, to set moments of parameter changes, to form the necessary visualization of results. We demonstrate the program functionality both on Forrester's example and on our example related with crisis.*

Keywords: *Forrester model, world dynamics, numerical analysis.*

Introduction

At far 1970 year the Roman Club (a nongovernmental organization of politicians and scientists) asked John Forrester, a professor of MTI, to create a model, which could predict the further development of our world. After two weeks he presented his model "World-1", but this model proved to be too crude. Next year Forrester developed a new model called "World-2" and we consider this model in our paper [Forrester, 2003]

In his work Forrester pointed five main problems, which could provoke the possible future World Crisis. It is overpopulation of our planet, lack of basis resources, the critical level of pollution, food shortages and industrialization. He included five variables related with the mentioned problems:

- Population (P)
- Pollution (Z)
- Natural resources (R)
- Capital investment (fixed assets) (K)
- The proportion of funds invested in agriculture (X)

His work attracted many followers: Sergey Makhov [Machov,2003], Vladimir Egorov [Egorov, 1980] et al. Unfortunately, by the moment there is no an accessible end-user program based on Forrester model and our goal was the development of such a program with a comfortable graphical interface in the framework of MatLab package [Vasilyev, 2012]

Program description

2.1 Forrester model and calculation scheme

Forrester's model is the system of 5 differential equation:

$$\frac{dP}{dt} = F_1(P, K, X, Z, R) \quad (1)$$

$$\frac{dK}{dt} = F_2(P, K, X, Z, R) \quad (2)$$

$$\frac{dX}{dt} = F_3(P, K, X, Z, R) \quad (3)$$

$$\frac{dZ}{dt} = F_4(P, K, X, Z, R) \quad (4)$$

$$\frac{dR}{dt} = F_5(P, K, X, Z, R) \quad (5)$$

Here F_i (i=1,2,3,4,5) are functions, which depend on the main variables. We used two methods for model calculation: Runge-Kutt method and Adams method [Petrov, 2006]. These methods are realized in MatLab (ode45 and ode113).

2.2. Input/output of the main variables

A user can get the results of classical Forrester model. For this he should open a set of menu:

"Options"-> "Counting settings"->Solve:

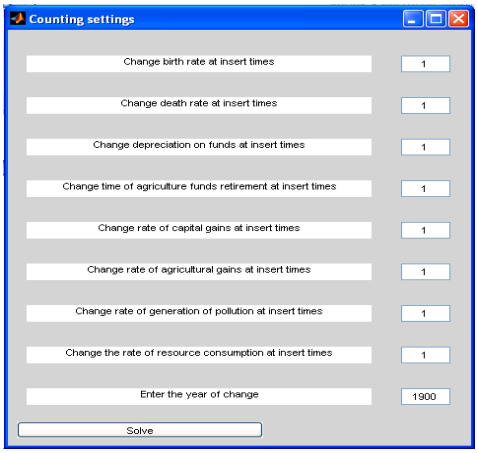


Fig.1. Model description

2.3. Definition of noise in the initial data and on the stage of forecast

A user can complete the experiments with noise. To make such an experiment in initial data the user should open "Options"-> "Noise settings (initial data)".

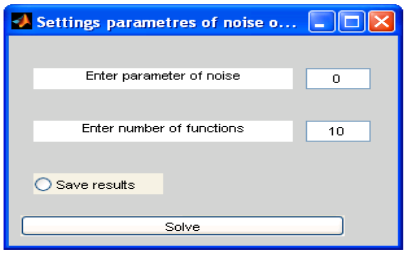


Fig.2. Menu for noise definition in the initial data

After that he chooses the noise level (parameter of noise) and the number of noise functions. To save the results the user points "Save results". The forecast will be save as "change_initial_*(name of variable)_ expectation_*(noise level)noise_*(the number of functions)functions_*(the percent of converge functions)%_converge". And finally the user enters "Solve".

In order to complete the experiment with noise related with all variables on a forecast stage the user should open “Options”-> “Noise settings (forecast)”:

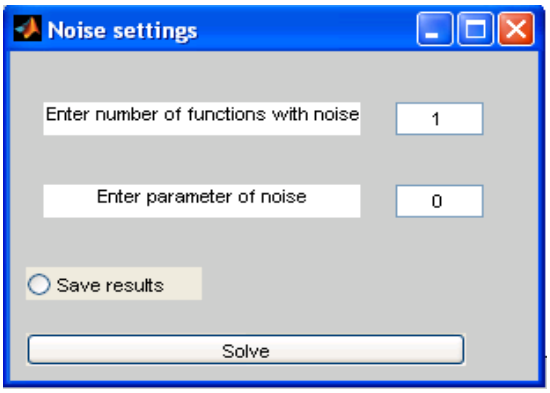


Fig. 3. Menu for noise definition on the forecast stage

After that he chooses the noise level (parameter of noise) and the number of noise functions. To save the results the user points “Save results”. The forecast will be saved as “change_all_*(name of variable)_expectation_*(noise level)noise_*(the number of functions)functions_*(the percent of converge functions)%_converge”. And finally, the user should enter “Solve”.

In order to complete the experiment with noise related with one given variable on a forecast stage the user should open “Options”-> “Noise settings (only one function)”:

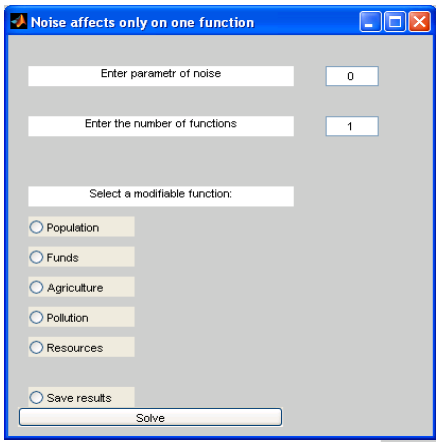


Fig. 4. Menu for noise definition on the forecast stage (one variable)

After that he chooses the noise level (parameter of noise), the number of noise functions, and the name of modifiable variable. To save the results the user points “Save results”. The expectation will be saved as “change_only_*(name of modifiable variable) _*(name of variable)_expectation_*(noise level)noise_*(the number of functions)functions_*(the percent of converge functions)%_converge”. And, finally, he should enter “Solve”.

2.4. Messages of the program

When the program World-Dyn works it may inform the user:

- about process of modeling (Fig. 5)
- about final of calculation (Fig. 6)
- about errors (Fig.7 and Fig.8)

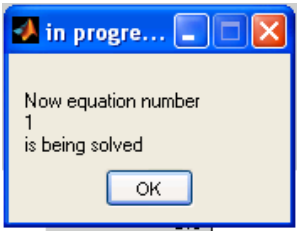


Fig. 5. Message about process of modeling

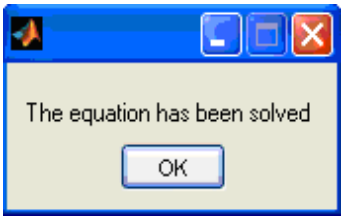


Fig.6. Message about final of calculation

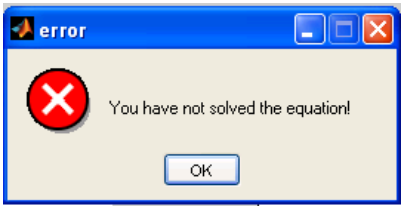


Fig.7. Message-1 about error

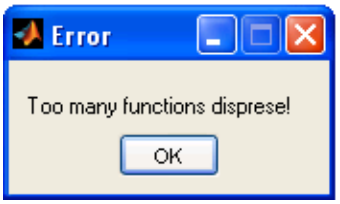


Fig.8. Message-2 about error

Experiments

3.1 Classical Forrester example

The program WorldDyn was tested on the Forrester example and gave the correct results. For example, for the population we have:

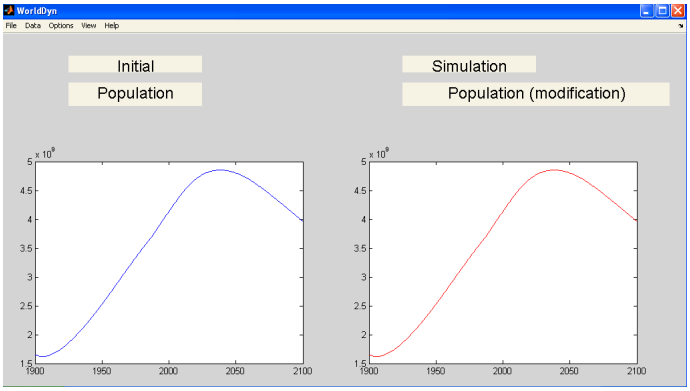
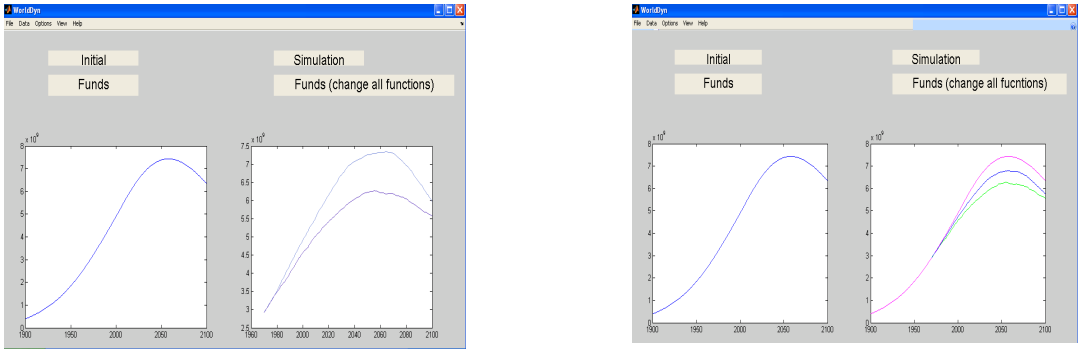


Fig.9. Classical Forrester model, calculation of population dynamics

With the noise we have (Fig.10):



(a) (b)

Fig. 10. Modeling with noise: (a) we display all noise functions; (b) we display initial function (magenta), expectation (blue) and the worst function (green).

3.2. Testing example

In our example, we change parameters of model: the birth rate decreases on 10% and the pollution decreases on 15% at 2012. We get the following results (Fig.11):

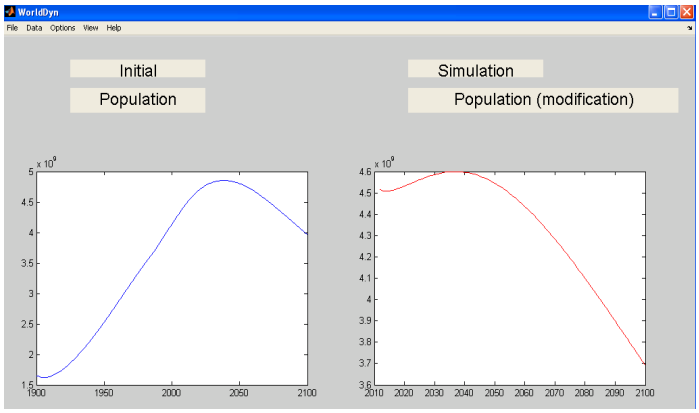


Fig.11. Abrupt change of the model parameters

Conclusion

In the paper we shortly described the program WorldDyn, which were developed in the MatLab shell. The program allows to model the world dynamics on the basis of Forrester model with noise. The program is supposed to be used by end-users which are not qualified in programming and mathematics

In the future this program will be transformed to the laboratory work for students of Russian Presidential Academy of national economy and public administration

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Authors' Information

Olga Proncheva *– B.Sc. in economy and app. math., the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physics and Technology (State University); Institutskii per 9., Dolgoprudny, Moscow Region, 141700, Russia*

e-mail: olga.proncheva@gmail.com

Major Fields of Scientific Research: mathematical modelling, world economy

ESTIMATION OF THE INVESTMENT ATTRACTIVENESS OF COMPANIES USING MULTIPLES THAT ACCOUNT FOR INDUSTRY SPECIFIC FACTORS

Evgeniy Ageev

Abstract*: The article is devoted to the issue of using financial multipliers to estimate the value of a company. In our research we identified the industries that account for more than 50% of Gross Domestic Product. We took the companies with publicly available information. Then we used multicriteria Muchnik's model to identify promising companies and receive the required sample. At the final stage, we used a comparative approach for the evaluation of companies in these industries. The results of experiments showed the essential advantage of the proposed method. Notably, we marked multiplier, which were most likely gave a more realistic evaluation of companies. The paper reflects the results of Bachelor research.*

Keywords*: financial multiples; company valuation; multicriteria Muchnik's model; comparable company*

ACM Classification Keywords*: I.2.m Miscellaneous*

Introduction

1.1. Problem setting

Determining the fair value of company is one of the major issues of corporate finance. Problem arises because there is no single method of assessment of companies as each company, just as any person, is individual. Problem requires a solution, because accurate assessments are need for mergers and acquisitions in order to determine the profitability of various investment strategies, in determining further management etc.

Traditionally there are three approaches to evaluate the companies:

1. The income approach;
2. The cost approach;
3. Market-based approach.

Income approach is the most labor-intensive approach in business valuation.

$$V = \sum_{t-1}^{t=n} \frac{CF_t}{(1+r)^t}$$

V – value of the asset;

CF_t – cash flows for the period *t;*

n – lifetime of the asset;

r – discount rate.

The cost approach is linked with the assessment of individual assets. Assets are summed to obtain the value of the firm.

The market approach is used in circumstances where there aren't insufficient data for the applying approach of discounting cash flow, when you need quick assessment [Damodaran, 2004].

The value of most assets is based on the price of a similar asset in market be it a house or a stock. In contrast to the income approach which aims to search for intrinsic value market-based approach is based on the market value. It is assumed that on the average market has well-defined stock prices, but makes mistakes, when created value of individual stocks. In our research we assume that use and a comparison of multipliers will reveal these errors. Can help determine which companies are undervalued. It's the purpose of any private investor.

1.2. Related work

The questions related with the general analysis of investment market are considered in the publications [Brealey, 2003; Copeland, 2005]. The assessments of investment attractiveness of different companies are reflected in the works [Alford, 1992; Baker, 1999; Barker, 2001; Fairfield, 1994].

The peculiarities of the Russian financial market are described in [Ivashkovskaya , 2008; Teplova, 2011]. All these publications proved to be the basis for the proposed method.

It should say that in most studies, analysts looked at the comparable firms that were in the same industry. They [Lie E., 2002; Park Y., 2003; Liu, 2002] have identified a set of specific multipliers that describe the factors of value companies. They assumed that between industries there are significant differences that affect business valuation. This is due to different income and capital intensity of different industries as well as different expected growth, and many other factors (company size, the degree of openness and protection of shareholders and etc.).

Method

2.1. Hypothesis

Need to check which method is suitable for public companies on the Russian market. We put forward the following hypothesis: *for each industry can be applied a multiplier which could help obtain an estimate of company's value with the smallest error.*

To confirm the hypothesis we analysed of public companies which located in Russia. For this purpose we used the annual reporting accounts of companies in 2010. In 2010 price of oil and gas which is exported from Russia, returned to normal level and Russian ruble has stabilized and strengthened. According to UNCTAD (http://archive.unctad.org/ru/docs/dom2011d1_ru.pdf) in the year 2010 Russia (in terms of attracting foreign direct investment (FDI)) was second after China among the BRICS countries. This year demonstrated the extent to which the Post-Crisis Economy of the Russian Federation is attractive for investors. To proceed to proof of hypothesis it is necessary to determine the sample. To begin with, we had to consider the industry which adds up to more than 50% of GDP. We have identified industries with the best data and with a large number of companies.Those are "Wholesale and retail trade" and "Transport and communications". Next, we used data on issuers which has been collected with help of System of Professional Analysis of Markets and Companies (SPAMC). Only public companies were subject to research. The next step was to apply to apply grouping.

2.2. Muchnik method

The algorithm of Muchnik's model implements a method of sequential sampling which allows us to solve the problem of multicriteria choice. The method assumes that the criteria is ranked according to importance. The model is as follows:

- lower level are the parameters which describe the activities of companies (candidates) on investments;

- medium level are private criteria, the following parameters or derivatives;
- upper level are integral criteria or utility function.

When evaluating companies for a given parameter we set a threshold which will separates interesting companies from the rest ones. Conditionally we assigned index 1 for a company if it satisfied the parametrized restriction and – 0, if it is not satisfied. We summarize the indices parameters of private criteria and commend the company.The algorithm is as follows:

1. choose the best company for the first criterion
2. choose the best company for the second criterion obtained from the best companies
3. selected the best of the third criterion of the companies received in the previous step, etc.

What do we have? We have the most promising group of companies. Then we remove these companies from the general list and repeat the algorithm for the remaining companies to get the next group. The process is repeated as many times as we want, depending on the desired number of groups of companies. The *age* and *size* of the companies have been chosen as the criteria. Age of the companies had to be more than five years, so we are warned by young companies. They are not yet accustomed to the specifics of the industry and are therefore at risk. Size of the companies were determined by the level of sales revenue for 2010 - more than 1 billion rubles, ie large enterprises.

Next, go to the assessment of companies on the given criterion. The essence of the criterion is an indexation of the companies. The specified index is the sum of the index companies in all the parameters which make up the selected private criterion. Select the criterion of "Return", consisting of three derivatives parameters:

- *Return on sales* (ROS), % - shows the share of net profit in the sales of the business. Calculated by the formula:

$$ROS = \frac{Net\ profit}{Net\ sales}$$

- *Return on assets* (ROA), % - shows how much profit has been generated of each monetary unit, embedded in the assets of the organization. Calculated by the formula:

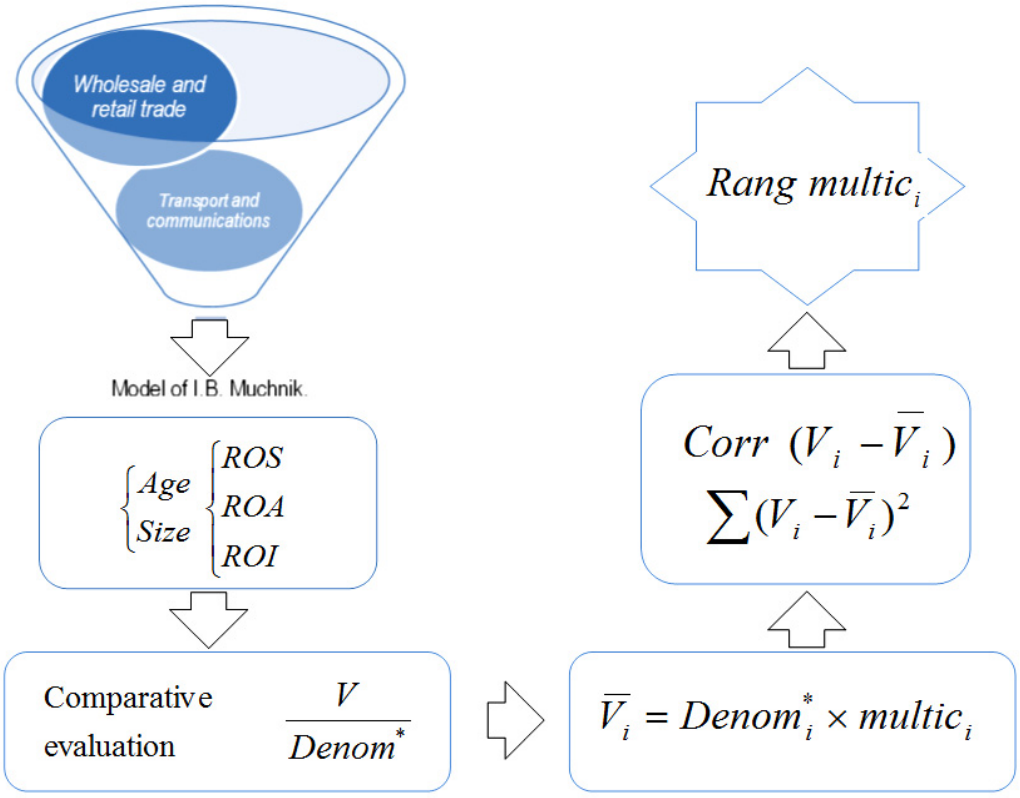
$$ROA = \frac{Net\ profit\ for\ the\ period}{Average\ assets\ for\ the\ period}$$

- *Return on investment* (ROI), % - shows how much money the company needed to produce every unit of profit. Calculated by the formula:

$$ROI = \frac{Net\ profit}{Own\ capital + Long - term\ commitment}$$

Experiments

3.1. Selection of companies



After application the method of selection and grouping we formed four groups companies (A, B, C, D). We selected as a training sample group A. We calculated the value of the company multipliers and considered them as true for the entire industry. We calculated based on these multipliers estimate the market capitalization and enterprise value of the remaining companies [Frykman, 2003]. The results were compared with those which were counted in advance. To identify an offset value in the valuation of companies we estimated the deviation in absolute value, standard deviation and correlation. We have compared the values of deviations and assign indexes to appropriate multiples.

Multiplier which has received the least amount of "points" is considered the best for the selection as it gives the smallest error in the valuation. We increased our training sample and added the companies from group B. The newly calculated values of the multipliers in this sample will be assumed true for the industry. We obtained a "new" value of market capitalization and enterprise value for the remaining companies. We re-estimated the error of the group.

The training sample is expanded by adding the companies from group C (ie A + B + C).

Again, acting in accordance with our logic and present the results in tabular form (Table 1, 2).

3.2. Interpretation of results

Thus, combining the results together we can talk about the identification of a specific multiplier which provides the smallest error. It's empirically determined that the same multipliers have a different error when assessing the value of companies in each industry. The total we have considered 367 companies.

The hypothesis was confirmed*: for each industry can be applied a multiplier which could help obtain an estimate of company's value with the smallest error.* We were able to confirm this hypothesis using the results by industries of "Wholesale and retail trade" and "Transport and communications". For each of these industries was determined a multiplier which found undervalued companies with the lowest error. For the industry "Wholesale and retail trade" the P\E multiple is the most efficient, and for the industry "Transport and communication" – a multiplier EV / EBIT.

Table 1. Results for the industry "Wholesale and retail trade"

Multiples	1*	2*	3*	*Sum*	Place
P/E	1	2	2	*5*	1
EV/S	5	5	5	*15*	5
EV/B	2	1	4	*7*	2
EV/EBITDA	3	3	1	*7*	3
EV/EBIT	4	4	3	*11*	4

Table 2. Results for the industry "Transport and communications"

Multiples	1*	2*	3*	*Sum*	Place
P/E	3	4	4	*11*	4
EV/S	5	5	5	*15*	5
EV/B	2	3	1	*6*	2
EV/EBITDA	4	2	3	*9*	3
EV/EBIT	1	1	2	*4*	1

Conclusions

It should be noted that the analysis of the two industries can demonstrate the efficiency of the proposed method on the example of Russian industries.

We can shortly formulate following results:

- We have set a problem of determining a multiplier to estimate the fair value of companies as a problem of multicriteria selection.
- This problem was resolved on the basis of proposed method which contains *Muchnik's model.*

Application of the results:

- Proposed method could be used to predict the value of companies.
- Investors can also use this methodology to identify undervalued companies.

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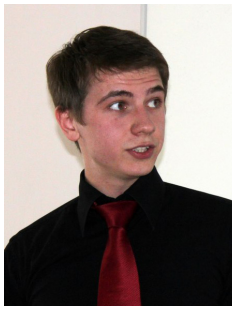
Authors' Information



Evgeniy Ageev *– Bachelor, The Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physics and Technology; Institutslii per. 9, Dolgoprudny, Moscow Region, 141700, Russia;*

e-mail: eageeev@gmail.com

Major Fields of Scientific Research: financial multiples; stock markets, econometrics.

SMOOTHING AND PROGNOSIS OF MULTI-FACTOR TIME SERIES OF ECONOMICAL DATA BY MEANS OF LOCAL PROCEDURES (REGRESSION AND CURVATURE EVALUATION)

Alexander Kovaldji, Vladimir Averkiev, Marina Sarkissyan

Abstract: *Smoothing and prognosis belong to the main problems, which we deal with when process various time series. Unlike the typical approaches related with lineal regression on polynomial and trigonometric functions we consider local procedures. We describe algorithms that resolve these problems and present results of experiments using data of the Russian State Statistical Committee. All procedures are realized in the Excel-VBA.*

Keywords: *econometrics, local regression, time series, seasonality*

ACM Classification Keywords: *I.2.m Miscellaneous*

Introduction

The modern econometrics includes many methods of time series (TS) smoothing and prognosis [Kandle, 1981; [Klayner, 2000; Bessonov, 2003; Nosco, 2011]. The majority of these methods take into account integral properties of a given TS. However, in many cases so-called local procedures can provide the better results. This paper describes the original methods of TS analysis: 1) smoothing based on local linear regression 2) revealing seasonal variations based minimization of function curvature. The first method uses the idea of weighted points in the regression model. The second method reduces to the solution of system of 12 linear equations. The similar approaches have been considered in the work [Gubanov, 2001].

Proposed methods

2.1 Smoothing procedure

In the proposed procedure we weight each point using exponential coefficients and then use the weighted least squares method (WLSM). The exponential coefficients are calculated according the formula:

$$w(i) = \frac{1}{2^{\frac{|x(j)-x(i)|}{\lambda}}}, \quad (1)$$

where *x(j)* is the point which the WLSM is used for.
The WLSM consists in minimization of the values:

$$\sum_{i=1}^{n} (w(i) * (y(i) - Ax(i) - B)^2), \quad (2)$$

To solve this problem we differentiate this sum with respect to A and B and then we obtain the following system of two linear equations:

$$\begin{cases} A * \sum_{i=1}^{n} \left(w(i) * x^2(i)\right) + B * \sum_{i=1}^{n} \left(w(i) * x(i)\right) = \sum_{i=1}^{n} \left(w(i) * x(i) * y(i)\right) \\ A * \sum_{i=1}^{n} \left(w(i) * x(i)\right) + B * \sum_{i=1}^{n} w(i) = \sum_{i=1}^{n} \left(w(i) * y(i)\right) \end{cases} \quad (3)$$

Having received A and B for each point we calculate:

$$z(i) = A * x(i) + B. \quad (4)$$

One should say that when weights are equal (an extreme case) the local linear regression reduces to the ordinary lineal regression.

2.2 Elimination of season cyclicity

Firstly we introduce the so-called curvature degree according te formula:

$$\sum_{i=2}^{n-1} \left(y(i) - \frac{y(i-1) + y(i+1)}{2} \right)^2 \quad (5)$$

For boundary points we use two additional formulae:

$$\left(y(1) \quad 2 * y(2) + y(3)\right)^2, \quad (6)$$

$$\left(y(n-2) - 2 * y(n-1) + y(n)\right)^2. \quad (7)$$

Therefore the degree of curvature is the sum of (5), (6) and (7)

We consider time series (TS) as a sum of trend and season function. The latter is a periodical function with the period 12 (it is the number of months in a year):

$$y(i) = y^{real}(i) + k(i) \quad (8)$$

So, the season function is a set of 12 season coefficients k(i):

$$k(i) = k(i+12), \qquad i \in [1, n-12]. \quad (9)$$

To find these coefficients we minimize the degree of curvature for TS $y^{real}(i)$:

$$\begin{aligned} &\left[\left(y(1) - k(1)\right) - 2 * \left(y(2) - k(2)\right) + \left(y(3) - k(3)\right)\right]^2 + \\ &+\left[\left(y(n-2) - k(n-2)\right) - 2 * \left(y(n-1) - k(n-1)\right) + \left(y(n) - k(n)\right)\right]^2 + \\ &+\sum_{i=2}^{n-1} \left(\left(y(i) - k(i)\right) - \frac{\left(y(i-1) - k(i-1)\right) + \left(y(i+1) - k(i+1)\right)}{2} \right)^2 \xrightarrow[k(1)\ldots k(12)]{} min \end{aligned} \quad (10)$$

To solve this problem we differentiate (10) with respect to *k(i)* having in view (9). Then we can calculate the TS values without season components:

$$y^{real}(i) = y(i) - k(i) \quad (11)$$

Program realization

The proposal methods are realized in the program Prophet. The program is prepared on Excel-VBA.

Input data includes: initial data set; parameter of smoothing; hypothesis about data generation model (additive or multiplicative season component); period of prognosis.

The program presents in graphical form: TS without outliers; TS without seasonality; smoothed TS without outliers and seasonality (trend); extrapolated trend; forecasted TS. One can see the program Prophet Interface on the figure 1.

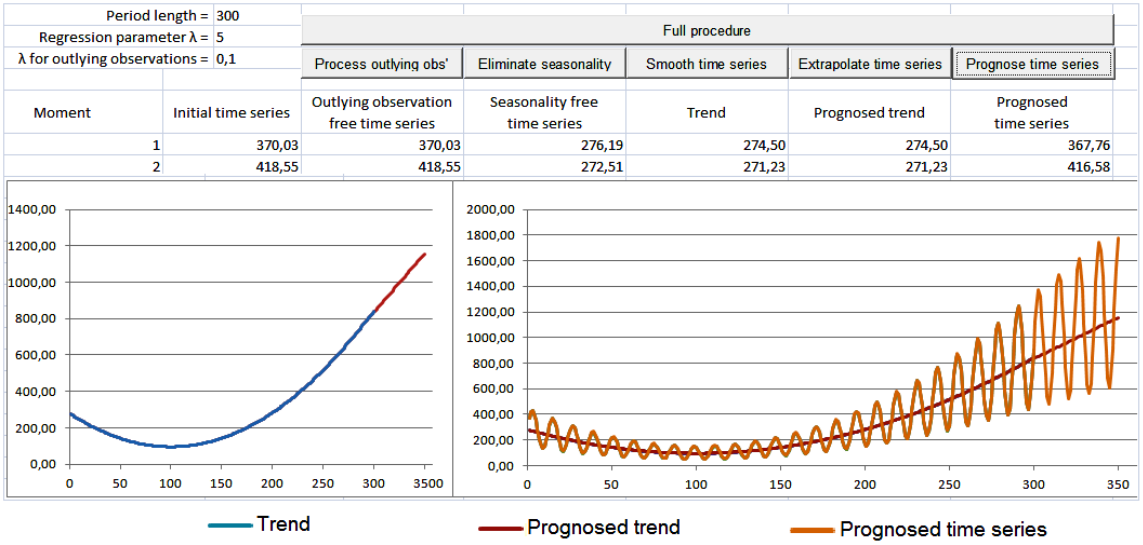


Fig.1. Program Prophet Interface

Experiments

4.1 Local regression

Figure 2 presents the result of smoothing by local lineal regression. TS is a set of oil prices (brand Brent) given on the interval of 25 years. The parameter of smoothing here is equal 500.

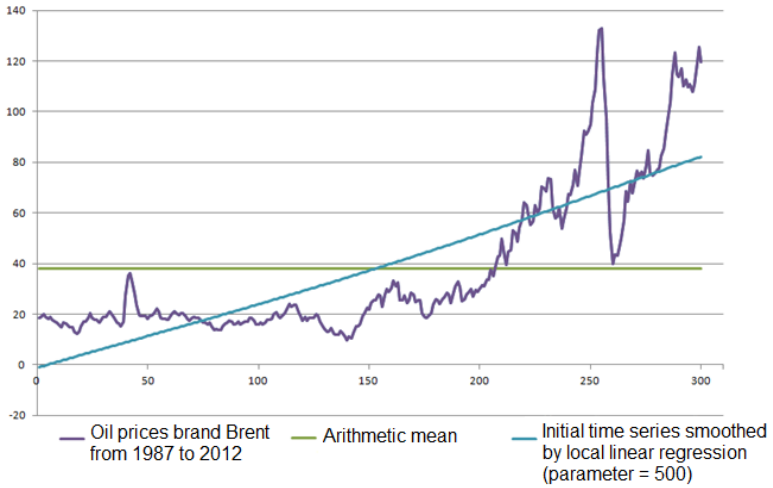


Fig. 2. Smoothing by local linear regression

We should note that the local linear regression does not inverse local minimums and maximums unlike moving average method with odd number of points in the window. We illustrate such an effect on figure 3.

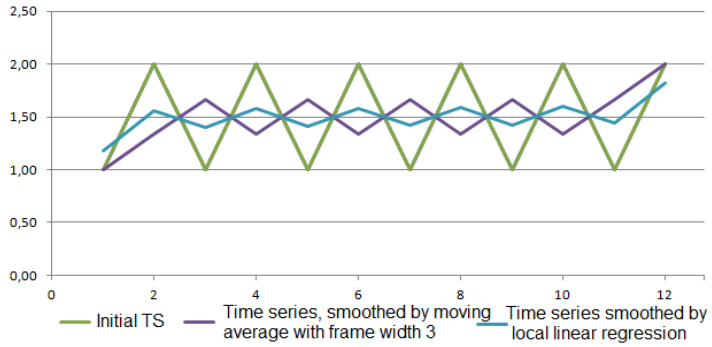


Fig. 3. Smoothing TS with local linear regression and with moving average (odd number of points in the window)

4.2 Elimination of season cyclicity

We prepared artificial TS by summing a given trend and a cyclic season wave. See this TS on figure 4

We could recover the initial trend having applied our method. The results are presented on figure 5.

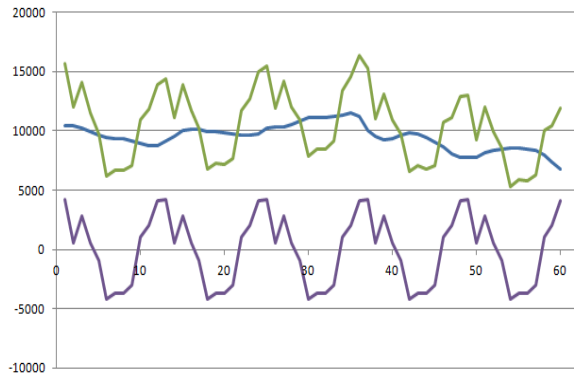


Fig. 4. Artificial TS as a sum of a given trend and a cyclic season wave

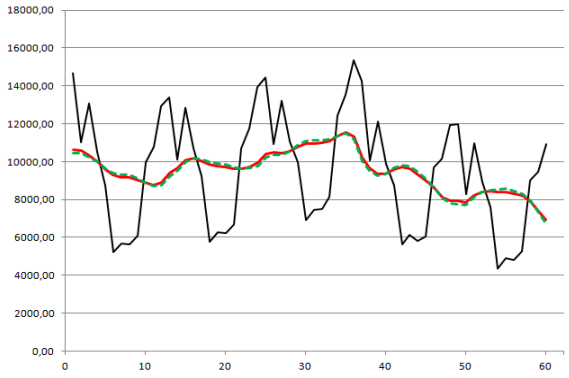


Fig. 5. Initial data, data with a season wave, and recovered data

One can see that the TS without a season wave proved to be close to the real data. Table `1 presents the quantitative values related with seasonality.

Table 1. Characteristics of seasonality

Month number	Initial seasonality	Obtained coefficients
Seas(1)	4205,18	4022,54
Seas(2)	560,18	425,95
Seas(3)	2858,11	2766,15
Seas(4)	527,54	518,81
Seas(5)	-892,84	-821,73
Seas(6)	-4205,19	-4076,85
Seas(7)	-3658,88	-3506,85
Seas(8)	-3650,12	-3510,47
Seas(9)	-3045,01	-2950,52
Seas(10)	1073,28	1097,07
Seas(11)	2071,83	2023,09
Seas(12)	4155,93	4012,82

Conclusions

The main results of the paper are:

1. New method of identification of non-parametric short- and long- run trend of time series by weighted local linear regression was developed.
2. New method for eliminating non-parametric season fluctuations of time series by minimization curvature of residual time series was suggested.
3. Both methods were realized in the computer program on Excel-VBA and their efficiency was demonstrated on real data.

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Authors' Information

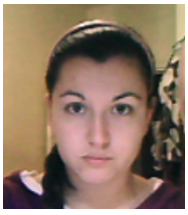
Alexandr Kovaldji *– Scientific Director of the Lyceum "School 2"; Fotievoy Str, bld. 18, Moscow, 119333, Russia; Visiting professor of the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia;*

e-mail: koval-dji@yandex.ru

Vladimir Averkiev *– student, the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia;*

e-mail: youdobob@gmail.com

Major Fields of Scientific Research: mathematical modeling, system analysis.



Marina Sarkisyan *– student, the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physic and Technology (State University); Institutsky pereulok, bld. 9, Dolgoprudny, 141700, Moscow region, Russia;*

e-mail: Sarkissyan.Marina@gmail.com

TIME SERIES PROGNOSIS OF GDP WITH THE SYSTEM GMDH-SHELL (EXPERIMENTAL WORK)

Victor Lebedev

Abstract: *Time series prognosis of economical indexes is one of the main problems of econometrics. In the paper we study possibility to give an interval prognosis of time series using the set of the best prognostic models. Speaking 'model' we mean a combined model of regression and auto-regression. Speaking 'the best models' we mean the ordered series of models constructed by the well-known Group Method of Data Handling (GMDH). The proposed simple approach consists in the following: a) one generates the fixed numbers of models on the basis of experimental data b) these models give correspondent prognoses c) the real value is supposed to belong to min-max interval the models provide. We shortly describe the software tool GMDH-Shell (GS) that implements GMDH and the results of experiments with GS. The experimental data are time series of the Gross Domestic Products (GDP) of 100 countries given on the period 1980-2000.*

Keywords: *GMDH, GMDH Shell, time series prognosis, gross domestic product*

ACM Classification Keywords: *I.2 Artificial Intelligence*

Introduction

Econometrics offers many methods for time series prognosis of economical indexes. Almost all of these methods are based on certain statistical assumptions and use various variants of regression analysis [Kandler, 1981; Klayner, 2000]. Group Method of Data Handling (GMDH) is an alternative to the traditional statistical approach. This method determines the model of the optimal complexity from the given class of models on the basis of experimental data. GMDH uses two or more subsets from a given data set for model construction, selection, and verification. It allows automatically to take into account indefiniteness concerning features of source data.

GMDH is effective when: a) we have limited information about the structure of a model; b) we have limited value of observation data. Often we know nothing about the model and often the number of observation data is less then the number of parameters to be determined. GMDH was introduced at 80s by Ukrainian academician Alexey Ivakhnenko and now it is developed by his colleagues and pupils. We can mention here some publications in English [Ivakhnenko, 1981; Ivakhnenko, 1994]. The theoretical basis of GMDH is presented in the paper [Stepashko, 2008]. The list of publications related with GMDH and its applications is presented in [GMDH, http].

The traditional way of using GMDH consists in construction of one the best model and its further application for prognosis. To make the prognosis more reliable one uses assembling or ensembling. In the first case the prognosis is an average value all models provide, in the second case the prognosis is an averaged value based on only some models from a given set. This approach is enough new and it needs additional research. We can mention here the work [Zhi-Hua Zhou, 2002] **where ensembling neural network for prognosis is considered**. In statistics a prognosis is usually accompanied by so-called confidential interval. In inductive modeling an interval prognosis can be obtain, for example, with fuzzy GMDH [Zaychenko, 2008]. In this paper we propose to form this interval using minimum and maximum values, which first the best GMDH models provide.

The paper is organized by the following way. In the section 2 we shortly describe the tool GMDH Shell (GS). Section 3 presents the results of experiments with GS. Section 4 contains the conclusions.

GMDH Shell

The set of models for time series prognosis is created by the tool (GS) mentioned in the Introduction. This software implements algorithms of GMDH and has very friendly user interface. One can meet with GS possibilities and download it [GS, http]. GS has a Wizard for new users with a series of typical examples (see Fig.1).

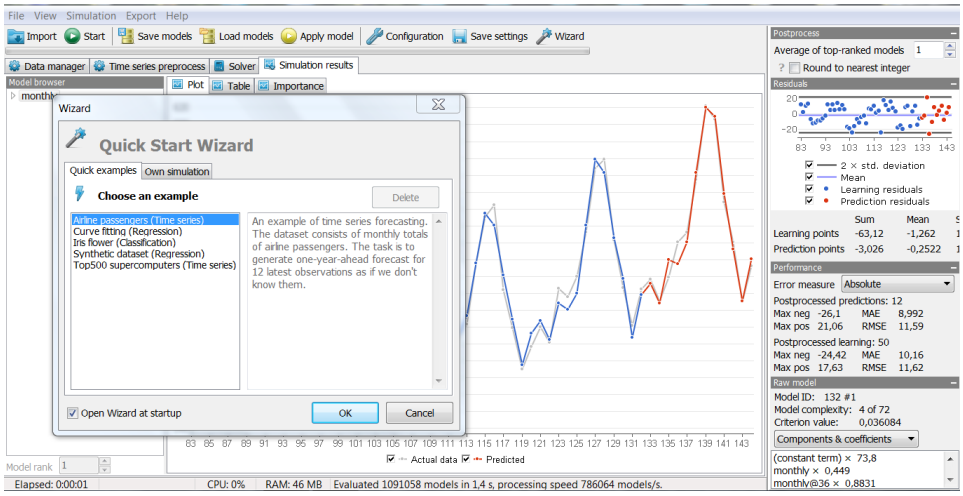


Fig. 1 Screenshot of GS interface

Traditionally GMDH offers 4 algorithms: combinatorial algorithm (COMBI), combinatorial selective algorithm (MULTI), multilayered Iterative algorithm (MIA), and relaxation iterative algorithm (RIA). GS uses modified COMBI and modified MIA. The modifications concern the limitations of models a user assigns. GS algorithms are described in [Koshulko, 2007; Koshulko, 2009]. GS includes many modes for testing model validity [Koshulko, 2011] that is very important for users [Latysh, 2012]. Figure 2 presents the procedures of GS.

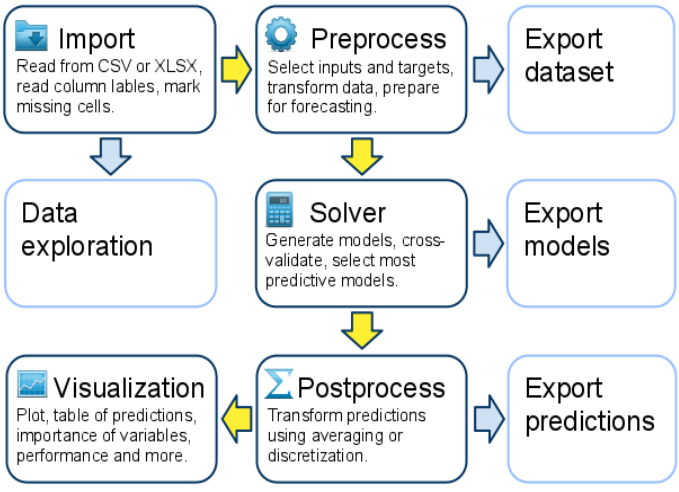


Fig. 2 Data processing in GS

In our research we used first of all the possibility to select the set of the most predictive models in the module Solver. These models allow to find the minimum and maximum values of the prognosis. On the stage of pre-processing we recovered missing data (not more then 5%). On the stage of post-processing we studied the most frequent variables used in models.

Experiments

The experimental data are time series of the Gross Domestic Products (GDP) of 100 countries given on the period 1980-2009 [WorldBank, http]. The part of this data is presented on Figure 3.

Variable	Gross Domestic Product, at current prices in national currency, in millions						
Year	1980	1981	1982	1983	1984	1985	1986
Country							
Australia	154648	178405	192066	216657	239161	264060	289214
Austria	76595,71	81596,949	87625,032	93331,881	98011,346	103419,239	108956,922
Belgium	90698,929	95093,801	102901,426	109016,03	117780,09	125266,165	131116,748
Canada	325910,25	365318	387740,75	420935	458615	492420,75	524143
Denmark	392875	430068	491088	541428	597727	648540	698783
Finland	33240	37568	42272	47074	52645	57271	61616
France	445233,05	500755,79	574445,4	636621,61	693087,94	743889,54	802364,52

Fig. 3 Source data (the part of full table)

In our experiment we consider 2 countries: US and Switzerland. The experiment consists in the following:

1 First 10 the best prognostic models of GDP for 2007 are generated. Here we use the data on the period 1980-2006

2 Prognoses with all 10 models are calculated and minimum and maximum values are founded

3 We test whether the real value belong to the interval of minimum-maximum values

The experiment is repeated for 2008 and 2009 using the data on the periods 1980-2007 and 1980-2008 respectively. Table 1 shows the results related with US, table 2 shows the results related with Switzerland.

Table 1. Prognoses for US

	2007	***2008***	***2009***
Model 1	14114673	14506527	14462123
Model 2	13975186	14660353	15242288
Model 3	13819792	14505804	14462021
Model 4	13938927	14702221	13934209
Model 5	14005305	14661333	14491801
Model 6	13900404	14684275	15156285
Model 7	13935342	14641953	15205031
Model 8	13914712	14619275	14610805
Model 9	13913198	14521542	15069660
Model 10	13914228	14714699	14677642
Minimum	13819792	14505804	13934209
Maximum	14114673	14714699	15242288
Real	**13830300**	**14221425**	**14107150**

Table 2. Prognoses for Switzerland

	2007	***2008***	***2009***
Model 1	515726	541035	530527
Model 2	515418	546639	530458
Model 3	507785	550349	530458
Model 4	506546	556283	561952
Model 5	507064	547059	568298
Model 6	503074	537962	530983
Model 7	503658	539430	586720
Model 8	506366	539430	531862
Model 9	507165	539374	532408
Model 10	508011	555281	528059
Minimum	503074	537962	528059
Maximum	515726	556283	586720
Real	**521100**	**544195**	**535282**

One can see that in 2 cases from the 6 ones the real data are outside the interval of minimum-maximum values.

Conclusions

The main results of the paper are:

- We proposed the way of prognosis based on the set of the best models generated by GMDH
- We shortly described the software tool GMDH Shell, which implements GMDH
- The results proved not to be completely perfect

In the future we suppose to study more detail the proposed way having in view both the number of models and the algorithm of modeling

Acknowledgement

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Authors' Information

Victor Lebedev *– student, the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physics and Technology (State University); Institutsky pereulok, bld. 9, Dolgoprudny, 141700, Moscow region, Russia;*

e-mail: viktor.lebedev@phystech.edu

Major Fields of Scientific Research: inductive modeling, business intelligence

STUDY OF INVESTMENT ATTRACTIVENESS OF RUSSIAN COMPANIES ON THE BASIS OF THEIR MARKET CHARACTERISTICS AND PERFORMANCE REPORTING

Dmitriy Bogachev

***Abstract**: In the paper different well-known market characteristics and indicators of financial accounting (net income, revenue, revenue growth, etc.) are considered. We propose new characteristics, which could be useful for company assessment. We also describe a classification technique based on Naive Bayes method to identify the most attractive companies.*

***Keywords**: classification, Naive Bayes, financial market, stock's returns.*

***ACM Classification Keywords**: I.2 ARTIFICIAL INTELLIGENCE*

Introduction

It is widely known that the utilization of accounting and other performance information of comparing business firms is highly subjective. Investment services provide a wide variety of lists of recommended securities classified into groups, where companies within a given grouping are perceived by the analyst as "similar" with respect to anticipated price appreciation, yield, and risk.

The purpose of this research is a quantitative analysis of similarity between business activity and the utilization of this similarity for grouping related firms.

Algorithm and Data

The classification algorithm used in this article is a Naive Bayes. This algorithm was selected because of its high speed in comparison with other algorithms (support vector machines, trees, nearest neighborhood) [Wang, 2008]. But it supposes the independence of object parameters. We cannot say that the indicators, which will be mentioned hereinafter, are completely independent. In reality they are mutually dependent. Naive Bayes often is not able to give good estimates of probability of correct class. He makes a correct estimate of the class, while the corresponding class is more likely than the others, regardless of how probabilistic assessment corresponds to reality. The classifier is sufficient robust at the ignoring the independents all the [Jensen, 1991].

Data were collected from 102 Russian companies from two industries: Manufacturing and Production of electricity, gas and water. One economic cycle during the period of 1999-2008 was considered. There are 51 companies in each industry divided by the level of total return for shareholders (TRS):

$$TRS = \frac{Price_{end} - Price_{begin} + Div}{Price_{begin}} \quad (1)$$

They are divided into four classes:

1. With high returns (greater than 20%),
2. With average returns (from 10% to 20%),
3. With low returns (from 0% to 10%),
4. With negative returns (less than 0%).

The next parameters were used in classification: Equity, Revenue, Revenue's growth rate, EBIT, Net profit, ROIC, ROE, TIE, Capitalization, P/E, P/S [Aslinger, 2004; Chen, 1998; Varaiya, 1987].

The indicators were considered in all possible combinations. The sum of all possible combinations is 2047 at n=11

$$\sum_{k=1}^{11} \frac{n!}{k!(n-k)!} = 2^n - 1 \quad (2)$$

Firms from each industry were divided into training and test samples. Because the number of companies is not so great the cross-validation procedure with 5 folds was implemented. To analyze the results of the classification the following ratios were introduced: accuracy, sensitivity and specificity. The accuracy of the classifier was defined as the proportion of companies whose classes are predicted correctly:

$$Accuracy = \frac{Number\ of\ companies\ whose\ classes\ were\ predicted\ accurately}{Total\ number\ of\ predictions} \quad (3)$$

Sensitivity is the proportion of underestimated companies. For example, a company with high returns was attributed to a class of low returns:

$$Sensttivity = \frac{Number\ of\ companies\ whose\ classes\ were\ underestimated}{Total\ number\ of\ predictions} \quad (4)$$

Specificity is the proportion of overestimated companies. For example, a company with negative returns was attributed to the class of average returns:

$$Specificity = \frac{Number\ of\ companies\ whose\ classes\ were\ overestimated}{Total\ number\ of\ predictions} \quad (5)$$

Sensitivity and specificity are analogues to error of the first kind and error of the second kind respectively.

The average difference between the true and predicted classes was calculated for all predictions as well. Obviously, the best combinations would be those having the greatest accuracy. With the equal precision you should choose a combination of parameters with greater sensitivity, and lesser specificity. The sum of accuracy, sensitivity and specificity is equal 1. It is better to find high profitable company, to consider it unattractive and not to invest in it, than to invest in a company with negative returns.

Results

3.1 Manufacturing industry

There are 51 companies in the manufacturing sector. They were ordered by TRS. This is reflected in the Figure 1:

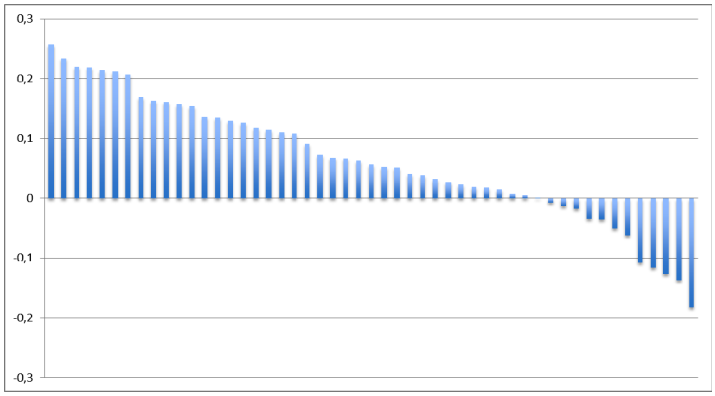

Fig. 1. Returns of companies in the industry of manufacturing

Below the five best combinations of accuracy indicators are given (Table 1).

Table 1. The results of the classification of companies in the industry of manufacturing

Parameters	Accuracy, proportion	Sensitivity, proportion	Specificity, proportion	Average distortion	F-measure
Revenue, EBIT, Net profit, ROE, Capitalization	0,471	0,275	0,255	0,020	0,546
Revenue, Net profit, ROE, Capitalization	0,471	0,255	0,275	-0,059	0,536
Equity, Capitalization	0,471	0,137	0,392	-0,451	0,410
Equity, Revenue, Revenue's growth rate, EBIT, Net profit, ROE, Capitalization	0,451	0,392	0,157	0,490	0,482
Equity, Revenue, EBIT, Net profit, ROE, Capitalization	0,451	0,275	0,275	0,039	0,523

The table shows that some combinations of parameters allow you to achieve accuracy in almost 50%. For example, a set of Revenue, EBIT, Net profit, ROE and Capitalization or Revenue, Net profit, ROE and Capitalization are equally accurate in 47.1%, proportions of the sensitivity and specificity are almost equal, and in the these sets do not distort the value of the class.

3.2 Industry of production of electricity, gas and water

Companies from the sectors of production and distribution of electricity, gas and water have also been ordered by TRS:

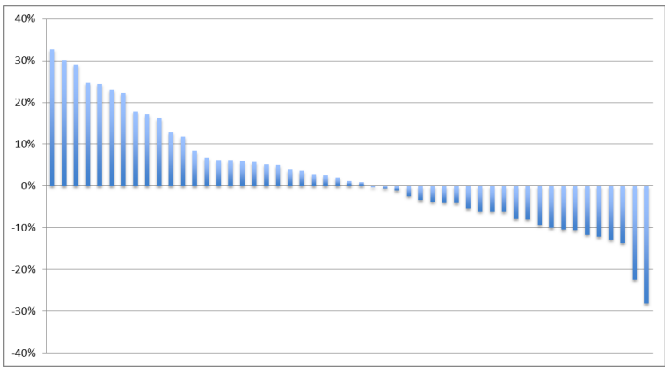

Fig. 2. Returns of companies in the industry of production of electricity, gas and water

Further classification was carried out similarly to the previous field. The table below shows the best five 5 sets of the accuracy.

The table shows that the maximum accuracy in the industry is slightly lower and is 43.1%. It is achieved in sets of Revenue, ROIC, P/S and Revenue, ROIC, TIE. There is low sensitivity (13.7% and 11.8% respectively) and high specificity (43.1% and 45.1% respectively) in these sets.

Table 2. The results of the classification of companies in the industry of production electricity, gas and water

Parameters	Accuracy, proportion	Sensitivity, proportion	Specificity, proportion	Average distortion	F-measure
Revenue, ROIC, P/S	0,431	0,137	0,431	-0,608	0,422
Revenue, ROIC, TIE	0,431	0,118	0,451	-0,529	0,378
EBIT, Net profit	0,412	0,235	0,353	-0,294	0,455
Equity, Revenue, Revenue's growth rate, ROIC, Capitalization, P/E, P/S	0,412	0,196	0,392	-0,294	0,324
EBIT, ROIC, P/S	0,412	0,157	0,431	-0,569	0,308

Conclusion

The purpose of this study is to propose a technique of finding companies with high returns for shareholders over the long term. This technique is based on splitting companies into classes of similarity of parameters. There is the permanent interest from investors and the virtual absence of research to this topic.

The technique involves the several stages:

a) The rationale for the initial parameters of the sample is provided;

b) The rationale for the choice of parameters is provided;

c) The companies are divided into groups by level of returns;

d) A comparison of predicted and a priori selected classes of companies is made. The sets of parameters are found, which ensure the greatest accuracy in predicting.

Empirical testing of the hypothesis showed that high returns companies could be identified not openly, but with the help of known values of parameters and returns for other companies.

This conclusion is valid for Russian companies in industries of manufacturing and production of electricity, gas and water in the period 1999-2008, including one economic cycle.

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Authors' Information

Dmitriy Bogachev *– Bachelor, The Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physics and Technology (State University), Institutslii per. 9, Dolgoprudny, Moscow Region, 141700, Russia, e-mail: myyy48@gmail.com*

Major Fields of Scientific Research: data mining, stock markets

DECISION MAKING SUPPORT AND EXPERT SYSTEMS

STUDY RELATIONSHIP BETWEEN UTILITY FUNCTION AND MEMBERSHIP FUNCTION IN THE PROBLEM OF OBJECT RANKING[1]

Stanislav V. Mikoni, Marina I. Garina

***Abstract**: We consider the condition of the same ordering of objects due to using the convolution of utility functions and membership functions. It turns out that the same order takes place when the each utility function of an attribute is constructed as a convolution of fuzzy membership functions of this attribute. To transform membership functions to utility function of an attribute the formula was deduced. The example illustrates that transforming. The paper provides examples of application of the transformation of membership functions in the utility function, and vice versa.*

***Keywords**: utility function, membership function, additive and multiplicative convolution.*

***ACM Classification Keywords**: G. Mathematics of Computing, I.2.1 Applications and Expert Systems.*

Introduction

In monograph [Mikoni, 2004] the author posed the problem of objects ranking based on the results of their classification. Naturally, such task can be solved only if the classes are ranked by quality. This means that each class h_k, $k = \overline{1,m}$ having an intermediate level of quality has only two adjacent class - with the best (h_{k+1}) and worst (h_{k-1}) level of quality. Thus, the best of the two objects x_s and x_t with the same value of membership function of the neighboring classes h_k and h_{k+1}, $\mu_k(x_t)=\mu_{k+1}(x_t)$, will be that one which belongs to the class with best quality level: $x_t \succ x_s$. The quality level of classes is expressed through the coefficients of importance: $p_{k+1} > p_k > p_{k-1}$, $\sum_{k=1}^{m} p_k = 1$. Considering the importance of classes the preference $x_t \succ x_s$ will take place if $\mu_{k+1}(x_t)\cdot p_{k+1} > \mu_k(x_s)\cdot p_k$.

It follows that the ratio of estimates of the objects obtained with the membership functions depends on the ratio of the importance of classes. This dependence is taken into account in this paper when searching for the general conditions of matching the results of objects ranking based on the classification results and obtained by the methods of multicriteria utility theory.

[1] The work had been fulfilled under Russian Fundamental Research Fund financial support (project № 10-01-00439)

The objects ranking with the utility functions

The following describes the objects ranking with the methods of multicriteria utility theory. First, for a given *j*-th criterion, $j=\overline{1,n}$, an utility function $u(y_j)$ is constructed. Its form can be both linear and nonlinear. The linear form is obtained by normalizing values of the criterion with the range of its scale. The usefulness of the *j*-th criterion, requiring the maximization, is calculated using the following formula:

$$u_{\max}(y_j)=\frac{y_j-y_{j,\min}}{y_{j,\max}-y_{j,\min}}, \qquad j=\overline{1,n}.$$

More complex, piecewise linear and nonlinear utility functions are constructed with expert data.

To convert a vector object evaluation $\mathbf{y}(x_i)=(y_{i1},\ldots,y_{ij},\ldots,y_{in})$ to a scalar evaluation additive or multiplicative convolution is commonly used:

$$u_a^*(x_i)=f(\mathbf{y})=\sum_{j=1}^{n} w_j u_j(x_i), \tag{1.1}$$

$$u_m^*(x_i)=\prod_{j=1}^{n} u_j(x_i)^{w_j}. \tag{1.2}$$

Based on their scalar estimates $y_a(x_i)$ or $y_m(x_i)$ the objects $x_i \in X$ are assigned ranks in ordinal scale.

The objects ranking with the membership functions

The following describes the objects ranking with the membership functions. First, the membership functions for each criterion are constructed using the experts. For this purpose the scale of the *j*-th criterion is divided into *m* ranges according to the number of classes. In the general case there is a nonempty intersection of the ranges allocated to neighboring classes, which is similar to fuzzy boundaries between them:

$[c_{k\,j,\min}, c_{kj,\max}] \cap [c_{k+1,j,\min}, c_{k+1,j,\max}] \neq \varnothing.$

Then for each object is computed its membership to each of classes on all criteria taking into accounts their importance w_j:

$$\mu_k(x_i)=\sum_{j=1}^{n} w_j \mu_{jk}(x_i), \quad k=\overline{1,m}, \tag{2.1}$$

$$h^*(x_i)=\arg\max_k \mu_k(x_i),$$

In the last expression h^* is the class which the object x_i belongs to stronger than the other ones. Then with the help of experts the importance of classes are assessed p_k, = $\overline{1,m}$, after which the estimate $y^*(x_i)$ of the object x_i is computed from its values of membership functions according to importance of classes:

$$y^*(x_i)=\sum_{k=1}^{m} p_k \mu_k(x_i). \tag{2.2}$$

Objects ranking is simply a sorting with values $y^*(x_i)$.

The condition of matching the results of objects ranking by utility functions and membership functions

The obvious way to achieve identical results of the ordering is to establish correspondence between the utility function and membership functions of each criterion [Mikoni, Garina, 2010]. Using the formula (1.1) (2.1) and (2.2) let us find out the conditions under which such a correspondence can be established:

$$
\begin{aligned}
& u_a^*(x_i) = y^*(x_i) \\
& \sum_{j=1}^{n} w_j \cdot u_j(x_i) = \sum_{k=1}^{m} p_k \cdot \mu_k(x_i) \\
& \sum_{j=1}^{n} w_j \cdot u_j(x_i) = \sum_{k=1}^{m} p_k \cdot \sum_{j=1}^{n} w_j \mu_{jk}(x_i) = \sum_{j=1}^{n} w_j \sum_{k=1}^{m} p_k \mu_{jk}(x_i) \\
& u_j(x_i) = \sum_{k=1}^{s} p_k \mu_{jk}(x_i).
\end{aligned}
\tag{3.1}
$$

Since the domain of the utility function $u(y_j)$ includes the domains of the membership functions of all classes, it is possible to calculate the utility function $u(y_j)$ on the basis of class membership functions on the with (3.1). In this estimates of objects will be identical and, therefore, objects ranking results will be identical too. Fig. 1 shows an example of constructing a utility function $u(y_j)$ of j-th criterion based on three classes of quality with trapezoidal membership functions.

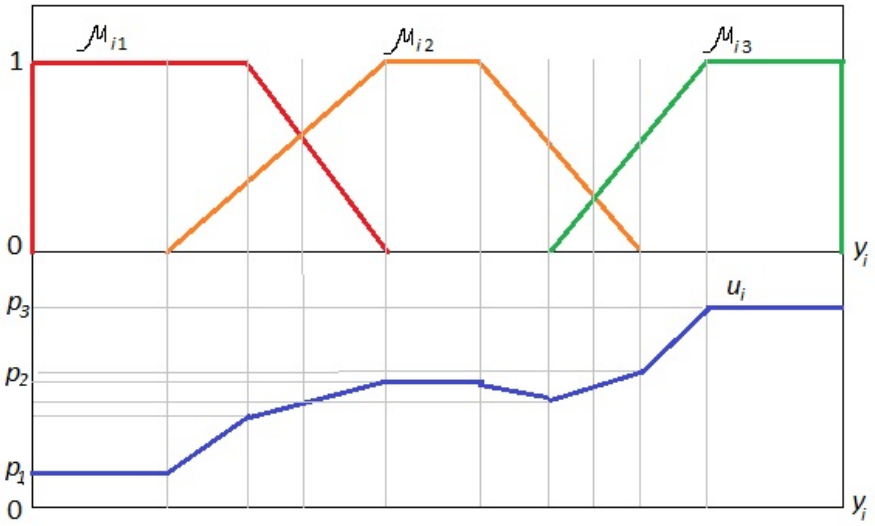

Fig. 1. Utility function constructed with (3.1)

On the border between the 2nd and 3rd classes utility function is non-monotonic, as in this area $\mu_{j2}(x_i)+\mu_{j3}(x_i)<1$, i.e. the requirement of mutual complementarities does not satisfied. Using the multiplicative convolution to compute the global membership is generally impractical, because in the areas of belonging to a class full zero affiliation other classes shall be reset generalized affiliation to them. The condition of application of a multiplicative convolution in classification is a common domain for all classes. In this case the ranking results will match when the utility function $u(y_j)$ is calculated by the formula $u_j = \prod_{k=1}^{s} \mu_{ik}^{\,p_k}$ (proof omitted). Utility functions will then be a piecewise polynomial.

Applications

According to (3.1) the reverse transition from the utility function to membership functions is ambiguity. A unique solution to this problem is possible only for a single membership function under certain other membership functions. Thus, suppose the membership function of *l*-th class is unknown, $l \neq k$, $k = \overline{1, m}$. Then with the known membership functions and utility function of *j*-th criterion the membership function of *l*-th class is calculated using the following formula:

$$\mu_{j,l}(x_i) = \frac{u_j(x_i) - \sum_{k=1, l \neq k}^{m} p_k \cdot \mu_{j,k}(x_i)}{p_l}.$$

This formula is applied when the additive convolution is using. For multiplicative convolution see the following:

$$\mu_{j,l}(x_i) = \sqrt[p_l]{\frac{u_j(x_i)}{\prod_{k=1, l \neq k}^{m} p_k \cdot \mu_{j,k}(x_i)}}$$

Another application is to restore the importance or weight vector of the classes. Let us represent the utility function, membership functions and the importance of classes in the vector form:

$$\mathbf{U} = \begin{pmatrix} u_1(x_i) \\ \dots \\ u_j(x_i) \\ \dots \\ u_n(x_i) \end{pmatrix}; \quad \mathrm{M} = \begin{pmatrix} \mu_{11}(x_i) & \mu_{1j}(x_i) & \mu_{1n}(x_i) \\ \mu_{k1}(x_i) & \mu_{kj}(x_i) & \mu_{kn}(x_i) \\ \mu_{m1}(x_i) & \mu_{mj}(x_i) & \mu_{mn}(x_i) \end{pmatrix}; \quad \mathrm{P} = \begin{pmatrix} p_1 \\ \dots \\ p_k \\ \dots \\ p_m \end{pmatrix}$$

Let us represent the formula $u_j = \prod_{k=1}^{s} \mu_{ik}^{p_k}$ in matrix form: $\mathbf{U} = \mathbf{P}^T \cdot \mathbf{M}$. The solution of system of linear algebraic equations for the non-singular matrix **M** at a fixed point x_i is a vector of weights **P**. Since there are *n* solutions of this system by the number of objects x_i, it is advisable to determine the weight vector for the best (or reference) object x^*.

Conclusion

The condition of matching objects ranking by multi-criteria optimization and classification is to compute the utility functions on the base of given membership functions of classes. The number of classes should be the same for all criterions. The multi-criteria utility functions and functions that calculate the utility based on the membership functions should have the same structure.

The value of weights of classes when ranking on the results of the classification is proportional to the quality of the classes. For complementarily classes the utility function is a monotonic.

The use of a multiplicative convolution in the general case is difficult because there are the different domains of the membership functions of the classes. Zero membership of at least one class leads a zero value of utility function. However, if the using of multiplicative convolution is justified, then to match the results utility functions should also be calculated by a given membership function.

The reverse transition from utility function defined on the entire scale of the criterion to the functions of membership defined on its parts could not be unambiguously. The procedure is unambiguous only for one class recovery when other classes and utility function are certain. Another task deriving from the considered condition is finding the vector of importance of classes by the certain utility function and membership functions.

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Authors' Information

Stanislav Mikoni *– Professor of St. Petersburg State Transport University, St. Petersburg 190031, Russia; e-mail: svm@sm4265.spb.edu*

Major Fields of Scientific Research: System analyses, Multicriteria choice, Intelligent Technologies, Simulation.

Marina Garina *– Associate Professor of Mathematics and Modeling of St. Petersburg State Transport University, St. Petersburg 190031, Russia; e-mail: migarina@gmail.com*

Major Fields of Scientific Research: System analyses, Multicriteria choice, Intelligent technologies, Software technologies, Simulation.

THE MODEL OF DECISION SUPPORT SYSTEM FOR A MANUFACTURING COMPANY

Monika Piróg-Mazur

Abstract: *Decision making processes in manufacturing companies are becoming extremely complex and require more and more knowledge, both of technological quality of products, concerning a production process, as well as the industrial engineering and control. The increase in the scale of production and the level of technological development have caused that industrial companies have become systems that require the application of modern effective methods of the decision making. This paper presents a study of the issues related to decision-making and knowledge acquisition in enterprises. The model of intelligent decision support system for the production company has been developed. The paper presents the main idea of system and data models in the form of ER diagram, that will finally be implemented in RDBMS environment. In addition, an attempt to assess such systems.*

Keywords: *decision support systems, knowledge base, knowledge representation, knowledge acquisition.*

ACM Classification Keywords: *I. Computing Methodologies, I.2.1 Applications and Expert Systems, J. Computer Applications,*

Introduction

Manufacturing companies operating in the market today collect more data on manufacturing processes, supply, customers and their preferences, the defects of products and control processes as well as customers' feedback. They accumulate large amounts of data, where you can find the information you need to make right decisions, at the design stage of products, in the manufacturing process and product control, as well as in the final stage - selling [Piróg-Mazur, 2010].

Currently the decision support systems, that continually collect data and analyze different areas of production processes, are beginning to play an important role. Managers and experts have begun to use these systems to obtain and evaluate collected information and to make use of gathered data in planning and decision making processes.

In order to effectively support decision-making processes, contemporary information systems are increasingly using artificial intelligence (AI) technologies [Dhar V., Stein R., 1997]. Owing to them, we are able to solve complex problems that require reasoning under conditions changing in a dynamic way, burdened with a high degree of uncertainty and sometimes with incomplete data [Sroka, Wolny, 2009].

Intelligent Decision Support System is the system that uses AI methods and techniques. An intelligent decision support system should behave like a human consultant; supporting decision makers by gathering and analyzing evidence, identifying and diagnosing problems, proposing possible courses of action and evaluating the proposed actions. The aim of the artificial intelligence techniques embedded in an intelligent decision support system is to enable these tasks to be performed by a computer, whilst emulating human capabilities as closely as possible [Turban E., J.E.Aronson, 2004].

The main goal of the research presented in this paper is to design of the intelligent decision support system for production company. The main purpose of development of an intelligent decision support system is to reflect experts' knowledge and experience, which are indispensable for solving problems by the system. Integration of

intelligent methods allows to create better and more precise methods which can be applied in this field. In intelligent decision support system the process of knowledge acquisition plays the most important role.

The process of knowledge acquisition

The concept of knowledge is not clearly defined in literature. Knowledge do not only encompass very extensive and dispersed resources of different types of information, but also, and above all, it is a complex structure of links between pieces of information and it involves information that is difficult to formalize. Experience, qualifications, human intuition, and models of different processes (including discreet, dynamic and stochastic processes) are all knowledge. Holsapple C.W. and Whinston A.B. [Holsapple C.W., Whinston A.B.,1996] define six types of knowledge that knowledge management applications can contain. These include descriptive, procedural, reasoning, linguistic, presentation, and assimilative knowledge.

Knowledge is immaterial wealth of the organization in terms of human action, if implemented, could be the basis of competitive advantage of organizations. It is connected with possessed resources such as data, information, procedures, and with experience and education. Knowledge strongly associates with factors such as culture, ethics, intuition, working conditions, management style. The last factor has a decisive influence on the efficiency of knowledge management system, and thus the competitiveness of the organization [Kisielnicki, 2004]. The knowledge refers to the various aspects of reality, it is diverse. Its classification encounters many difficulties. Marking types of knowledge is made up from many points of view. The division is into formalized knowledge contained in information bases and personalized knowledge which is in the workers' minds. [Sroka, Wolny, 2009].

Since knowledge can be structured in the decision support system, it can also be used to unify and extend the usage possibility of specialist knowledge base. The knowledge and expertise can be passed on others through teaching, and also conveyed by a single person throughout the organization. The consequence of this phenomenon is the treatment of knowledge in the organization as an important resource that can be administered outside of the human mind. Thus, it avoids making the effort to collect and maintain knowledge and gain a greater uniformity in decision making.

Knowledge acquisition is the process that allows understanding and obtaining the answer, by an expert, on how to solve problems in a specific domain, combined with the recording of acquired knowledge in the formal representation or model of decision-making [Knosala, 2002].

The growing role of knowledge-based systems will be based on the spread of knowledge in the organization. From a technical point of view the needs of employee, who uses the knowledge base, can be characterized as follows [Sroka, Wolny, 2009]:

- there must be an access to various information resources,
- there must be a variety of tools available for processing and presenting information or knowledge,
- the exchange and distribution of information among co-workers must be provided.

Data acquisition and knowledge for decision support systems shall be carried out both by traditional and formal methods [Pondel, 2003]. Data concerning materials and the means of production is obtained from the standards, **catalogs, literature, records and databases that already exist in the enterprise.**

The traditional method of knowledge acquisition is to observe the technologist and interview with him. In this method, the key role plays a knowledge engineer, who observes an expert. The expert works on solving the problem. Then, the engineer analyzes the knowledge on the basis of instructions and real examples solved or given by the expert, and he/she gathers knowledge by analogy. Further, the knowledge engineer selects and organizes the knowledge handed by experts so it could be stored and used effectively on a computer [Zieliński, 2000].

Technological knowledge is a collection of information on the technological process carried out in specific realities of the company. Technological knowledge is a dynamic set, which means that it changes over time as the parameters undergo changes. It is assumed that technological knowledge can be processed in an appropriate manner in every stage of building an advisory system. There are the following stages of this process:

- acquisition of technological knowledge,
- models' development representing technological knowledge,
- storage of knowledge in the technological knowledge base system.

Participation of an expert in the construction of the advisory system is vital because it is necessary to benefit from his experience both in terms of tasks solved in the past and ways to solve certain tasks and how to select appropriate methods of solving problems.

For the evaluation of knowledge sources an engineer takes:

- information necessary to carry out the work (materials derived from literature sources, both compact and continuous),
- information about all processes conducted at the manufacturing system (material collected in the glassworks, consultation with the Head of the Department OI Manufacturing Poland, consultations with specialists in various phases of the process – expert's knowledge),
- methods to assess the quality of finished products (high standard or acceptable standard),
- permissible options for development (purchase of new machinery, upgrading of existing ones, new technologies, new materials, etc.),
- criteria for evaluating options for developing the system.

An important component in the processes of data processing is the operation of extracting data or knowledge discovery, which can be defined as computer-aided search process and analysis of vast amounts of data. Extracting data is used to describe the historical trends, as well as determining future trends. Implementing this process requires knowledge and understanding of applications and the knowledge about the quality of sources where data is gained from. The first step to solve the problem of decision-making is to define access to the necessary data. When solving complex decision problems data from different sources should be used. Figure 1 shows the process of gathering data to provide a basis for decision making.

Data warehouse is a dedicated, read-only database that supports decision-making process. The concept of "separate database" means that a data warehouse cannot work on operational data. You need to prepare a separate database designed for this purpose. The concept of "read only" means that the stored data is historical.

Model of decision support system

The process of model development has been based on technological documentation of an industrial enterprise, with which a cooperation agreement was signed (Glass Works, Owens-Illinois Manufacturing Poland). The results of work can be practically tested and applied in the same industrial plant, limiting the scope of research to support the process of quality control of finished products. The advisory system is designed to classify defects in products and select appropriate method (most preferred way) to eliminate them. This system responsibility is to assist the line manager and the people working on the production line. Its functioning will be based on a dialogue between the system itself and the user in a natural language. It will collect information not only from the user, but also from external sources such as databases, spreadsheets, statistics, etc.

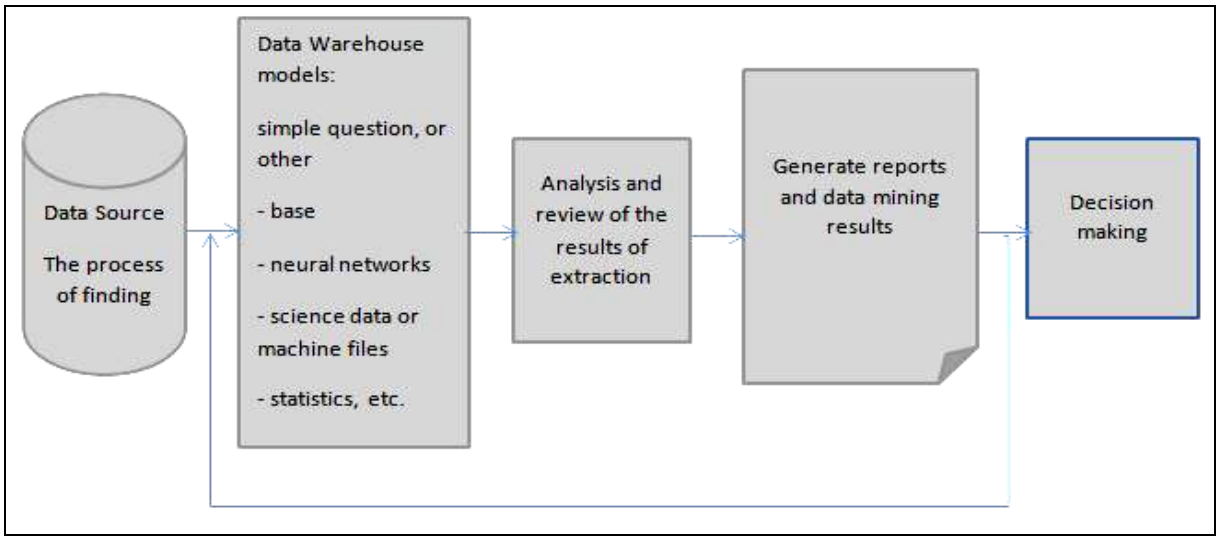

Fig. 1. The process of data acquisition. Source: [Fayyad, 1995]

As a result of dialogue, based on data entered from the keyboard by the user, and the data taken from the measurement points the advisory system will execute a process consisting of:

- defect diagnosis and qualification into relevant group,
- identification of the cause of defect formation (whether it is a mechanical defect, form defect, etc.),
- identification of ways or methods to eliminate the resulting defect,
- selection (from the previously established ways or methods) an optimal solution.

Currently, the management staff in decision making processes, concerning the elimination of defects, does not use any IT systems. Actions that can be described as the most important, most expensive and generating the longest effects are not supported by computer. These decisions are usually made intuitively or with the use of "trial and error" method based on previous practice.

Verification in practice is the only way to confirm the correctness of assumptions of the model. As the evaluation criteria elements user friendliness, data security, their integration and system vulnerability to modification were adopted.

The data structure in the system

Data models can be developed at different levels of detail using the technique of modeling relationships among entities (ERM - Entity Relationship Model), which graphical equivalent is the entity relationships diagram (ERD). The project is usually expressed in graphical form and supplemented by a verbal description in which the information contained in the graphic design is characterized in detail. In the diagram, entities are usually denoted as rectangles, and the relationships between them are marked with lines connecting rectangles and the symbols placed next to these lines, describing the type of relationship.

The figure 2 shows an excerpt of ERD that has been made for the manufacturing enterprise needs.

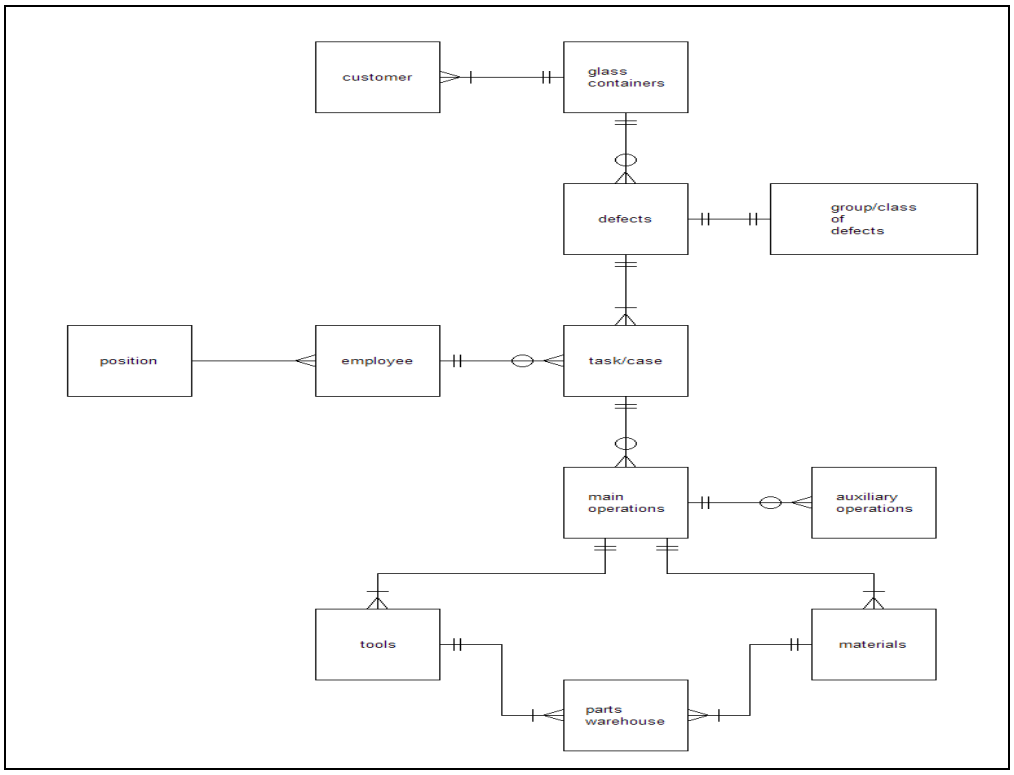

Fig. 2. Entity Relationship Diagram. Source: own work

One of the first stages of database design is to develop a conceptual data model, which is crucial to usefulness and quality of the proposed database. It is created independently of solutions specific to any logical model and database management systems. Conceptual model will enable to conceive the technological process described above in a formalized way. The main goal of the conceptual modeling of database is to create a design that reflects the fragment of reality, that is being analyzed, free from details, which could place it among models of a particular class (object, relational or other) and platform-independent programming. The end result of the conceptual design process is to identify a set of facts in the analyzed company (objects), properties of these elements (attributes) and inter-dependencies between these elements (relationships).

This process involves both the designer and the future user of the system. The head of the production line and the production line operator, in the future, will be the users of that system in a manufacturing company [Piróg-Mazur, 2012].

In the relational database model, shown in figure 3, for the proposed decision support system the following tables have been included:

- glass containers / product packages - contains information about the manufactured product (product data sheet, specification of the final product),
- materials - contains information about the materials used (semi-finished product) for repair,
- tools - contains information about the tools used and their storage for repairs
- task / issue - a list of tasks / things to do in order to eliminate the resulting defects,
- the main operations - provides a list of consecutively performed operations (process steps) to repair,
- auxiliary operations - provides a list of additional activities to do destined for specific products (additional operations),

- defects - contains detailed information regarding all possible defects, where they occur, the causes of creation, whether there is a risk of consumer injury etc.
- defects group / class - provides a classification of defects,
- employees - a list of people involved in the technological process,
- position - includes the allocation of particular competence, duties to perform.

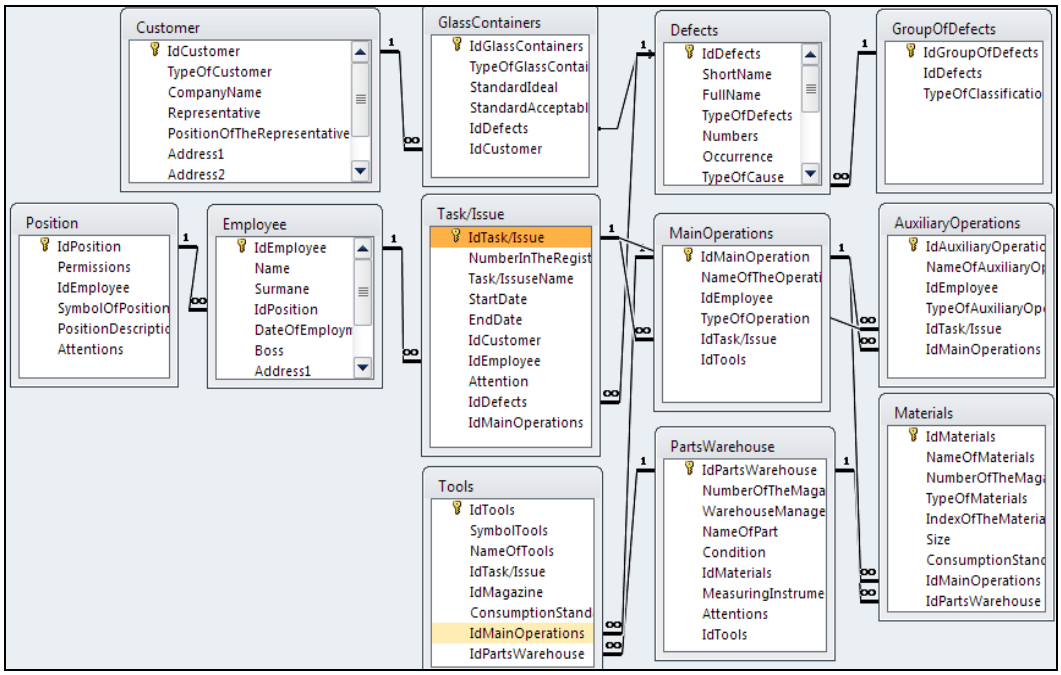

Fig. 3. Relational database model. Source: own work

Methods of evaluating decision support systems

Evaluation of IT systems, in particular decision support systems, is one of the most difficult aspects of their design methodology and implementation. These issues concern both the implementation and the evaluation itself. The system can be assessed according to [Sroka, Wolny, 2009]:

- the results of decisions,
- changes in decision-making processes,
- changes in revealing decision situation by the decision maker,
- alteration in procedures,
- analysis of costs and effects,
- measure of service,
- decision-makers estimation of the system value.

Not all of the above methods are suitable for the particular situation. In situations, where designer's intent was to obtain measurable effects, use the analysis of costs and effects, estimation of the decision results or service measurement. To avoid the situation in the form of negative results of DSS usage, to the evaluation of a situation, more than one way of evaluating should be used. The agreement on the choice of assessment approaches between designers and users must be obtained already in the preliminary design phase. One of the better ways to assess whether the system actually makes decisions, is the current result of the decision. This measure is not always possible to explain. In a situation where the production or rate of return on investments are higher, the

improvement may be caused by other factors. Another way is to assess the changes that the system brings to the way of making decisions. If you cannot prove that the introduction of a new system will improve the decision, you need to refer to the assessment accepted by the user, based on comparison of subjective feelings of the user, concerning the advantages of new decision-making process, from the previous one. As acceptable solution, one that meets expectations and satisfaction of specific teams is considered.

Regardless of the difficulties in many examined DSS can be clearly seen [Sroka, Wolny, 2009]:

- facilitation of problem identification,
- faster acquisition of information through graphic images,
- acceleration of recognition and realization to which part of bank's methods qualify the problem,
- improvement in the assessment of the actual cost,
- use of routine sources of information that are only available to the analysts,
- stimulation of new approaches to strategy development,
- pressure on thinking about the results,
- conviction of decision maker about the fact that investing in the improvement of intellectual work is an effective undertaking.

We can distinguish four possibilities for improving the efficiency of decision making [Sroka, Wolny, 2009]:

- reducing time of decision making,
- decreasing the number of people involved in making decisions,
- better preparation of printed documentation in the decision-making process,
- reducing delays in decision making.

Conclusion

The application of decision support systems can provide multiple educational outcomes. These systems offer the opportunity to pass knowledge and experience of older workers on younger staff. In this situation, experienced workers may be directed to more important tasks. The very process of creating a system may have educational value due to the deepening and structuring knowledge. What is more, less experienced workers can supplement their knowledge by the use of such systems as a practical help in carrying out their tasks. It is also important to reduce spending on education by improving employees productivity by enabling them to efficiently handle tasks without the need for long training and gaining experience [Sroka, Wolny, 2009].

Key areas for expert systems applications in decision support issues depend on the knowledge provided by an expert. They make conclusions on the basis of knowledge provided by system creators, which is stored in data base, and use learning methods or automatically by the absorption of the examples provided, or by providing additional information. Most often, they support decision making in the field of:

- developing optimal financial plans,
- planning of production Portfolio,
- analysis of market data,
- selection of an appropriate set of suppliers,
- workforce planning with variable working time,
- evaluation of investment projects,
- development of product design, etc.

The system guides the user through the problem, asking a structured set of questions and draws conclusions based on received responses. Problem-solving skills are based on a set of programmed rules, modeled on the reasoning processes of specific field experts. Advisory systems can serve its knowledge if there are no specialists and often reach the knowledge faster than the experts do.

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Authors' Information

Monika Piróg-Mazur *– Editor in chief, Institute of Technical Engineering, The Bronislaw Markiewicz State School of Technology and Economics in Jaroslaw, Czarniecki Street 16, 37-500 Jaroslaw, Poland; e-mail: m_pirog@pwste.edu.pl*

Major Fields of Scientific Research: knowledge representation, decision support system, project management.

A MULTI-LEVEL FUZZY LOGIC SCHEME FOR MODELING COMPLEX PROBLEMS

July Diana Banda-Tapia, Regina Ticona Herrera, Dennis Barrios-Aranibar

Joe Tekli, Richard Chbeir

***Abstract**: In this paper, we propose to extend traditional Fuzzy Logic(FL) techniques by creating a second set of inference rules (and the corresponding inference mechanism) in order to effectively produce results exploitable by decision makers. We present a formal definition of a multi-level FL scheme and its application in the development of: i) a break-even inference machine and ii) a legal argumentation system. The proposed scheme is shown to be useful in modeling systems where intermediary fuzzy concepts come to play, and it could be applied in several problems analog to the ones presented in this study.*

***Keywords**: Multilevel Fuzzy Logic, Knowledge Based Systems, Legal Argumentation System.*

Introduction

FL began in 1965 with the work of Lofti Zadeh; Zadeh aimed to propose a mathematic formalism for leading with imprecise concepts, like high risk, low speed, high cost, etc. Nowadays, FL is being applied in several areas as medicine, engineering, management, law, gesture recognition, etc. Knowledge based systems built on FL could be applied to non-lineal or non-defined problems, because it remains one of those few techniques able to model expert knowledge even if it is ambiguous. [Reiter, 1980], [Garmendi, 2010].

However, FL systems follow a well known paradigm of implementation, where developers have a unique set of fuzzy variables and a corresponding set of inference rules, which are not always applicable to real problems, [Casali, 2002], [Bourcier, 2003], [Trillas, 1992]. For instance, solutions to model the break-even in subsidy health systems, or to model the statement on legal argumentation, have proven to be extremely difficult to realize with traditional FL techniques, due to the presence of intermediary and multi- level fuzzy concepts. In these type of systems, the first level refers to uncertainty and concepts part of the nature of the problem. For example, in the break-even system, concepts that model the relation between the cost given by the government, as well as the market price, both need to be fuzzified. [P. Cohen, 1983], [bar, 2001], [Perez, 2005]

On the other hand, in the argumentation system, concepts like aggravating and mitigating facts also require fuzzification. Nevertheless, after acquiring all the costs (e.g., in the break-even system) and the facts (e.g., in the argumentation system), these have to be counted and processed to infer whether we are in a break-even situation or not (break-even system), and whether the person is guilty or innocent (argumentation system).

Also, the decision is not based on crisp sets, but rather on others fuzzy concepts, [Trillas, 1992] for example: with the break-even system, several costs might be equivalent in both government and market price, or few government costs might be more expensive than market price; similarly with the argumentation system, many aggravating facts could emerge and minimum mitigating facts could possibly occur. Such systems remain extremely difficult to model using traditional (single-level) FL schemes.

The present paper have been organized as follows, section 2 present an overview of knowledge-based systems and fuzzy logic, section 3 shows the law and legal reasoning, section 4 present the approach and finally sections 5 shows the conclusions and future works.

Knowledge-based Systems and Fuzzy Logic

Fuzzy Logic was developed by first time in 1965 to process and handle information specially to represent mathematically uncertainty no probabilistic, which is present for example in non-linear problems [Funkhouser et al., 2005], [Giarratano, 2001]. One of its main advantages over the classic logic is that it allows to reproduce the reasoning, considering the certainty of a preposition such as a level given; so, if logic is the science of the formal and normative principles of the reasoning, fuzzy logic concerns to the formal and normative principles of the approximate reasoning and considering the classic logic such as his limit [Brio, 2006], [Doyle, 1979]. Figure 1 shows the fuzzy and classic logic.

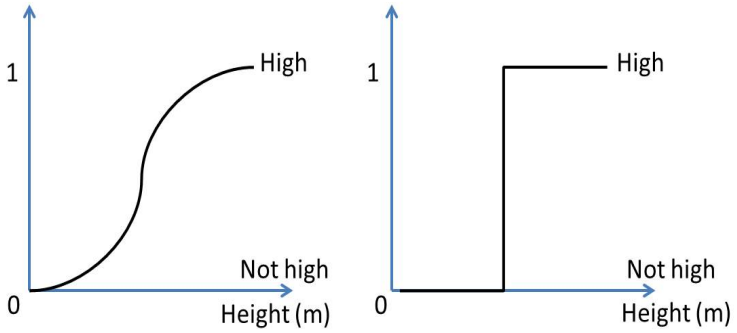

Fig. 1. Fuzzy and Classical Logic

Fuzzy logic use rules that shows the relation between antecedent and consequent; usually it uses IF-THEN rules, however, these rules can be also inferred; this work use the Modus Ponens as inference rule as it is shows as follow:

Knowledge : If *x* is A, then *y* is B

Fact : *x* is A

Conclusion : *y* is B

After the fuzzyfication process is done, it is necessary a defuzzyfication to convert the outputs of the fuzzyfication in an linguistic approximation or an arithmetic value that represent the fuzzy set.

Law and Legal Reasoning

The law is a cognitive technology, i.e. a set of practices described as a product of intellectual activities and the acquisition of knowledge capable of being processed by computer. These technologies aim to do more intelligible rationalization of legal knowledge.

3.1. Expositive part

In this part, it is found the description of the main fact, furthermore is identified to the guilty, the juridical and factual imputation, penal consequence, the facts pleaded by the defense.

3.2. Preamble

This is the valuative part of the judgment, i.e. the charge and discharge facts, the law and the criminal law to apply.

3.3. Resolute part

The last part of the judgment explains the declaration of the criminal liability. The penalty is calculated in this part.

Proposal

The present paper proposes the application of the multilevel fuzzy logic in a legal argumentation system based on an extension of the FL techniques by creating a two level fuzzyfication process. The figures 2 and 3 shows the general schema of the process and the inference machine, respectively.

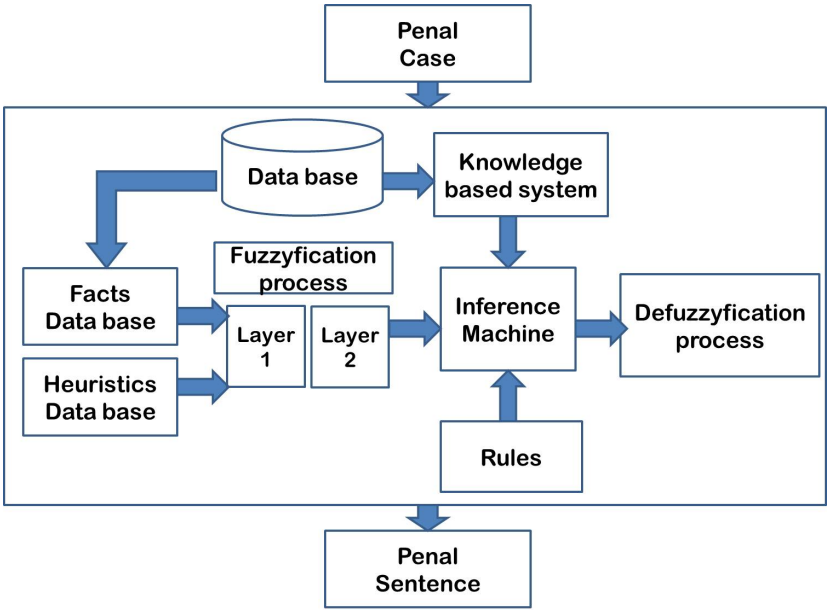

Fig. 2. Approach Schema

As can be seen in the Figure 2, the input of the system is given by the case to judge, it means, the description of the principal fact and which will be storage such information and inferences. After the facts and information are storage, the system determine if the case is or not of penal type; this will be done based on the search of key words (i.e. die) in the feature vector of the case to judge.

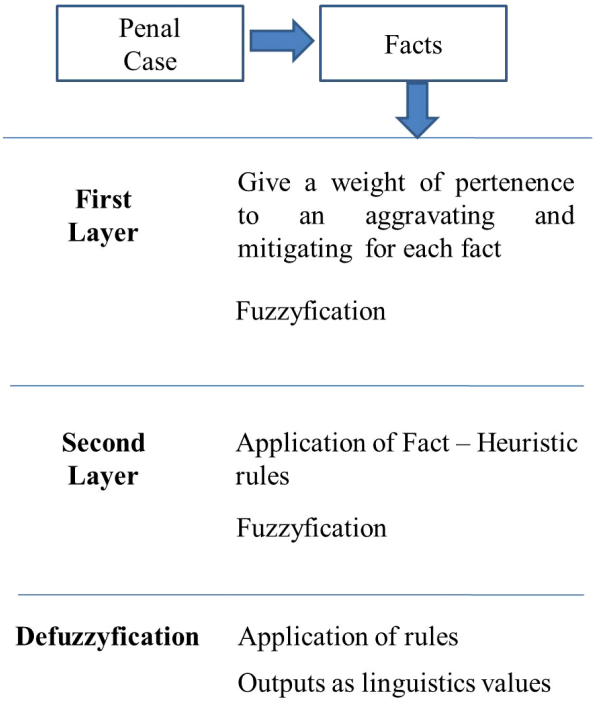

Fig. 3. Inference Machine

4.1. First Layer

In this layer the judge gives a weight, from 1 to 10, for each fact; this in order to establish the degree of membership in the aggravating and mitigating1 fuzzy sets as it is shown in the figure 4. In order to compute the membership function of the sets; it is used the triangular function being 5 the break point, which means that a fact with 5 as value of degree of membership is considered as normal and does not affect the assessment of the case to judge because this is the cross point between both sets.

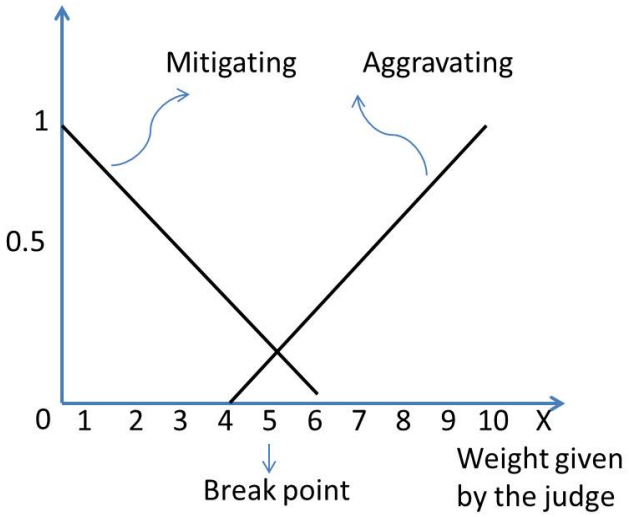

Fig. 4. Aggravating and mitigating fuzzy sets

After the assessment is given to each fact, the level of guilt is calculated using the following rules:

if $\mu_{MITIGATING}(Fact_I) > \mu_{AGGRAVATING}(Fact_I)$,

then $FR1 = \sum_{i=1} Fact_I * (\mu_{MITIGATING}(Fact_I)) + FR1$

else $FR2 = \sum_{i=1} Fact_I * (\mu_{AGGRAVATING}(Fact_I)) + FR2$

Where F R1 is the sum of mitigating facts, F R2 is the sum of aggravating facts and n is the number of facts. These output values (F R1 and F R2) in this layer, will be the inputs in the next layer.

After all the facts are assessment, it is necessary to determine which ones are relevant evidence, in consequence, an α cut that allow to make the filter process was applied. In this case, the value used was 0,6 (α0,6) in view of it had a high rate of incidence in the selected data. In this way, it is possible to determine if the mitigating or aggravating facts are higher.

4.2. Second Layer

A difference of the layer before, this layer make an assessment of the heuristics related to the facts; as in the case before, a weight from 1 to 10 will be given for each one, as shows the figure 5, and a fuzzyfication process will be make.

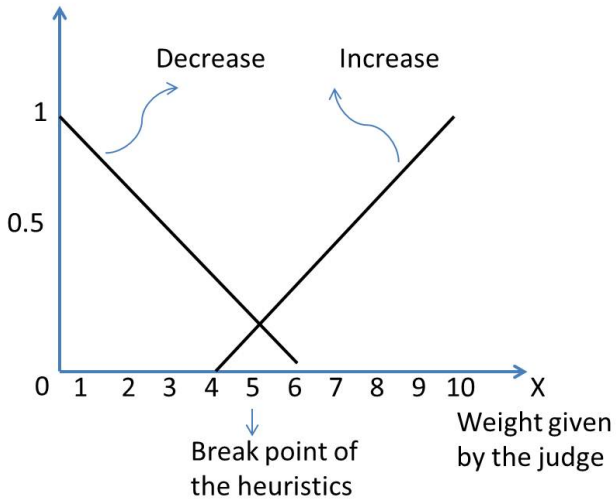

Fig. 5. Fuzzy sets respect to heuristics

This will allow to establish the sentence of the defendant applying the rules Fact - Heuristic (FH), where the heuristic chosen will be applied to the fact and will fulfill the height of the fuzzy set, in other words, the higher value will be chosen to calculate the sentence according to the higher fuzzy set, it is shown as follow:

if $\sum FH_i * (\mu_{DECREASE}(FH_I)) > \sum FH_i * (\mu_{INCREASE}(FH_I))$

then $\max(\mu_{DECREASE}(FH))$

else $\max(\mu_{INCREASE}(FH))$

As can be observed the sentence given is based in the relevant facts related with the computation of the resolutive part, where a sentence is given according to all the facts related with the heuristics and applying the following rules.

if *max,* $\mu_{INCREASE}(FH)$

then JudgmentGiven = MinSentence + $\mu_{INCREASE} * \omega$

else JudgmentGiven = MinSentence + $\mu_{DECREASE} * \omega$

Where MinSentence and MaxSentence are the minimum and maximum sentence repectively and ω is given by:

$$\omega = MaxSentence - MinSentence$$

4.3. Defuzzification

The inference machine is strongly related with the defuzzification process, because in this layer the system shows the outputs as linguistics values which are obtained applying the inference machine. The rules used in this process are:

if (F R1 > F R2),

then Subsumption — Culpability = Inocent

else Subsumption — Culpability = Guilty

The subsumption of the crime is also done by the inference machine using the following rules:

if
- The main fact is of penal type AND
- typef act = Degreeof enf orcement AND
- F actdescription = T entative OR

- F actdescription = C onsumation AND
- F acttype = P articipation OR
- F actdescription = Autor OR
- F actdescription = P articipate

then Subsumption – Quality of Typical = Typical

else Subsumption – Quality of Typical = Atypical

if • Subsumption – Quality of Typical = Typical AND
- FH ─ Type = Justification AND
- Decrease level = 1

then Subsumption ─ Antijustified = Justified

else Subsumption ─ Unlawful = Antijustified

After these rules, the fact rules are also included, so:

if • Subsumption − Unlawful = Unlawful AND
- Subsumption – Quality of Typical = Typical AND
- Subsumption ─ Culpability = Guilty

then Subsumption ─ Crime = Positive

else Subsumption ─ Crime = Negative

At this point all the considerative part that must be write and the sentence is done.

Conclusions and Future Works

The process of make a decision in a judgment and find the best statement for the sentence is an important and complex task, in this sense, it is necessary the use of a system that can help in this process, making it essayer, having a database of historic data for consult previous cases and using fuzzy logic that helps to establish the sentence, based in the evaluation of the facts. In this sense, an inference machine with two fuzzyfication levels is necessary in order to reach better results, also, the uncertainty of the data does not allow the application of classic logic.

The proposed system is also flexible allowing the judge to give a valuation for each fact; likewise, the use of an α cut of 0.6 in the system is also important to distinguish between the relevant and irrelevant facts, avoiding that unnecessary facts appears in the sentence. Finally and as future works it is proposed the implementation of this system as well as a dynamic cut, that can be computed by the system automatically.

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Authors' Information

July Diana Banda Tapia *– Junior developer and researcher at the Research and Software Development Center of the Saint Agust\'in National University - Cathedra CONCyTEC in TIC's. Arequipa, Peru.*

E-mail: inf.jdtapia@gmail.com

Major Fields of Scientific Research: Bioinformatics, image processing and artificial intelligence.

Regina Ticona Herrera *– Researcher at San Pablo Catholic University and Ph.D. Student in Computer Science, Bourgogne University- France.*

E-mail: reggi.ticona@gmail.com

Major Fields of Scientific Research: Data Bases, XML processing and information retrieval.

Dennis Barrios Aranibar *– President of Computing Peruvian Society and Peruvian Representative to the Latin American Studies in computer Scienc.*
E-mail: dennisbarrios@gmail.com

Major Fields of Scientific Research: Robotic and automation applied to industry, multiagent systems, and machine learnin.

Joe Tekli *–Post-Doc at Shizuoka University, Post-Doc at Università degli Studi di Milano, Professor at Bourgogne University, France*

E-mail: jtekli@gmail.com

Major Fields of Scientific Research: XML processing, web services, data semantics, data clustering and classification, and multimedia fragmentation.

Richard Chbeir *–Vice-president, Institute of Information Theories and Applications FOI ITHEA, P.O. Box: 775, Sofia-1090, Bulgaria;*

E-mail: richard.chbeir@u-bourgogne.fr

Major Fields of Scientific Research: Multimedia information retrieval, XML and RSS Similarity, access control models, multimedia document annotation.

MULTICRITERIA SELECTION OF PERSPECTIVE OBJECTS FOR INVESTMENTS: DSS SVIR VS. MUCHNIK METHOD

Pavel Mogilyov, Mikhail Alexandrov, Stanislav Mikoni

Abstract: *The problem of selection of perspective objects for investments is considered. Objects are Russian companies of mobile communication. To solve this problem we use the decision-making support system (DSS) SVIR and manual procedures of the Muchnik method. We shortly describe these tools and show that both approaches lead to close results. The paper is prepared on the basis of B.Sc. thesis of the first author*

Keywords: *multicriteria selection, DSS SVIR, Muchnik method*

Introduction

Selection of perspective objects for investments is usually formulated as a multicriteria problem. Such a selection needs a lot of subjective information, which can not be easy formalized. So, experts prefer to solve the mentioned problem independently without support of any automated decision-making support systems (DSS). However, there are advanced and available DSS on software market, which could solve such problems more effectively and give the results being close to expert opinions. In the paper we consider a particular problem related with the selection of companies of mobile communication to be perspective for investments. This problem is resolved with the support of DSS SVIR and simultaneously by means of the Muchnik method. DSS SVIR was developed in Saint-Petersburg Transport University and it is used in various applications [Mikoni, 2009a, 2009b]. The Muchnik method was proposed by his author to one large Russian company of mobile communication [Alexandrov, 2011]. We demonstrate that both approaches lead to close results. So, the trained DSS SVIR could substitute the work of qualified experts in the mentioned problems.

Multicriteria problem setting

2.1. SPARK data base

Data for this research were taken from the Russian large data base (DB) SRARK, which contains information about financial activity of almost all registered legal entities. SPARK is created on the basis of annual reported data presented by state and private Russian companies. It contains hundreds of lines (objects) and 51 columns (parameters) for each object. Figure 1 demonstrates the part of SPARK. Here: the columns titled as ‘Активы’ (Actives) , ‘Амортизация’ (Amortization), et al mean the parameters reflecting economical activity of companies under consideration, RUR means Russian National Currency ‘Rubles’. To construct criteria one uses both primary parameters taken directly from the SPARK and so-called derivative parameters, which are the certain combinations of the primary parameters.

	A	B	C	D	E	F	G	H	I	J
1	СПАРК									
2	1	2	3	4	5	6	7	8	9	10
3	АКТИВЫ всего	Амортизация	ВНЕОБОРОТНЫЕ АКТИВЫ	Валовая прибыль	Внереализационные доходы	Выручка от продажи (за минусом НДС, акцизов ...)	ДОЛГОСРОЧНЫЕ ОБЯЗАТЕЛЬСТВА	Дебиторская задолженность (более года)	Дебиторская задолженность (менее года)	Денежные средства
4	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR	2007, RUR
5	71 913 000		4 426 000	40 175 000		186 009 000	284 000		8 601 000	58 201 000
6	525 796 000		248 013 000	40 551 000		46 780 000	180 515 000		193 789 000	25 409 000
7	466 064 000	30 098 000	365 663 000	69 527 000		327 478 000	303 000	1 282 000	73 708 000	2 576 000

Fig. 1. The part of DB SPARK

For our research we took the group of the first 60 companies having the complete data list. Its activity refers to 2007 year that was the last year before the world crisis came. To simplify the analysis we did not consider the data related with the other years although such a dynamics helps to correct the decision-making

2.2. Criterion for object selection

For decision-making our experts created 3 criteria. Each criterion is defined by a set of derivative parameters. Here is its description:

1) Particular criterion **Profitability**

Parameters of the criterion are:

- *Profitability of investments*: net profit / (equity capital + long-term liabilities)
- *Profitability of property*, plant and equipment: net profit / (property, plant and equipment)
- *Profitability of products*: net profit / cost of sold goods

We need the maximization of all these parameters. The parameter preferences are:

Profitability of investments > *Profitability of property, plant and equipment* > *Profitability of products*

Here the sign '>' means the preference between the parameters

2) Particular criterion **Liquidity**

Parameters of the criterion are:

- *Current liquidity ratio*: (current assets – long-term account receivable)/ (short-term liabilities). The recommended values of this indicator are 1.5-2.5
- *Cash liquidity ratio***:** (cash resources + short-term financial investments)/(short-term liabilities). The recommended values of this indicator are 0.2 – 0.5.

The parameter preferences are:

Cash ratio > *Current ratio*

3) Particular criterion **General financial rate**

Parameters of the criterion are:

- *Operating period, days***.** It is defined as a difference between the registration date and the reporting date (31.12.2007).
- *Current assets*. It is the primary parameter taken from the SPARK

We need the maximization of all these criteria. The parameter preferences are:

Current assets > *Operation period*

The group of parameters related with the criterion **Profitability** has the first priority for investors. This group provides the high profit from investments. The group of parameters related with the criterion **Liquidity** has the second priority. This group provides the low risk of investments based on good financial conditions. The group of parameters related with the criterion **General financial rate** has the last priority. This group provides the low risk of investments based on a high reputation**.**

Decision making with the DSS SVIR

3.1. General description of SVIR

The DSS SVIR was developed in St. Petersburg State Transport University for the solution of typical problems of multicriteria selection. SVIR consists of four groups of methods:

- Methods of **vector optimization**. The methods of this group operate with relations on the set of preferences
- Methods of **scalarization** of vector assessments. These methods are associated with the transformation of a vector optimization problem to a scalar optimization problem
- Methods of **classification**. They deal with relations between objects and classes, whose descriptions are fixed by experts
- Methods of **analysis of hierarchies**. They use pairwise comparisons of objects by experts

SVIR has the convenient graphical user interface and instructional material to study the system functionality. These circumstances make the system be useful both for students and for experts. This moment there are two versions of the program: the Russian version and B-release of the English version. In the paper we use the methods of vector optimization and the methods of scalarization in the framework of the Russian version.

3.2. Forming hierarchy of targets

The first step for problem solution in the DSS SVIR consists in constructing a graph of goals. Such a graph is determined by an expert using the set of given criteria. It is presented on figure 2

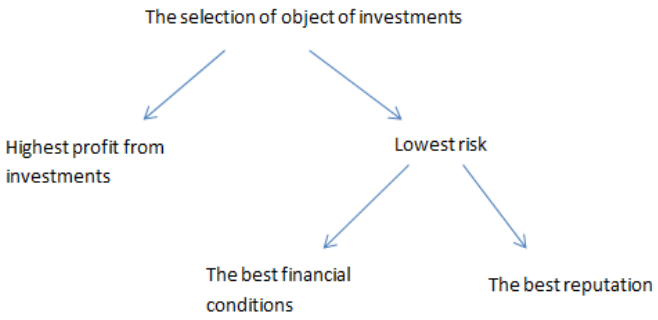

Fig. 2. Graph of goals.

Three final tops on the mentioned graph correspond to three groups of parameters mentioned in the section 2.2. This graph allows SVIR to construct the model of choice. This model is presented in three sheet tables. Figure 3 shows one of these tables. .

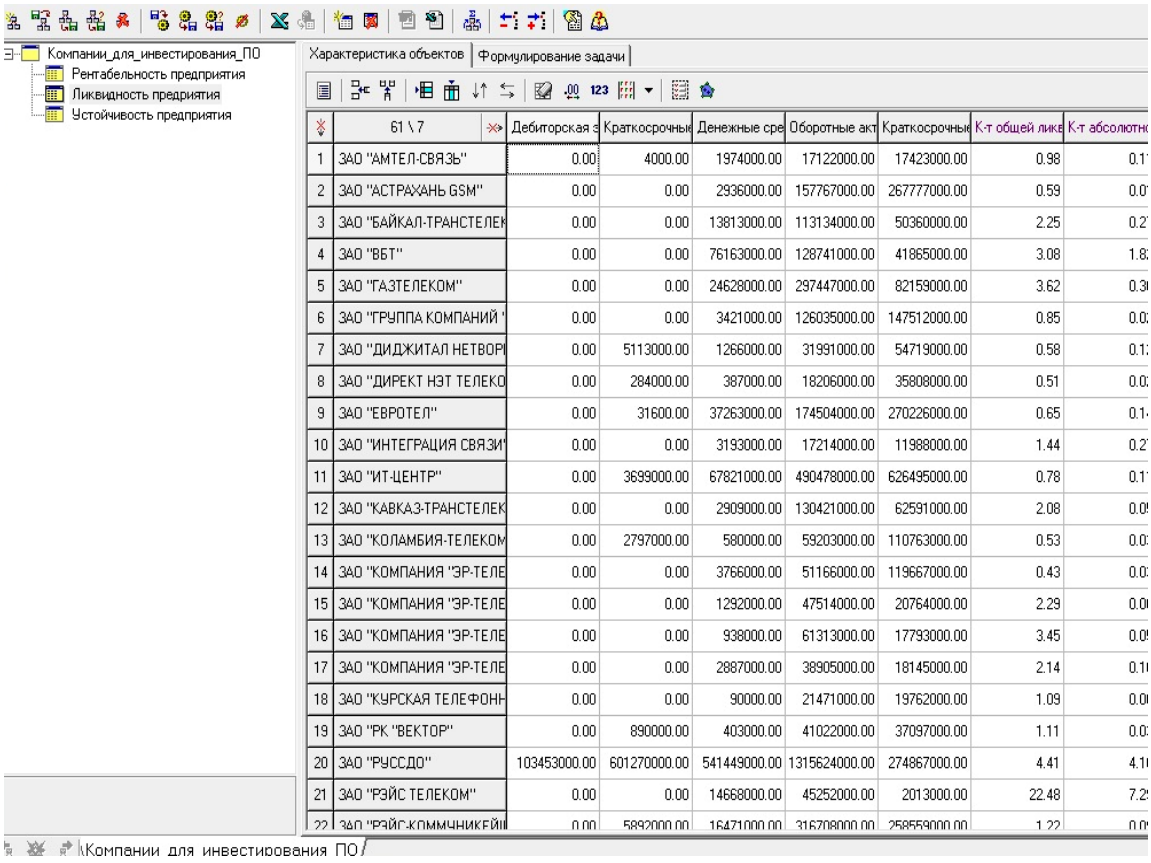

Fig. 3. Objects/Parameters table formed in SVIR.

3.3. Problem solution with methods of vector optimization

These methods forms so-called Pareto set, which consists of non-dominated objects [Wiki, Pareto]. To select the Pareto set one uses the correspondent option from the SVIR menu. The list of options is presented on the left low part of figure 4. We also used the other two methods of vector optimization: lexicographic optimization and leximin ordering. Although the former is enough crude and the latter is good rather for the purpose of education however they allowed to reduce the Pareto set.

3.4. Problem solution with methods of scalar optimization

These methods deal with the results of vector optimization that is with Pareto set. Scalarization reduces the vector form of objects presentation to its scalar form [Wiki, Convolution]. In our work we used the general additive convolution method, which averages the particular criteria using their coefficients of importance. Therefore here we deal with weighted sum of 3 normalized criteria Profitability, Liquidity and General financial rate. Figure 5 presents the interface for direct weight assignments.

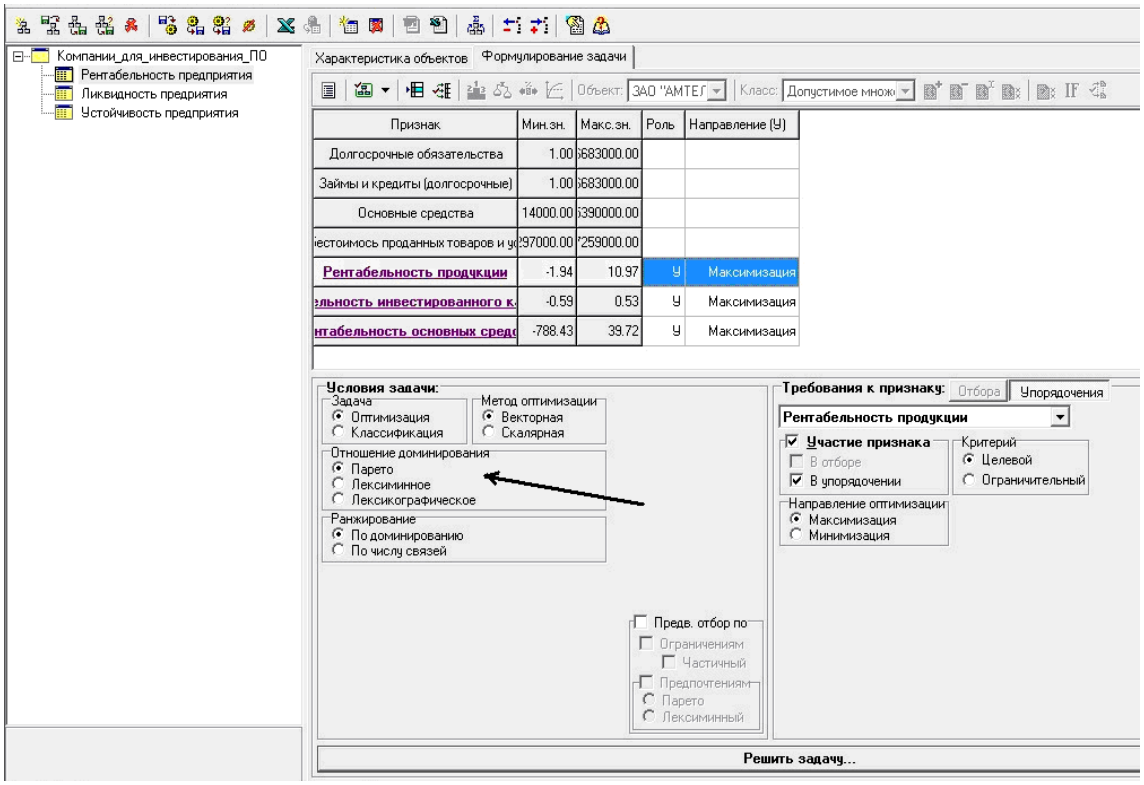

Fig. 4. SVIR is tuned for Pareto-optimization method

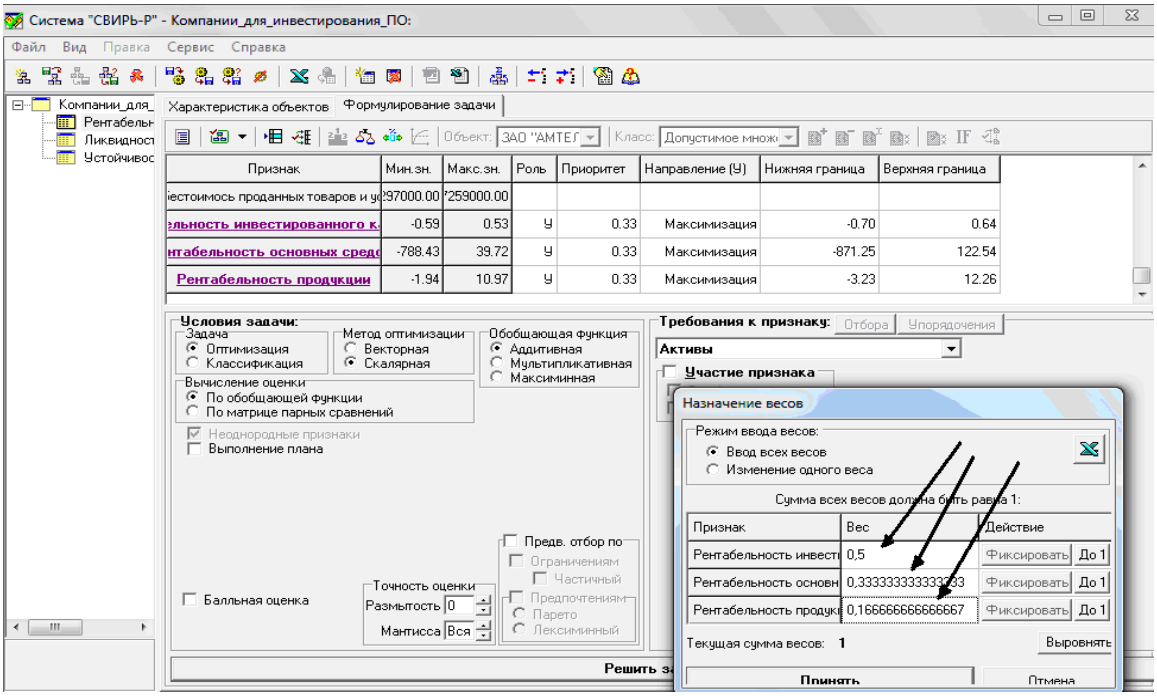

Fig.5. SVIR interface for direct weight assignment.

Finally we obtained the list of companies to be preferred for investments. This list is presented in table 1

Table 1. Final list of the selected companies (SVIR)

"Baikal-transtelecom" JSC
"Nachodka telecom" Ltd
"Prestige-internet" Ltd
“Teleset” Ltd
“VyatKTV” Ltd
"Gaztelecom" JSC
"Integracia svyazi” JSC
"Megapayge" Ltd
"Borodino-telecom" Ltd
"Sky link" JSC

It is necessary to emphasize that the tuned DSS SVIR can be repeatedly used without any expert for other set of objects (lists of companies) in the framework of the same problem setting (goals, criteria). Speaking “without any expert” we mean the possibility of problem solution by a user, which is not qualified in the area of multicriteria optimization.

Muchnik procedures

4.1. Method description

Muchnik method is a set of manual procedures based on:

- visualization of objects distribution in the space of their parameters
- the simplest binary assessment of objects success on each parameter

According the mentioned method an expert first of all specifies a set of particular criteria and ranks them. Each criterion is considered as a set of primary or derivative parameters. A company can be successful on each of these parameters or can be unsuccessful. In the first case its assessment is equal 1 otherwise 0. Therefore, if a criterion has 3 parameters then a criterion value varies from 0 to 3.

Then our expert constructs a histogram of companies distribution on each parameter from a given criteria and then we set the threshold (thresholds) of success. If we want to have the maximum values of the mentioned parameter then the successful companies are located to the right of the threshold. If we want to have the minimum values of the mentioned parameter then the successful companies are located to the left of the threshold. If we want the values of parameter be inside a certain interval then the successful companies are located between two thresholds. The threshold position is determined very subjectively. Usually one fixes the approximate number of successful companies (5%, 10%, 20%, etc.) and this number allows to determine the threshold (thresholds) position. Figure 6 illustrates such a separation of companies for the parameter «Profitability of investments». The arrow shows the possible threshold position.

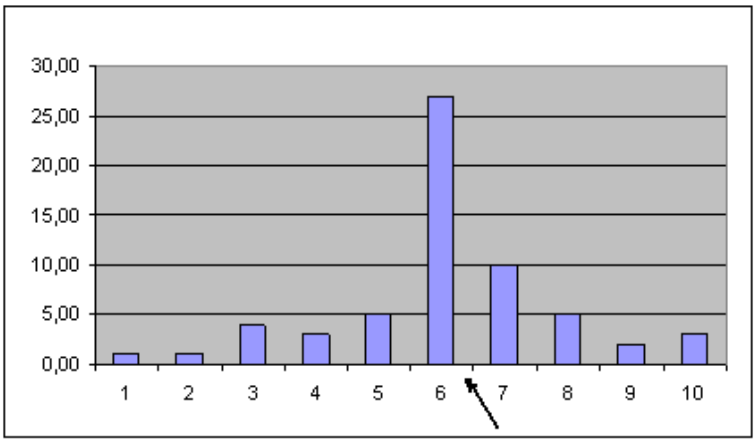

Fig. 6. The histogram of companies distribution on the parameter 'Profitability of investments'. Axis Y is the number of companies, axis X is the category.

The level of success for each criterion also depends on expert opinion and therefore is very subjective. As we mentioned above the criterion Profitability includes 3 parameters and its value varies in the interval [0-3]. An expert can set the value 2 as a threshold for successful companies. It means that the best companies on this criterion are successful on any two or three parameters of this criterion.

The selection procedure contains the following steps:

1) Choice of the best companies on the criterion 'Profitability', the other ones are eliminated
2) Choice the best companies on the criterion 'Liquidity', the other ones are eliminated
3) Choice the best companies on the criterion 'General financial rate'

As a result we obtain the most promising group of companies. If the number of 'the best companies' proves to be too large or too small then one should change the thresholds of success both for parameters and for criteria.

We applied the Muchnik method to the same 60 companies that were used with DSS SVIR. Having made three steps of selection describe above we obtained the list of companies presented in the table 2.

Table 2. Final list of the selected companies (Muchnik method)

"Baikal-transtelekom" JSC
"RUSSDO" JSC
"Sky link" JSC
"SSU" JSC
"Borodino-telecom" Ltd
"Prestige-internet" Ltd
"Radio station "Serebryaniy dozhd" Ltd
"TV Technopark" Ltd
"TC "OSTANKINO"" JSC

Conclusion

In the paper

- the short description of the DSS SVIR and Muchnik method is presented,
- the problem of selecting perspective companies of mobile communications for investment is solved,
- the coincident of results proves to be equal 60% and the experts confirm that SVIR list of selected companies is promising.

In the future we suppose to repeat our experiments in DSS SVIR:

- with the extended list of the criteria,
- with the methods of classification,
- with the methods of analysis of hierarchies,

and compare the results between themselves and with those obtained in this paper

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[Wiki, Pareto] http://en.wikipedia.org/wiki/Pareto_set

[Wiki, Convolution] http://en.wikipedia.org/wiki/Free_convolution

Author's information

Pavel Mogyliov – *Bachelor of the Russian Presidential Academy of National Economy and Public Administration, Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; Moscow Institute of Physics and Technology, Prosp. Institutskiy 7, Dolgoprudniy,Moscow Region, 147001, Russia;*

e-mail: nismorus@gmail.com

Major Fields of Scientific Research: applied mathematics, computer science, business intelligence

Mikhail Alexandrov *– Professor of the Russian Presidential Academy of National Economy and Public Administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; fLexSem Research Group, Autonomous University of Barcelona, 08193 Bellaterra (Barcelona), Spain;*

e-mail: MAlexandrov@mail.ru

Major Fields of Scientific Research: data mining, text mining, mathematical modelling

Stanislav Mikoni *– Professor of the St. Petersburg State Transport University, St. Petersburg 190031, Russia; e-mail: svm@sm4265.spb.edu*

Major Fields of Scientific Research: System analysis, multicriteria choice, Intelligent technologies, simulation.

NATURAL LANGUAGE PROCESSING AND SOCIAL NETWORK ANALYSIS

STUDYING SPECIAL TEXT RUSSIAN CORPORA BY THE LEXICO-SYNTACTIC MODELS

Maria Khokhlova, Victor Zakharov

Abstract: *The paper presents the results of automatic term extraction from a special text corpus (a collection of papers on corpus linguistics) by means of statistical methods (association measures) combined with certain syntactic models. The approach undertaken in the paper is based on lexico-syntactic models that can be viewed as models of phrases for the Russian language. The Sketch Engine system represents itself a corpus tool which takes as input a corpus of any language and corresponding grammar patterns. The system gives information about a word's collocability on concrete dependency models, and generates lists of the most frequent phrases for a given word based on appropriate models. The extracted terms belong to various clusters and represent the lexical structure of the texts in question. The applied method includes statistical analysis that enables estimating paradigmatic and syntagmatic relations between lexemes based on their distribution.*

Keywords: *Corpora, distributional and statistical methods, collocations, automatic term extraction, thesaurus.*

ACM Classification Keywords*: I.2.7 Natural Language Processing*

Introduction

This research was based on using the Sketch Engine system, a corpus tool which takes as input a corpus of any language and corresponding grammar patterns and which generates word sketches for words of that language [Kilgarriff, et al., 2004; The Sketch Engine]. We have developed syntactic patterns (models of phrases or word sketches) for the Russian language based on a morphologically annotated corpus. These syntactic patterns can be viewed as lexico-syntactic models of phrases. One can understand word sketches as typical phrases determined on the one hand by syntax that restricts words' collocability in a given language and on the other hand by the probability closely related to word usage [Kilgarriff, et al., 2004; Rychly, Smrz, 2004; Mel'cuk, 1998].

Lexico-Syntactic Models for the Russian Language

Lexico-syntactic model is a structural pattern of a linguistic construction having an indication of grammatical properties of a number of lexemes (that belong to the construction) and of syntactic conditions of using the verbal expression built according to the pattern (for example, rules for agreement of morphological properties of the lexemes in phrases, e.g. in Russian adjectives agree with nouns in gender,

case, and number). This approach can be supplemented with a statistical approach that takes into account frequencies of words and their combinations [Bol'shakova et al., 2007; Mitrofanova, Zakharov, 2009].

The notion of lexico-syntactic model was applied while describing syntactic phrases for the Russian language. We developed syntactic patterns (models of phrases) for the Russian language based on a morphologically annotated corpus. This grammar was integrated to the Sketch Engine that generates on its basis word sketches reflecting the words' lexical and syntactic collocability. While writing word sketch grammar we used theses described in [Russkaya grammatika, 1980; Zolotova, 1988; Bol'shakov, Bol'shakova, 2006].

While describing the syntactic patterns inherent to the Russian language we distinguished the following models:

- `coordination (=and/or);`
- `subjective model (`N_1`+V: =subject/subject_of, =passive/subj_passive, =to_be_adj/subj_to_be);`
- `objective model (V+`N_2`, V+`N_3`, V+`N_4`, V+`N_5`: =object2/object2_of, =object3/object3_of, =object4/object4_of, =inst_modifier/inst_modifies; V+Vinf: =post_inf/verb_post_inf; Adj_short+V: =modal_inf/modal);`
- `attributive model (N+`N_2`: =gen_modifier/gen_modifier; Adj+N =a_modifier/modifies);`
- `comparative model (N+Adjcomp+`N_2`: =comparative);`
- `adverbial model (=adv_modifier/adv_modifies);`
- `prepositional model (Prep+N, V+Prep: =prec_prep, =post_prep; N+PP, V+PP: =pp_%s, =pp_obj_%s).`

Within the models there are 18 relations. Thus, the attributive model can be described by two relations that are N+N_2 and Adj+N.

The latter relation includes three cases: 1) Adj + (Adj) + N; 2) Adj + («,» + Adj) + «или» ('or') / «и» ('and') +Adj + N; 3) Adj + («,» + Adj) + N. Here are the examples from the corpus taking into account each case respectively:

- *Рассмотрим в качестве иллюстрации высказанной мысли* ***английские синонимичные прилагательные*** *(English synonymic adjectives*) *easy, simple (на основе COCA) (Adj + (Adj) + N).*
- *Подкорпус содержит только целые тексты, имеющие* ***метатекстовую, морфологическую и семантическую разметку*** metatextual*, morphological* and *semantic annotation) (Adj + («,» + Adj) + «или» ('or') / **«и» ('and') +**Adj + N).*
- *Особенностью данных топонимического корпуса является то, что несмотря на однотипность базовых единиц корпуса – топонимов, наблюдается существенная их неоднородность как в плане языковой принадлежности (**русский, финский, ижорский, водский, эстонский, шведский, немецкий языки**) (Russian*, *Finnish,* Ingrian, *Votic, Estonian*, Swedish*, German languages), так и в плане характеристик материалов и их носителей (карточки, карты, списки и другие источники) (*Adj + (**«,»** + Adj) + N*).*

As next stage of our research we uploaded the described grammar into the Sketch Engine to get examples of terms and phrases from the corpus.

Special Text Corpus

Specialized languages occupy a prominent place in both linguistics and the information technology. This study implies a scientific text to be treated as a special one. Special texts are rich in terminology and that calls for developing methods to automatically extract terms from a special text corpus. The corpus itself is a collection of papers on corpus linguistics published in a number of conference proceedings in Russian, totally about 343000 tokens. The automatic term extraction is based on grammatical patterns and statistics allowing to weight terms, to estimate them. The area of corpus linguistics is a rapidly developing field of linguistics with its own methodology and terms [Mitrofanova, Zakharov, 2009]. Moreover a vast majority of terms come from the English language, and sometimes there is no agreement in spelling (for example, «тэг» or «тег» for the English 'tag').

In terms of linguistics, we are talking about a plethora of units (notions) defined by the terms "lexical field", "lexico-semantic field", and "functional semantic field". In modern information technology the same notions can be normally called thesaurus or ontology.

The Sketch Engine has special tools that allow to measure syntagmatic and paradigmatic relations between lexical units based on lexemes distribution and syntactical collocatibility rules: Word Sketches, Thesaurus, Clustering, and Differences. The statistical measures enable ranking the extracted terms; most of them represent set phrases and collocations.

Experiments

Below there's a list of the 30 most frequent single-word terms (with a high index of collocability) found in the corpus: "tekst" ('text'), "korpus" ('corpus'), "slovo" ('word'), "yazyk" ('language'), "slovar'" ('lexicon', 'vocabulary'), "dannyje" ('data'), "sistema" ('system'), "znachenije" ('meaning', 'sense'), "tip" ('type'), "razmetka" ('tagging', 'annotation'), "analiz" ('analysis'), "predlozhenije" ('sentence'), "forma" ('form'), "issledovanije" ('research'), "rabota" ('work'), "vremya" ('tense'), "jedinitsa" ('item'), "glagol" ('verb'), "sluchaj" ('case'), "chast'" ('part'), "informatsiya" ('information'), "sozdaniye" ('creation'), "rech" ('speech), "material" ('material'), "struktura" ('structure'), "suscestvitel'noye" ('noun'), "baza" ('base'), "primer" ('example'), "zadacha" ('task'), and "svyaz'" ('relation').

The output for each term is represented by a class of words that can be semantically related to it. Below in Fig. 1 one can see the results for the key word "tekst" ('text') selected by the Thesaurus function with enabled clustering option:

текст

Corpus Linguistics freq = 3220

Lemma	Score	Freq	Cluster
корпус	0.298	2708	словарь [0.181, 918] материал [0.169, 452] система [0.144, 768] база [0.104, 421]
язык	0.267	1782	
слово	0.215	1814	единица [0.122, 492] глагол [0.112, 489] лексема [0.077, 166] существительное [0.075, 432]
предложение	0.173	574	часть [0.142, 476]
документ	0.151	230	файл [0.068, 128]
контекст	0.137	347	характеристика [0.079, 284]
разметка	0.117	615	
пример	0.116	402	случай [0.085, 487]
информация	0.111	467	
значение	0.11	671	структура [0.108, 439] тип [0.105, 648]
речь	0.1	461	
конструкция	0.098	284	словосочетание [0.076, 208] термин [0.063, 200]
форма	0.093	566	
версия	0.09	94	лексика [0.072, 140]
источник	0.086	199	объект [0.076, 232]
ошибка	0.084	168	

Fig. 1. Thesaurus for the word "tekst" ('text')

Among the presented results one can distinguish between the following clusters: 1) “source of research” — “korpus” (‘corpus’), “slovar’” (‘dictionary’), “material” (‘material’), “sistema” (‘system’), “baza” (‘basis’); 2) “object of study” — “slovo” (‘word’), “jedinitsa” (‘unit’), “глагол” (‘verb’), “leksema” (‘lexeme’) etc.

Two-word terms can be extracted from the corpus by applying the Word Sketch function. Fig. 2 shows typical collocations for some frequent lexemes (sorted by frequency) that match predefined lexico-syntactic models.

All the extracted terms were grouped according to their grammatical structure. For the term “razmetka” (‘tagging’, ‘annotation’): 1) Adj N — “morfologicheskaya razmetka” (‘morphological tagging’), “semanticheskaya razmetka” (‘semantic annotation’), “syntaksicheskaya razmetka” (‘parsing’) etc.; 2) N N_2 — “glubina razmetki” (‘depth of annotation’), “uroven’ razmetki” (‘level of annotation’) etc. For the term “glagol” (‘verb’): Adj N — “frazovyj glagol” (‘phrasal verb’), “modal’nyj glagol” (‘modal verb’), “kauzativnyj glagol” (‘causative verb’) etc.

There are two groups of collocations among the extracted terms. The former includes the terms themselves that can be added to the dictionaries, the latter is represented by high frequent collocations: “opusceniye glagola” (‘omission of verbs’), “angliyskiy glagol” (‘English verb’) etc. Both groups can be used while describing the term system of corpus linguistics as such lexis is not often reflected in dictionaries.

разметка *(noun)* **Corpus Linguistics freq = 615** (1790.7 per million)

subject_of	61	2.3
заключаться	8	11.27
осуществляться	9	10.89
проводиться	4	10.11
производиться	3	10.02
состоять	2	8.72
включать	2	8.18
позволять	3	7.96
являться	4	7.8
быть	2	5.99

a_modifier	287	3.8
морфологический	64	11.68
семантический	48	11.21
синтаксический	35	10.99
автоматический	20	10.38
лингвистический	16	9.81
грамматический	11	9.6
структурный	5	8.99
Библиографическая	4	8.82
полный	5	8.71
Экстралингвистическая	3	8.41
Метатекстовая	3	8.41
просодическая	3	8.39
стандартный	3	8.26
автоматизированный	3	8.18
экстралингвистическая	2	7.82
морфосинтаксическую	2	7.82
частеречная	2	7.82
метатекстовую	2	7.82
морфемной	2	7.81
многоуровневый	2	7.8
частеречной	2	7.78

gen_modifies	215	1.4
способ	6	9.1
схема	5	9.03
тип	14	8.87
глубина	3	8.75
этап	5	8.71
технология	4	8.71
техника	3	8.61
пример	6	8.59
инструмент	4	8.56
просмотр	3	8.49
проблема	5	8.45
процедура	4	8.4
принцип	4	8.4
система	12	8.38
программа	5	8.34
тэговой	2	8.23
экстралингвистической	2	8.22
морфосинтаксической	2	8.21
вид	6	8.16
процесс	4	8.15
скорость	2	8.14

Fig. 2. Word sketches for the word “razmetka” (‘tagging’)

Conclusion and Further work

The above described methodology of using Sketch Engine instruments on scientific text corpus of Russian allows to extract terminological phrases (not single word terms only), to define paradigmatic relations added to syntagmatic ones, and to quantitatively estimate the strength of semantic relations.

There is a question of corpus volume. For example, different association measures extract different collocations but here one can’t see differences between results obtained by a number of statistical measures, it means that collocates will be quite the same. This problem arises from low frequencies of words and phrases. As was pointed above we are going to work on further corpus data increase.

A number of problems arise from errors in morphological annotation as: 1) every punctuation mark has its own tag (so it should be excluded in the sketch grammar); 2) parts of compound nouns also have different lemmas

that is why in sketch tables we can find only one part of such words as a collocate; 3) usual mistakes of annotation, e.g. homonyms or homographs, mistakes in assigning the correct case or number; 4) mistakes in assigning correct lemmas (it is especially the case while annotating special texts).

Further development of this mechanism of collocation extraction is closely related to writing more exact grammatical rules (that will be based on syntactically parsed corpus or even take into account semantic annotation), more corpus data etc. Most errors in the word sketches result from errors in lemmatization and POS-tagging. We are currently explore alternative tools for automatic morphological annotation. Manual morphological disambiguation can be seen as a possible solution for the problem of reducing errors of annotation. But this work is labour- and time-consuming and unfortunately can be applied only to a small part of a corpus.

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Authors' Information

Maria Khokhlova *– Assistant Professor, Saint-Petersburg State University, Universitetskaya emb., 11, Saint-Petersburg 199034 Russia; e-mail: khokhlova.marie@gmail.com*

Major Fields of Scientific Research: Natural Language Processing

Victor Zakharov *– Associate Professor, Saint-Petersburg State University, Universitetskaya emb., 11, Saint-Petersburg 199034 Russia; e-mail: vz1311@yandex.ru*

Major Fields of Scientific Research: Corpus linguistics, Computational Lexicography

AUTOMATED TAG EXTRACTION & CLUSTERING IN DOCUMENTS CONTAINING COMPOSITIONAL PHRASEMES

Vera Danilova, Xavier Blanco, Dmitry Stefanovskiy

Abstract: *This article aims to present the results of clustering in documents, extracted from Internet and related to compositional phrasemes (pragmatemes). We are studying conditions (situation, context), which can stipulate presence of these units in a text. Pragmateme's structure and functioning particularities are taken into consideration. An important objective of the work is selection of an adequate algorithm for tag extraction and clustering, so that we can further compare and apply the results, obtained for different languages.*

Keywords: *pragmateme, compositional phraseme, tag extraction, clustering analysis*

ACM Classification Keywords: *I.2.7. Natural Language Processing*

Introduction

The present work is dedicated to defining context/situations, characteristic of compositional phrasemes (pragmatemes) usage, by means of tag extraction and clustering results analysis.

The description of the term "pragmateme" is taken from [Mel'čuk, 1995] and [Blanco, 2010]: the meaning (or signified) of a pragmateme is not freely built from a specific conceptual representation, though it can be a regular sum of meanings for lexemes A and B. Thus, the meaning of these structures isn't free and cannot be replaced by any other meaning. There are two types of phonetic representation of the phrase (or signifier): it is not freely built from the signified and regular (in such case the meaning and the form of the phrase are totally limited by the situation) or it is relatively freely built (there are several synonymic forms of phonetic representation, regulated by the rules of the language).

A pragmateme presents a complex semiotic sign: text, which is often accompanied by a correspondent image. This combination is used to communicate a message of certain content (prohibition, indication etc.).

Such pragmatemes as routine or conversational formulae are used for stereotypical social interaction. They include discourse formulae, opening and closing conversations, psycho-social formulae [Nunes, 2007]. Some proverbs also can be understood as pragmatemes, according to [Pastor, 1995] point of view.

This work is a part of the project "Compositional pragmatic phraseology" of MCuT being accomplished at the Department of Romance Languages at the Autonomous University of Barcelona [MCyI, 2010-2012]. Our research has been carried out within the framework of R programming language system [R, http].

Problem setting

At this stage is selection of an adequate algorithm to carry out clustering processes so that we can obtain an appropriate distribution of context words.

The general purpose of defining contexts for pragmatic phrasemes is improvement of automatic translation for texts, containing these units.

In prospect we plan to dedicate our study to the functioning of pragmatic phrasemes in intercultural context, because major part of them is related to the fundamental realities of different countries and certain situational/contextual regularities, relevant to the correspondent country, may be revealed.

Within the limits of this experiment only those pragmatisms, which can be represented by both text and graphic sign (e.g., road signs, indicators, such as *"No camping", "No parking"*), will be examined.

Indexing & clustering

To reveal the topics related to the given pragmatic phrasemes we use the following technique:

1) Extraction of documents from Internet depositories using the well-known Google search machine.
2) Construction of term list as the basis for document set indexing
3) Performing clustering applying selected terms

There are many approaches for constructing list of terms to be used in clustering/classification process. Entropy based methods select the most informative words in the corpus. Statistics based methods use non-uniformity of word distribution among the documents. We use criterion of term specificity. Namely we select words whose frequency in a given document set exceeds their frequency in the General Lexis by K times. In our situation the General Lexis was a list of words taken from the British National Corpus of documents. Coefficient K is titled as a word specificity. The higher the K is the fewer words will be extracted from a given document set. This procedure is easily performed by the program LexisTerm [Lopez, 2011]. We suppose that such an approach to term selection is relevant to the goal of the research.

At present there is a large variety of clustering methods, which belong to different groups: 1) hierarchy based methods where number of clusters is not fixed 2) exemplar based methods where number of clusters is given in advanced and 3) density based methods where number of clusters is determined automatically [Alexandrov, 2007]. The methods of the second group are the most common and simple, but they cause more errors and critical comments (the reason is the fixed number of clusters). Nevertheless we use K-means within the framework of the procedure where K varies. Namely we increase K since K=2 till the moment when Dunn criterion (measure of cluster validity) reaches its maximum. This type of approach is popular in Machine Learning.

Experiment

Our corpus consists of 40 documents, containing English pragmateme "Camping prohibited" (all documents represent two topics by default: rules for campers and general information for tourists). We used this amount of documents, because at this stage it's essential to be able to check the results manually.

The procedure of indexing was implemented with the program LexisTerm two times with the coefficients of specificity K=10, 50, 100, 500. The coefficient of K=100 was selected as optimal and the resultant number of terms was 254. This result was adjusted and applied for the further clustering (non-relevant terms were excluded and some relevant ones were added).

Our assumption is that the documents shall form cluster for each context basing on key-words. Clustering was accomplished in R programming language system. There were created several interrelated scripts, setting the variables for each text and stop-words and two main scripts for clustering and key-word test. A term document matrix was compiled on the basis of the resulting data set. Punctuation and stop-words were eliminated. The value of each matrix point was divided by the sum of the values in a correspondent row to normalize the vectors. The optimal number of clusters (two) for the given set of documents was obtained using Dunn's partition coefficient. The information on the resulting clusters is given in the below.

	size	max_diss	av_diss	diameter	separation
[1]	261	1.0613199	0.75311746	1.4142136	0.1732051
[2]	59	0.6123724	0.09783235	0.6123724	0.1732051

Graphic representation of clustering results confirmed the aforementioned calculations (Fig. 1): the first cluster contained 261 elements (rules and regulations for campers) and the second - 59 elements (information for tourists on different types of accommodation).

The key-words were first manually selected from the matrix, according to their degree of occurrence in the given documents. The result was compared with the sequence of interrelated key-words, obtained automatically: a formula was derived, applying coefficients, obtained in calculation of polynomial regression (coefficients, expressing the dependencies between key-word frequencies). There were found two sets of key-words, marking the first cluster: x2:x3 (property: parking) = 1.34120743 and x2:x4 (property: trail) = 13.00345224. The presence of each set in a document stipulates the assignment of the latter to the first cluster (regulations (code) for campers). The rest of the documents shall be automatically assigned to the second cluster (general information for tourists) respectively.

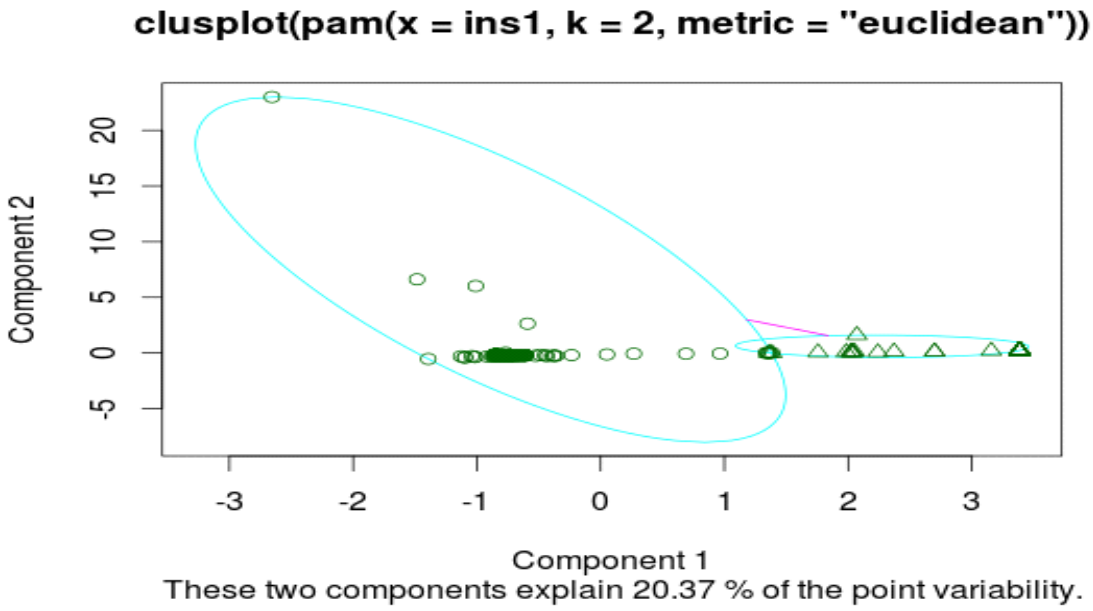

Fig.1 Results of clustering

Conclusions

The results of the present pilot experiment represent a successful automatic assignment of the given documents to clusters (and contexts respectively) by means of R programming language system. They coincide with the results of manual distribution.

In prospect we plan to study the distribution of pragmateme contexts in different languages so that we can reveal regularities in the use of these units in different countries. The key-words will be presented not only by words, but also by fixed word combinations, because they tend to be more useful for the interpretation of a context. Also we plan to take into account the synonymy of words and collocations.

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Authors' Information

Vera Danilova *– Autonomous University of Barcelona, the Department of Romance Languages, PhD program student;*

e-mail: maolve@gmail.com

Major Fields of Scientific Research: Automated translation, Pragmatic structures

Xavier Blanco – *Cathedratic University Professor (Full Professor), fLexSem Research Laboratory (Fonètica, Lexicologia i Semàntica), Department of French and Romance Philology, Autonomous University of Barcelona, 08193 Bellaterra (Barcelona), Spain;*

e-mail: Xavier.Blanco@uab.cat

Major Fields of Scientific Research: lexicology, lexicography, machine translation

Dmitry Stefanovskiy *- Assoc. Prof., Ph.D, the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571;*

e-mail: dstefanovskiy@gmail.com

Major Fields of Scientific Research: Modelling for Analysis of Socio-Economic Processes

THE STUDY OF FACTORS RELADED WITH SINGLE-DOCUMENT KEYWORD EXTRACTION

Popova Svetlana

***Abstract**: In this paper we consider the problem of keyword extraction for the document annotation. We study different statistic-based measures for such extraction and compare the results with the annotations made by skilled experts. The experiments were completed with the Inspec data set. The quality of annotation was evaluated by means of R-Precision score.*

***Keywords**: keywords extraction, single document annotation, natural language processing.*

***ACM Classification Keywords**: I.2.7. Natural Language Processing*

Introduction

The aim of keyword extraction is to find a small number of terms representing the document content "in a few words". Keyword extraction systems may be useful in automatic texts classification, clustering, document indexing, novelty detection, question-answering, text representation etc. In this paper we focus on the problem of keyword extraction for the purpose of document annotation. Our approach consists of two steps. The first step includes token selection and their grouping into multi-words candidates. At the next step we rank all candidates and then top-ranking candidates are selected as keywords. We tested efficiency of various statistics for these procedures. It was experimentally shown that it is more preferable to remove candidates having one-word-length than to use any statistics from a given list. We used R-Precision for final evaluation.

State-of-the-art

The majority of keyword extraction approaches are statistical-based and graph-based. P. Turney [Turney, 2000] proposed a supervised system that combined genetic algorithm with the parameterized keywords extraction system Extractor. E. Frank [Frank, 1999] used supervised system based on a Naive Bayes classifier. A. Hulth [Hulth, 2003] combined learning process and linguistic information to deal with keyword extraction problem. In her work it was shown that POS tagging improves all results independent of the applied term selection approach. Unsupervised graph-based approach was proposed by [Mihalcea, 2004]. In this approach text entities were presented as vertexes linked with each other. The scores of the graph vertexes were computing using formula based on PageRank. X. Wan [Wan, 2008] explored neighborhood knowledge to score co-occur statistics to TextRank. T.Zesch [Zesch, 2009] proposed the generalized framework for comprehensive analysis of keywords extraction that included different combinations of candidate construction and candidate ranking.

The analysis of the state-of-the-art shows that the problem of keyword extraction is far from its solution. The obtained results are not high and so the problem should be elaborated more carefully. Another difficult question is evaluation of results quality. New measures for quality evaluation were proposed in [Zesch, 2009; Su Nam Kim, 2010]. But by the moment there is no experience in application of these measures. In this paper we use the quality measures proposed in [Zesch, 2009], and compare our results with those described in [Zesch, 2009].

Dataset

This research is based on experiments with Inspec, one of the main datasets mentioned in the state of the art review. It contains 2000 abstracts from Computer science and Information Technology and consists of three subsets: trial set (1000 abstracts), validation set (500 abstracts) and test set (500 abstracts). As in all previous works we based our research on the test subset. Every document in Inspect has a gold standard, which was created by experts. The gold standard includes two sets of keywords: "contr" set and "uncontr" set. We used "uncontr" set. More detailed information about the collection could be found in the paper [Hulth, 2003].

Evaluations

Previously, the method based on *F–score* [Manning, 2009] was used to evaluate results in the keywords extraction problem. But there was a problem to understand how many keywords should be extracted. Recently it has been proposed to use *R-Precision* (R-p) [Zesch, 2009]. R-p is Precision when the number of extracted keywords is equal to the number of keywords in the gold standard. R-p allows us to consider the problem of keywords extraction as the problem of ranking, when candidates to keywords should be ranked in order to detect the most important among them. Another question is how to understand that extracted keyword k is correct. T. Zesch [Zesch, 2009] considered k correct if it overlapped the keyword g from the gold standard or if k and g were morphological variants of each other. In our research we use R-p to evaluate results in two cases: 1) exact: k consider correct if it equals to g in each word, 2) include: k is correct if it overlaps g .

Algorithm

The pre-processing step included: stop words removing, splitting text into sentences and part of speech tagging (Stanford POS tagging tool). All words except for nouns and adjectives were removed from texts. For each text three statistics were exploited separately to select tokens. These statistics were: *tf-idf* [Manning, 2009], *within document term frequency* and *Transition Point* which has been successfully used for the term selection in the clustering problem [Pinto, 2006]. Tf-idf requires information from all documents in a collection. Other two statistics work with single documents. Transition Point technique is based on the idea that mid-frequency terms are semantically close to the text content. Basically, formula of this technique that calculates TP_d for the document d is:

$$TP_d = \frac{\sqrt{8 * I_1 + 1} - 1}{2},$$

I_1 is the number of words with the frequency equal to 1 in *d*. All words with-within document term frequency *wdf* are selected from d if:

$$U_1 \le wdf \le U_2,\ U_1 = (1 - c) * TP_d,\ U_1 = (1 + c) * TP_d,\ 0 \le c < 1.$$

We grouped selected tokens that followed each other in the original document to construct multi-words candidates. Most of keywords contain 1 to 4 words and we reconstructed candidates not longer than four words [Zesch, 2009]. The next step was ranking process. The final score for the candidate was calculated as average value of all the contained tokens. We explored three statistics to score token's value: 1) *tf-idf*, 2) within document frequency, 3) transition point (that was calculated as: $tp_{token} = | TP_d - wdf_{token} |$). Additionally we used average mutual information (*MI*) for ranking candidates [Manning, 2009] calculated between all words pairs in a candidate. If a candidate included only one word its score was equal to zero.

Experiment

We compared all combinations of the token selection methods (tf-idf, within document frequency (*wdf)*, transition point (*tp*)) and the candidates ranking criteria (tf-idf, within document frequency (*wdf*), transition point (*tp*), MI). Experiments showed that the best results were obtained if all tokens were selected independently of the token selection strategy. Additionally in experiments we tried to remove words that occur in the text only once, but it reduced quality. Results of experiments with four candidates ranking methods present in Table 1 a) assuming that all terms were selected on the term selection stage. MI showed the best results because scores of all one-word-long candidates were calculated as zero. The majority of these candidates were not included in the keywords list because the values of these candidates were minimal. In the next experiment we changed ranking step for every criterion: firstly all one-word-long candidates were removed and then all other candidates were ranked. Table 1 b) presents results for this experiment and it shows that all ranking strategies are equal, except MI having lower result. Comparing Table 1 a) and b) allows us to draw an interesting conclusion: deletion of one-word-long candidates improves results and has more influence on quality than any of the performed ranking criteria. It could mean that content words rather follow each other in the text frequently than appear alone. Evaluation with R-p (include) 0.37 outperforms all results for Inspect dataset present in the work [Zesch, 2009].

Table 1. Experiment Results a) all candidates, b) without one-word-long candidates

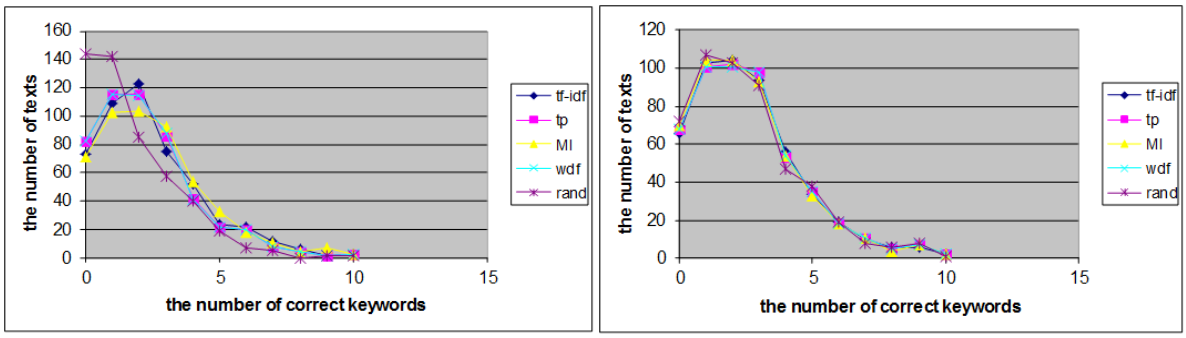
all candidates	R-p (exact)	R-p (include)
tf-idf	0.25	0.32
transition point	0.23	0.30
MI	0.28	**0.36**
wdf	0.23	0.30

a)

except one-word-long candidates	R-p (exact)	R-p (include)
tf-idf	0.28	**0.37**
Transition point	0.28	**0.37**
MI	0.28	0.36
wdf	0.28	**0.37**

b)

In the next step we explored why all ranking methods gave the same results in Table 1 b). We selected keywords randomly (*rand*) from candidates assuming that all one-word-long candidates had been removed. The result was positive: R-p (exact) 0.28, R-p (include) 0.37. It happened because in the major part of cases the number of constructed candidates for the text was almost the same as the number of keywords in the gold standard. However if we do not remove one-word-long candidates, random selection of keywords from candidates will reduce quality: R-p (exact) 0.17, R-p (include) 0.22. Diagram 1 a) and b) shows dependence between the number



a) *b)*

Fig. 1. a) all candidates, b) without one-word-long candidates

of documents and the number of correct extracted keywords per document for different ranking strategies (case: exact). Diagram 1 shows that removing one-word-long candidates allows increasing the number of correct extracted keywords per document and all ranking strategies do it in the same way (include random selection). It proved that candidates to keywords with one-word length bring noise in ranking step.

Conclusion

In this paper we studied the influence of various statistic methods on keyword extraction problem. We propose the approach related with this problem, which includes token selection and candidate ranking steps. The result is that the difference between performed measures in proposed approach is poor. If we remove all words from text except for nouns and adjectives, group the remained words into multi-words candidates, and then remove all one-word-long candidates, no ranking will be needed. It means that additional information and other measures or methods are needed to improve results. Removing from the text words that only once occur in it reduces quality. It proved that some of these words were included in keyword list. We detected that deletion of one-word-long candidates during ranking step improves results. It means that content words rather follow each other in the text frequently than appear alone. In the future we suppose to study graph-based and knowledge-based measures.

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Authors' Information

Svetlana Popova *– Saint-Petersburg State University, the Department of Programming Technology, PhD program student; e-mail: spbu@bk.ru*

Major Fields of Scientific Research: documents clustering, scientific documents processing

SPANISH SENTISTRENGTH AS A TOOL FOR OPINION MINING PERUVIAN FACEBOOK AND TWITTER

Roque López, Javier Tejada, MikeThelwall

***Abstract**: SentiStrength is a well-known tool for opinion mining texts circulated in social networks. There are English, Spanish, Russian versions of SentiStrength, which demonstrated their advantages in numerous examples. In the paper we present our classifier of opinions for analysis of comments from the Peruvian Facebook and Twitter. We corrected and enriched SentiStrength Spanish vocabularies having in view the properties of Peruvian Spanish. We also slightly modified the SentiStrength algorithm rules. We demonstrate the results we have reached with our classifier and SentiStrength. The experimental results are competitive with traditional approaches developed in this area, and the total accuracy proved to be 72%.*

***Keywords**: SentiStrength, Opinion Mining, Facebook and Twitter*

Introduction

Facebook and Twitter have become huge repositories of information. Around 400 million tweets [CNET, http] and more than 2.7 billion comments on Facebook [CNBC, http] are generated every day. Due to the popularity of these social networks, more and more users leave comments expressing their experiences with products or commercial services. This information is of much interest to business, because they would know their strengths, and, most importantly, their weaknesses.

Due to the large volume of data, a manual analysis of this information is an almost impossible problem. For this reason, in recent years, several methods of NLP have been developed to extract and identify subjective information in texts. This area is known as sentiment analysis or opinion mining. Opinion mining aims to extract attributes and components of a text to determine whether comments are positive, negative or neutral [Pang, 2008].

SentiStrength is a tool that has demonstrated good results in opinion mining for the social web [Thelwall, 2010]. SentiStrength estimates the strength of positive and negative sentiments in short texts, even for informal language. SentiStrength uses a dictionary of sentiment words, each one associated with a weight, which is its sentiment strength. In addition, this method uses some rules for non-standard grammar.

This research presents an opinion mining tool based on SentiStrength for analysis of comments from the Peruvian Facebook and Twitter (Spanish). The rest of the paper is organized as follows. In section 2 we explain the SentiStrength algorithm. In section 3 we describe the proposed method for opinions classification. Section 4 contains the test data used in this work, as well as, the results obtained in experiments. Finally in section 5 we present our conclusions.

SentiStrength

SentiStrength is a method oriented to detect sentiment in informal texts [Thelwall, 2010]. For this reason, in addition to a sentimental word dictionary it takes into account the most common spelling styles in social networks (e.g. "h8" and "hate" have the same meaning). This algorithm uses two scales, from 1 to 5 and from -1 to -5, to

classify a text. SentiStrength evaluates the contribution of positive and negative sentiments separately and makes a decision based on their values.

The main resources used in this algorithm are [Thelwall, 2012]:

- A sentimental word list, this is a collection of 298 positive terms and 465 negative terms. Each word has a value from 2 to 5, if positive, or -2 to -5, if negative.
- A spelling correction algorithm for English language.
- A booster word list is used to strengthen or weaken the emotion of a list of sentiment words.
- An idiom list is used to identify the sentiment of a few common phrases.
- A negating word list is used to invert emotion words (skipping any intervening booster words).
- An emoticon list, which has an associated sentimental weight.
- Sentences with exclamation marks have a minimum weight.
- Stemmers are not used

The proposed classifier

The proposed classifier uses a lexicon-based approach [Taboada, 2011]. We consider 3 categories: positive, negative and neutral. This algorithm uses a scale from 0 to 1 to classify a text. Our classifier uses the SentiStrength resources described in the previous section. However, unlike SentiStrength, we consider some linguistic particularities used in Peruvian comments on Facebook and Twitter. We consider slangs, abbreviations and Peruvian combinations

Also, we use a parameterization module to identify: sentimental words, booster words, negating words, emoticons, exclamation marks, idiom words and Peruvian slang. To classify a comment as positive, negative or neutral we take into account 3 types of contributions: words, combination of words and emoticons contributions. The classifier evaluates the contribution of positive and negative sentiments and makes a decision based on their values.. Figure 1 shows the contents of classifier.

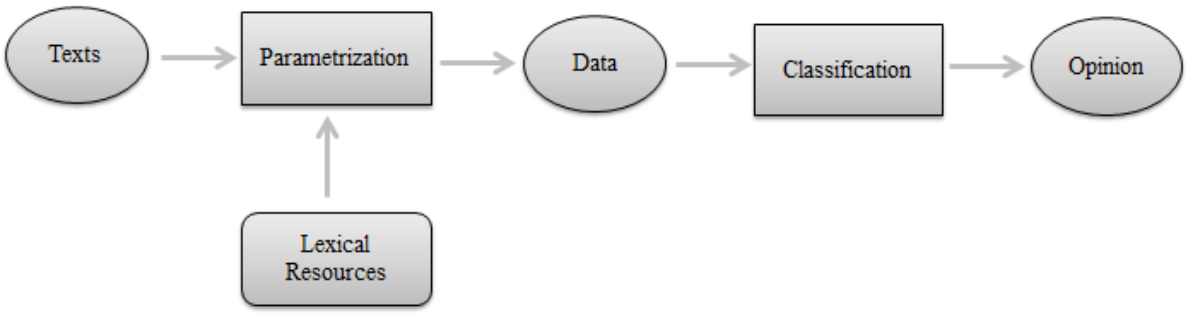

Fig. 1. Contents of opinion classifier

Experiments

Document set

We realize experiments to evaluate the quality of classifier performance. We also compared it with SentiStrength Itself. For the experiments we used a collection of 282 comments from Facebook and Twitter, which were collected from various Peruvian Internet pages. The collection was created manually and every comment was

classified as positive, negative or neutral by 3 experts. The coincidence of classification of the 282 comments by experts was 82.5%. Table 1 shows the composition of this collection.

Table 1. Composition of comments collection

Category	Facebook	Twitter
Telecommunication	21	21
Fast food chain	22	22
Cinema	19	19
Bank	20	20
Chocolate shops	21	--
Filling station	20	--
Gastronomic Festival	11	--
Public personalities	16	--
Life Insurance	15	--
Soda	17	--
Airlines	18	--
Total	**200**	**82**

Results

Table 2 shows positive, negative, neutral and total accuracy obtained by SentiStrength and our proposed classifier for Facebook and Twitter. In both cases the classifier overcomes standard SentiStrength. The reason is: the classifier is specially adjusted for Peruvian texts. The results for comments on Facebook are better than on Twitter. The reason is: comments on Twitter are shorter (at most 140 characters). The best neutral accuracy proves to be reached with Twitter comments, because the vast majority of comments in Twitter do not express sentiment.

Table 2. Results on Facebook and Twitter

	Facebook		Twitter	
Accuracy	**SentiStrength**	**Classifier**	**SentiStrength**	**Classifier**
Positive Accuracy	85.37%	86.90%	52.17%	34.78%
Negative Accuracy	62.34%	83.33%	51.43%	62.86%
Neutral Accuracy	26.83%	15.79%	29.17%	62.50%
Total Accuracy	**64.5%**	**72.0%**	**45.12%**	**54.88%**

Conclusion

The main results of the paper are:

- We proposed a classifier which uses 3 types of contributions: words, word combinations and emoticons. This classifier uses lexical resources of standard Spanish SentiStrength enriched by Peruvian lexis.
- The experiments demonstrate the essentially better results than the standard SentiStrength provides.

In the future we suppose:

- to use more categories of classification, such as very positive and very negative
- to improve the grammatical rules used

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Authors' Information

Roque López *– Student of System Engeenering at San Agustin National University, calle Santa Catalina Nº 117 Arequipa, Peru; e-mail: rlopezc27@gmai.lcom*

Major Fields of Scientific Research: natural language processing, text mining, social network analysis

Javier Tejada Cárcamo *– Professor of Computer Science Department, San Pablo Catholic University; Research and Software Development Center of San Agustin National University (Cátedra Concytec); e-mail:* jawitejada@hotmail.com

Major Fields of Scientific Research: natural language processing, word space models, business intelligence

Mike Thelwall *– Professor, Department of Information Studies-Abo Akademi University. Research Associate, Oxford Internet Institute-Oxford University; e-mail:* m.thelwall@wlv.ac.uk

Major Fields of Scientific Research: Cybermetrics, scientometrics, information science and social metadata (tagging, folksonomy)

PARAMETERIZATION OF COMMENTS FROM PERUVIAN FACEBOOK AND TWITTER: LEXICAL RESOURCES AND ALGORITHM

Angels Catena, Mikhail Alexandrov, Roque López

Abstract: *Millions of Facebook and Twitter users send their comments all over the world about products and services, political and economical events, etc. (almost 3 billions each day) The principal problem of opinion mining such information is text parameterization, and in the paper we describe our experience in solution of this problem with Peruvian Facebook and Twitter. We use enriched vocabularies of Spanish SentiStrength and propose a simple algorithm for evaluation of sentiment contribution. The work was completed in the framework of the project WAYRA (Telefonica-Peru). The results proved to be promised: opinion analysis of parameterized texts showed the accuracy about 75% with elementary classifier*

Keywords: *opinion mining, SentiStrength, Facebook and Twitter*

ACM Classification Keywords: *I.2.7 Natural Language Processing*

Introduction

Social Networks became an important source of information for very different applications. Around 400 million tweets [CNET, http] and more than 2.7 billion comments on Facebook [CNBC, http] are generated every day. People want to share their opinions about products and services, economical situation and political events and this feedback proves to be very useful for those who offer these products or who are responsible for these events.

The first NLP tools for Opinion Mining dealt with so-called 'ordinary' documents. Speaking 'ordinary' we mean not very short documents with usual normative lexis. As an example we can mention here the well-known program SO CAL. This program was applied for processing messages on forums, where the quality of various products and services were discussed. It provided the average accuracy 80% for binary classification of opinions [Taboada, 2006]. The other example is the program Opininer-UAB. We used this program for processing analytical texts in electronic publications concerning economical crisis in Europe. Opininer-UAB showed the accuracy 75%-80% for binary classification and about 60% for more detail classification with four categories [Catena, 2010].

But we meet the absolutely other situation when we have to work with comments from Facebook and Twitter. They are super-short (usually 2-5 phrases) and they use non-normative lexis (abbreviations, slang, emotional punctuation, etc.). For this reason it is difficult to reach the accuracy we pointed above. The SentiStrength program is one of the best tools we know for Opinion Mining texts from Facebook and Twitter [Thelwall, 2010; Thelwall, 2012]. By the moment there are versions of SentiStrength in English, German, French, Italian, Spanish, and some other languages. The usual Spanish SentiStrength version provides the accuracy 65% and its last modification especially oriented on the Peruvian Facebook and Twitter provides the accuracy 74% [Lopez, 2012]

This paper is the continuation of the previous work. It was completed in the framework of the ambitious project WAYRA by the company Telefonica-Peru [WAYRA-a, http; WAYRA-b, http]. In this work we concern only the process of text parameterization, which have the decisive role in Opinion Mining texts from social networks. The program is written on Python. The document collection includes 200 comments.

In the section 2 we describe the linguistic resources. Section 3 demonstrates step by step the work of algorithm. The results of experiments are shortly presented in section 4. Section 5 contains the conclusions.

Linguistic resources

Beta version of our program includes 6 vocabularies. The examples below present English translation of Spanish words and word combinations. The values in brackets mean weights or marks. We use 4 values for the scale of sentiment weights {-2, -1, 1, 2}. Here are these vocabularies:

1) Vocabulary-W (words). It is stop words: pronouns, prepositions and articles
2) Vocabulary-P (palabras = words, Spanish). It is single words presented in shorten flexible form with their weights. The vocabulary contains normative lexis and slang. Some examples are: excellen# [2], better[1], problem# [-1], terrible [-2]. Here '#' means possible letters.
3) Vocabulary-C (combinations). It is fixed word combinations with their weights. The vocabulary contains normative lexis and slang. Some examples are: nothing bad [1], it is worth [1], never one can [-1], nothing good [-1]
4) Vocabulary-N (negations). It is patterns with marks. Some examples are: nobody [2], no [1]. Here mark 2 means that a word related with this pattern changes its polarity and its absolute weight doubles; mark 1 means that a word related with this pattern only changes its polarity.
5) Vocabulary-R (realces = emphatic constructions, Spanish). It is patterns with marks. Some examples are: super [2], ultra [2], more [1], less [-1]. Here: marks mean increasing or decreasing the value of an adjacent word respectively.
6) Vocabulary-S (signs). It is patterns with weights. The vocabulary contains emoticons and punctuation. Some examples are: :-)[1], :-([-1], !![0], ?[-1], ??[-2]. Here the elements with the weight '0' increase the value of previous sentiment over its basic value. Let we have two sentiments: good [1] and terrible [-2]. According this rule the total weight of 'good!!' is equal (1+1)=2, and the total weight of 'terrible!!' is equal (-2-1)=-3.

We are not sure whether it is worth to use our scale of weights {-2, -1, 1, 2} instead of the rude one {-1,1}. Such a question needs the additional experiments. In particularly, the paper [Kaurova, 2010] demonstrates examples where we lose only 2%-4% of accuracy with the scale {-1,1} instead of the detail scale {-5,-4,…4,5}.

Algorithm

3.1 Preprocessing

On this stage we introduce four arrays: **Comment, Text, Mark-1, Mark-2.** To demonstrate how the algorithm works we consider an example:

- no noa no me gustaa este producto muya malooo :-(:-(vale la pena olvidarlo (incorrected text in Spanish)

- *no I don't like this very bad product it is worth to forget it* (text translated to English after correction)

1) **Comment**. It is a comment presented in the lineal form without the division on phrases. Each cell contains one word or one sign before correction

No	noa	no	me	gustaa	este	producta	muya	maloo	;-(	;-(	vale	la
pena	olvidarlo											

2) **Text**. It is a comment presented in the lineal form without the division on phrases. Each cell contains one word or one sign after correction

N no n m g est pro m m ;- ;- v L
o o e usta e ducto uy alo ((ale a
P olv
ena idarlo

Having eliminated the repeated elements we have a new list of words and signs

n m g e pro m m ;- v l p olv
o e usta ste ducto uy alo (ale a ena idarlo

Having eliminated stop-words we have the other list. But stop-words being the part of fixed word combinations are not considered. See here: vale **la** pena (= it is worth).

gu pro m m ; v l p olv
no sta ducto uy alo -(ale a ena idarlo

3) **Mark-1.** It is the set of denominations, which reflect the type of elements. We use the following list of denominations:

- P is a word from the Vocabulary-P
- C is a word combination from the Vocabulary-C
- R is an emphatic construction from the Vocabulary-R
- N is a negation from the Vocabulary-N
- S is a sign from the Vocabulary-S
- Z means that an element has no any weight

Therefore for our example we have:

N P Z R P S C Z

4) **Mark-2.** This array is directly related with the array **Mark-1**. Namely, here each cell contains the marks and weight of a correspondent element from the **Mark-1.**

1 1 0 1 - - 1 0
1 1

These data are taken from the vocabularies.

3.2 Processing

On this stage we use two arrays: **Indicator** and **Weight**

5) **Indicator.** It is a set of indicators, which show each moment whether the correspondent element of text has been evaluated or no. The program evaluates a given text from left to right revealing patterns according the list of rules (we mention them later). The elements are marked with '1' step by step.

6) **Weight.** It is the array of points, each pattern of a comment contributes to the total assessment. Here the array **Mark-2** is used**.** The array **Weight** changes its contents having revealed each pattern. The points are written to the first cell this pattern occupies

Initially we have:

Mark-1

N P Z R P S C Z

Mark-2

1 1 0 1 - - 1 0

1 1

Indicator

0 0 0 0 0 0 0 0

Weight

0 0 0 0 0 0 0 0

After the first step:

Mark-1

N P Z R P S C Z

Mark-2

1 1 0 1 - - 1 0

1 1

Indicator

1 1 1 0 0 0 0 0

Weight

0 0 0 0 0 0 0 0

-1

After the second step:

Mark-1

N P Z R P S C Z

Mark-2

1 1 0 1 - - 1 0

1 1

Indicator

1 1 1 1 1 0 0 0

Weight

0 0 - 0 0 0 0

-1 2

After the third step:

Mark-1

N P Z R P S C Z

Mark-2

1 1 0 1 - - 1 0

1 1

Indicator

1 1 1 1 1 1 0 0

Weight

-	0	0	-	0	-	0	0
1			2		1		

After the fourth step:

Mark-1

N	P	Z	R	P	S	C	Z

Mark-2

1	1	0	1	-	-	1	0
				1	1		

Indicator

1	1	1	1	1	1	1	1

Weight

-	0	0	-	0	-	1	0
1			2		1		

Then all positive and negative scores are summed. The Table 1 shows the final result of text processing

Table 1. Results of comment processing

Positive scores	***Number of positive sentiments***	***Negative scores***	***Number of negative sentiments***
1	1	-4	3

In this example we indirectly used some rules for processing sequences NPZ, RPZ, etc. Here the symbols 'N', "P', 'Z' mean the types of elements in a phrase under consideration (see section 3.1). This moment the program includes 6 different rules for processing phrases.

Experiments

4.1 Elementary classifier

To demonstrate the effectiveness of proposed algorithm we used 200 comments from the Peruvian Facebook and Twitter. All comments were evaluated by 3 experts using the scale: positive, neutral, negative. Then these comments were parameterized: the part of texts (150) was used for constructing classifier, and the other part (50) for testing.

The elementary threshold-based classifier is formed by the following way

- All parameterized comments are presented in the scale

  $r = (PosScore + NegScore) / (PosScore + | NegScore |)$. Here: *PosScore* and *NegScore* are contributions of positive and negative sentiments respectively. Obviously, $|r| \leq 1$
- Histogram of the learning set (150 comments in our case) is constructed on the basis of variable *r*
- Thresholds for decision-making are manually adjusted to provide the maximum accuracy

Of course, we do not pretend here to have any sophisticated classifier. The modern approaches for opinion mining are known and these approaches have been already described in detail in the publications [Pang, 2008; Taboada, 2011]. The only we want is to show that our algorithm of parameterization allows to obtain good results even with the simplest classifier.

4.2 Results of classification

The Table 2 shows some results with the classification of testing set (50 comments)

Table 2. Results of classification

Categories and the number of objects	***Thresholds***	***Rules***	***Accuracy***
Positive (42%) Neutral (39%) Negative (19%)	Up = 0,05 Un = - 0,05	*I* ≥ Up Positive *I* < Un Negative The other ones are Neutral	72%
Positive (42%) Indefined - Negative (19%) The neutral category is not considered	Up = 0,2 Un = -0,2	*I* ≥ Up Positive *I* < Un Negative The other ones are Indefined	77%

Notes.

1) We have to introduce the so-called undefined category to improve the quality of results: sometimes is better to say “I do not know” instead of any erroneous answer
2) We suppose the results will be essentially better if to use any more advanced classifier instead of the elementary one

Conclusions

The main results of the paper are:

- We proposed method (linguistic resources and algorithm) for parameterization of comments from Facebook and Twitter.
- Experiments with real Peruvian Facebook and Twitter showed the promised results
- The method with modifications can be used for processing comments on other languages

In the future we suppose:

- to extend the list of grammatical rules
- to test the binary scale for sentiment classification

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Authors' Information

Angels Catena – *Professor, Department of French and Romance Philology, fLexSem Research Group, Autonomous University of Barcelona, 08193 Bellaterra (Barcelona), Spain;*

e-mail: Angels.Catena@gmail.com

Major Fields of Scientific Research: sentiment analysis, French lexis and semantics sentiment analysis,

Mikhail Alexandrov – *Professor of the Russian Presidential Academy of national economy and public administration; Prosp. Vernadskogo 82, bld. 1, Moscow, 119571, Russia; research fellow of the fLexSem Research Group, Autonomous University of Barcelona, 08193 Bellaterra (Barcelona), Spain;*

e-mail: MAlexandrov@mail.ru

Major Fields of Scientific Research: data mining, text mining, mathematical modelling

Roque López – *Student of System Engeenering at San Agustin National University, calle Santa Catalina Nº 117 Arequipa, Peru;*

e-mail: rlopezc27@gmai.lcom

Major Fields of Scientific Research: natural language processing, text mining, social network analysis

INTELLIGENT TUTORING SYSTEM FOR BELARUSIAN AS A FOREIGN LANGUAGE

Olga Yeliseyeva, Yury Kim

Abstract: *The paper presents the concept of an intelligent tutoring system for learning Belarusian as a foreign language. At the heart of the system is a model of learning consisting of the following models: tutor model, learner model, model of Interaction, learning process structure model, learning activity forms model, academic discipline model.*

Keywords: *learning model, tutor model, learner model, model of Interaction, learning process structure model, learning activity forms model, academic discipline model.*

ACM Classification Keywords: *I.2 ARTIFICIAL INTELLIGENCE - I.2.1 Applications and Expert Systems - Natural language interfaces General.*

Introduction

Preserving the Belarusian language is nowadays a pressing problem. On the other hand the number of its foreign learners has recently seen a significant increase. This results in a high demand for quality digital educational resources for Belarusian as a foreign language.

The use of computer technologies in foreign language teaching has already proven to be efficient [http://www.itlt.edu.nstu.ru], [Karamysheva, 2001]. However there is still a significant number of unsolved problems related to linguistics, pedagogics, didactics, psychology and many other fields, which results in the development of applied disciplines (e.g., applied linguistics), or even new schools (such as the computer assisted language teaching [Bovtenko, 2006]). The terminology becomes more precise [http://llt.msu.edu], the problems of semantical language description are being solved [Fillipovich, 2002], methods of automated task generation are being developed [Bashmakov, 2003], significant advances are being made in the understanding of texts by the computer [Leontyeva, 2006], machine translation [Stepanov, 2000] and natural language user interface [Popov, 2004], [Yeliseyeva, 2009], [http://nai.shergin.com/head.htm], [http://iii.ru/garage]. In order to increase the efficiency of computer assisted teaching new remote forms of teaching are being implemented [Brusilovsky, 1994], new generations of digital tutoring systems., i.e., intelligent tutoring systems [Brusilovsky, 1990], [Petrushin, 1993], [Helander, 1997], [Golenkov, 2001], [Graesser, 2005], [Chad Lane, 2006] and expert tutoring systems (ETS) [Petrushin, 1991], [Rybina, 2008] are being developed.

One of the biggest issues in the development of intelligent tutoring systems (ITS) is that such fields as pedagogy and psychology are still not sufficiently formalized, as instructors can't describe with necessary detail their teaching methods. When creating ITS for foreign language instruction, the problem of automatical text processing add up to the above [Skorokhodko, 1983], [Jurafsky, 2009] as well as problems related to its formalization and the creation of appropriate knowledge bases [Gavrilova, 2001], [Golenkov, 2004], [Russel, 2006]. Therefore such systems can be developed only as a joint effort of linguists, foreign language instructors and IT-specialists. This work presents the concept of an intelligent tutoring system for Belarusian as a foreign language (ITS BFL). The main purpose of this concept is to provide all ITS BFL developers with a general formal description of its components in order to enable them to pursue their work independently.

To create a computer tutoring system one needs to model the learning process. From the very first computer learning systems the following aspects have constantly changed: system development approaches, computer assisted teaching methods, computer technologies. The evolution of computer technologies is probably the most important, as it defines the viable models. However, some systems developed 10 - 15 years ago can still serve as a standard in the modern research. The most precious part of such systems are teaching methodologies that were carefully elaborated for particular subjects.

The Learning Process Model

Above we have pointed out the main issues that we will deal with further. First we will need an exact definition of the learning process. We can easily find various definitions in pedagogical, didactic and even psychological sources. However our goal is not to register all possible definitions, but to understand the nature of the learning process in order to eventually model it. From pedagogical writings we can conclude that the learning process is a multidimensional concept. This process involves the following elements that also need to be modelled:

- The participants of the learning process (the tutor and the learner).
- The interaction (between the participants).
- The structure of the learning process (a set of particular stages forming a sequence in time).
- Various learning activities (lectures, seminars, practicals, tests, etc.).
- The educational content (the academic discipline within which all the information has a hierarchical structure based on particular teaching methods).

Thus formally, **the learning process model** can be described as follows:

$$LM = \{ mT, mL, mI, mSLP, mFLA, mAD \},\ LM - \underline{L}earning\ \underline{M}odel,\ mT - \underline{m}odel\ of\ \underline{T}utor,\ mL - \underline{m}odel\ of\ \underline{L}earner,\ mI - \underline{m}odel\ of\ \underline{I}nteraction,\ mSLP - \underline{m}odel\ of\ \underline{S}tructure\ of\ \underline{L}earning\ \underline{P}rocess,\ mFLA - \underline{m}odel\ of\ \underline{F}orms\ of\ \underline{L}earning\ \underline{A}ctivities,\ mAD - \underline{m}odel\ of\ \underline{A}cademic\ \underline{D}iscipline \quad (1)$$

A model cannot reflect all particularities of a real object. We replace real participants, objects, processes and states completely or partially with their computer models. Thus in the given learning model LM within an intelligent tutoring system we have a complete **model of tutor** mT and only a partial **model of learner** mL. The learner model reflects the tutor's vision of him and thus can be formalized only partially.

Goals and Tasks of Learning. Tutor Model and Learner Model

Just like any other process, the learning process has a goal and intermediate tasks, which are defined depending on the expected results. Therefore within the above mentioned models we need to point out appropriate **goals**, **subgoals**, **tasks** and **subtasks**. It will result in the following:

$$mT \supset \{ Gt, SGt, Tt, STt \},\ Gt - \underline{G}oals\ of\ \underline{t}utor,\ SGt - \underline{S}ub\underline{G}oals\ of\ \underline{t}utor,\ Tt - \underline{T}asks\ of\ \underline{t}utor,\ STt - \underline{S}ub\underline{T}asks\ of\ \underline{t}utor,\ Gt = \{ Gt_i, i=1, \dots, Nt \},\ SGt = \{ SGt_i, i=1, \dots, Kt \},\ Tt = \{ Tt_i, i=1, \dots, Lt \},\ STt = \{ STt_i, i=1, \dots, Mt \} \quad (2)$$

$$mL \supset \{ Gl, SGl, Tl, STl \},\ Gl - \underline{G}oals\ of\ \underline{l}earner,\ SGl - \underline{S}ub\underline{G}oals\ of\ \underline{l}earner,\ Tl - \underline{T}asks\ of\ \underline{l}earner,\ STl - \underline{S}ub\underline{T}asks\ of\ \underline{l}earner,\ Gl = \{ Gl_i, i=1, \dots, Nl \},\ SGl = \{ SGl_i, i=1, \dots, Kl \},\ Tl = \{ Tl_i, i=1, \dots, Ll \},\ STl = \{ STl_i, i=1, \dots, Ml \} \quad (3)$$

$$mI \supset \{ Gi, SGi, Ti, STi \},\ Gi - \underline{G}oals\ of\ \underline{i}nteraction,\ SGi - \underline{S}ub\underline{G}oals\ of\ \underline{i}nteraction,\ Ti - \underline{T}asks\ of\ \underline{i}nteraction,\ STi - \underline{S}ub\underline{T}asks\ of\ \underline{i}nteraction,\ Gi = \{ Gi_i, i=1, \dots, Ni \},\ SGi = \{ SGi_i, i=1, \dots, Ki \},\ Ti = \{ Ti_i, i=1, \dots, Li \},\ STi = \{ STt_i, i=1, \dots, Mi \} \quad (4)$$

Obviously the sets of subgoals and subtasks in each of the models can turn out to be empty. However the sets of goals and tasks cannot be empty. Therefore in order to simplify the creation of an intelligent tutoring system we can concentrate on simplified models containing only non-empty sets of goals and tasks:

$$mT \supset \{ Gt, Tt \}, Gt \neq \varnothing, Tt \neq \varnothing, mL \supset \{ Gl, Tl \}, Gl \neq \varnothing, Tl \neq \varnothing, ml \supset \{ Gi, Ti \}, Gi \neq \varnothing, Ti \neq \varnothing \quad (2'), (3'), (4')$$

2.1. Result of Learning

In order for a learning process to be successful and to generate ultimate outcome all set goals need to be achieved, which in turn requires the accomplishment of all tasks. All the above mentioned goals make up the **result of learning**:

$$RL \Leftarrow \{ Gt, Gl, Gi \}, RL - \underline{R}esult\ of\ \underline{L}earning, LM \supset RL \quad (5)$$

2.2. Refinement of Tutor Model and Learner Model

The success of the learning process depends on the level of coordination between goals and tasks set within each model. For instance the goal that the tutor sets has to be well understood by the learner and moreover be in line with his personal goal. The tutor sets the following global goal: "bring the learner to a level of proficiency in Belarusian sufficient for basic communication". Based on this, the learner's goal will be something like: "acquire a level of proficiency sufficient for basic communication". However if there is a discrepancy between their goals, some of the learning tasks won't be accomplished or will be only partially accomplished. Therefore the number of goals and subgoals within the tutor and the learner models should be the same. There are obviously hierarchical connections between goals and tasks. We shall call the coordination of goals $\leftrightarrow$, hierarchical connections – $\rightarrow$. We can refine the models mT (2) and mL (3) as follows:

$$Gt \leftrightarrow Gl \Rightarrow Nt = Ns = N, \ N \text{ stands for the number of goals} \quad (6)$$

$$SGt \leftrightarrow SGl \Rightarrow Kt = Ks = K, \ K - \text{stands for the number of subgoals} \quad (7)$$

$$mT \supset \{ Gt \rightarrow SGt \rightarrow Tt \rightarrow STt \}, Gt = \{ Gt_i, i=1, \dots, N \}, SGt = \{ SGt_i, i=1, \dots, K \} \quad (8)$$

$$mL \supset \{ Gl \rightarrow SGl \rightarrow Tl \rightarrow STl \}, Gl = \{ Gt_i, i=1, \dots, N \}, SGl = \{ SGl_i, i=1, \dots, K \} \quad (9)$$

As for the teaching tasks definitions - they need to reflect the learning content. It would be even better to reflect the rating of skills and knowledge expected from the learners at a certain level. For instance, in order to achieve the above mentioned goal of Teaching Belarusian at the level of primary acquaintance to learners who have no prior knowledge of the language, we will need to accomplish the following tasks: "Teaching the pronunciation of separate phonemes of the language", Teaching the rules of reading a text", etc. Similarly we can formulate some goals within the learner model mL: "Learning Belarusian at the level of primary acquaintance", "Learning Belarusian at the level of general mastery", etc.

These are obviously hypothetical goals, as real-life learners are often unable to formulate their goals. Here we can see the confirmation of the above cited statement, that the learner model is just a reflection of the tutor's vision of him. They simply reflect the similar tasks of the tutor model mT. These tasks cannot be fully set by the learner because he has only a vague idea of the goals and tasks of the learning process. Therefore an ITS should be able to set goals and tasks by itself. By harmonizing the goals and tasks of the tutor with those of the learner we can tailor goals and tasks for a given learner. Then they are placed in a knowledge base representing a personal learner mode - mS_{pid} (pid - a learner's personal identifier). The goals and tasks should be defined at the early stages of the system designing.

2.3. Personal Set of Goals and Tasks

Thus the learning model should include the mechanism of coordination between the goals and tasks of the tutor and those of the learner, as well as the resulting generation of a personal set of goals and tasks for each learner. Letter F will stand for these mechanisms, which will be treated as functions contained within the tutor model:

$$mT \supset \{ F(Gt, Gl, \ldots), F(SGt, SGl, \ldots), F(Tt, Tl, \ldots), F(STt, STl, \ldots) \} \quad (10)$$

In order to be able to set personal goals and tasks for a given learner the ITS needs first to have some initial information on him. Therefore the learner model should include the following additional elements:

$$mL \supset \{ PID, PNS, PD, CLK, PLA, IPC, PP \},$$ PID – Personal IDentifier, PNS – Personal Name and Surname, PD – Personal Data (gender, age, etc.), CLK – Current Level of Knowledge, PLA – Protocol of Learning Activity, IPC – Individual Psychological Characteristics, PP – Personal Preferences. (11)

Then the set of parameters of coordination between the goals and tasks of the tutor and the learner may be further refined as:

$$mT \supset \{ F(Gt, Gl, PID, CLK, PLA, IPC, PP), F(SGt, SGl, PID, CLK, PLA, IPC, PP), F(Tt, Tl, PID, CLK, PLA, IPC, PP), F(STt, STl, PID, CLK, PLA, IPC, PP) \} \quad (10')$$

The current set of learning goals and tasks defined for the given learner will be the output of the functions.

Almost all formulations of learning tasks within the learner model mL describe expected results of the learning process. It confirms the above mentioned formula (5). Besides, sets of learning goals and tasks as well as expected results correspond to particular stages within the structure of the learning process:

$$RL \leftrightarrow mSLP \quad (12)$$

The Interaction Model

The Interaction model within the ITS represents a real-life process of communication between the tutor and the learner. As in the ITS the tutor is replaced by a computer system, we need to take into account the human-computer interaction. In this paper we will try to refine the existing models of communication and models of human-computer interactions. Besides, bearing in mind the particularities of the ITS BFL we are designing, we will consider that the interaction will be in a natural language. Thus, the interaction model mI will look like this:

$$mI = \{ mScI, IPs, mSIn, USM, mDg, mLgs, mW \},$$ mScI – model of Scripts of Interaction, IPs – Interaction Protocols, mSIn – model of the System Interface, USM –User Speech Model, mDg – model of Dialogue, mLgs – models of Languages, mW – model of the World (13)

3.1. The Interaction Scenarios Model

Within the **interaction scenarios model** mScI we build scenarios of interaction between the ITS and a given learner ScI_{PID} in accordance with current learning tasks. Every step of the scenario is associated with the structure of the learning material within the model of a given academic discipline mAD. For instance, for the task "Teaching the pronunciation of separate phonemes of Belarusian" we can build the following scenario: "1. Suggest the learner learning content relevant for the topic "Phonemes". 2. Suggest the learner relevant exercises. 3. Suggest the learner a test to evaluate the knowledge".

This scenario is very simplified. But it shows that before creating scenarios within the ITS design process one should first have thoroughly elaborated the structure and the content of the academic discipline. In order to build individual scenarios Scl_{pid} within the interaction model first we need to implement the following functions:

$$mScl \supset \{ F(Gl, PID, SAD) \}, SAD - \underline{S}tructure\ of\ \underline{A}cademic\ \underline{D}iscipline, SAD \subset mAD \quad (14)$$

3.2. Interaction Protocols

In the process of interaction between the ITS and the learner special **interaction protocols** (IPs_{pid}) are created: they will be identical to scenarios if the learner followed exactly all the recommendations from the system. But as in real-life learning process, the learner can skip some tasks or get a score lower than required, or start learning materials not included in the current learning scenario etc. Such situations should be reflected in the interaction protocol, based on which sets of learning goals and tasks can be modified later. Thus, learning goals and tasks are based on the analysis of interaction protocols:

$$mT \supset \{ F(Gt, Gl, PID, CLK, PLA, IPC, PP, IPs), F(SGt, SGl, PID, CLK, PLA, IPC, PP, IPs), F(Tt, Tl, PID, CLK, PLA, IPC, PP, IPs), F(STt, STl, PID, CLK, PLA, IPC, PP, IPs) \} \quad (10'')$$

3.3. The System Interface Model

Within the mSIn **system interface model** we need to describe all supported modes of interaction between the ITS and the user (interface elements: windows, menus, toolbars, text fields, etc.), as well as the structure and design of the interface:

$$mSIn \supset \{ StrI \supset \{ IEls, LSI \}, IDsgn \}, StrI - \underline{Str}ucture\ of\ the\ \underline{I}nterface, IEls - \underline{I}nterface\ \underline{El}ements, LSI - \underline{L}inguistic\ \underline{S}upport\ of\ \underline{I}nterface, IDsgn - \underline{I}nterface\ \underline{Desi}gn \quad (15)$$

We will not enumerate all possible **elements of the interface** (IEls). In the standard Windows interface it will be a commonly known set of elements, each of these elements will have a unique ID a predefined set of functions within the model. All interface elements identified in this way will be included in the description of **the interface structure** StrI, a tree of elements and their vertical and horizontal connections. In order to implement the natural-language interaction within the interface model appropriate elements need to be included.

3.4. The Interface Linguistic Support

Particularly important in the interface model mSIn is **the interface linguistic support** LSI. Unfortunately many developers still underestimate this component. This negligence makes many applications almost totally occult for users or at least seriously degrades the user experience. It is even more important in the ITS, because the efficiency of the learning process depends on the overall usability, simplicity and relevance of menu items, pop-up tips, messages, warnings, dialogs and other linguistic components.

Now, as we are dealing with the creation of an ITS for learning Belarusian as a foreign language, the linguistic support of the interface should include a possibility to use an interlingua, i.e., the mother language of the learner or any other language which he commands well.

The interface model may be incomplete, but this component of the ITS seems to be one of the most important ones and requires special attention: after all, the efficiency of the learning process relies on the level of the system usability. This is in a direct connection with motivating the learner. Besides all issues experienced by user due to the interface inconvenience or unintelligibility will have an overall negative impact on the teaching of the given subject, i.e., in our case of Belarusian.

3.5. Flexibility and Customization of Interface

As we are discussing the concept of an intelligent system, it's natural to suppose that its interface has to be flexible and customizable to fit the particularities of individual users (PD, IPC), as well as to meet their preferences PP - (11). Therefore when elaborating the interface structure StrI we must provide a possibility for various types of branching. Just as flexible should be the interface IDsgn - it should be customizable when switching between different users, modes of use included in the learning process structure model mSLP, different forms of learning activities mFLA or academic disciplines mAD. One can't describe all possible interface configurations in advance. Therefore, within the interaction model one should include mechanisms for customizing the structure and design of the interface:

$$\begin{gathered} \text{mSIn} \supset \{ \text{F(StrI, IDsgn, PID (PD, IPC, PP), SEP, FLA, SAD)} \}, \\ \text{SEP – Structure of Educational Process, SEP} \subset \text{mSLP, FLA – Forms of Learning Activities,} \\ \text{FLA} \subset \text{mFLA, SAD – Structure of Academic Discipline, SAD} \subset \text{mAD} \end{gathered} \tag{16}$$

Obviously there has to be coordination between the mechanisms construction of custom interaction scenarios or structure interface structure. Thus the following models are coordinated:

$$\text{mScI} \leftrightarrow \text{mSIn} \tag{17}$$

3.6. User Speech Model and the Dialog Model

User Speech Model USM is introduced in the interaction model mI in order to point out that ITS takes into account the learner's individual characteristics when communicating with him using natural language. The user speech model will include the following characteristics of the user: vocabulary; complexity of grammatical constructions used; the speech rate (this includes not only the actual speech but also the keyboard input speed); speech perception rate. This evaluates the speed at which the learner can comprehend the spoken language as well as how fast he can read; speech defects, including frequent grammar mistakes in the written input.

As the system in question should enable natural language dialogue functionality, the interaction model mI includes **the dialogue model** mDg. In the majority of natural language dialogue systems the interaction is almost completely defined by the particular topic of the system. It's quite easy to describe, for example, the dialogue of the user with a ticket-reservation system. In the ITS BFL it's hard to define one particular subject. Thus within the dialogue model mDg it makes more sense to speak of a set of models, each corresponding to a particular subject area. This concerns especially the dialogue subject. However there are general principles for creating the dialogue interaction. Researchers distinguish particular phases of a dialog, different types of dialogs, make attempts to model dialogs, etc. In the present work we are not trying to give an overview of all achievements in the dialogue theory. This would require a much larger volume. We will only try to point out particular components of the dialogue within the ITS discussed. We will take into account the fact that the communication is taking place within the learning process. Thus, the dialogue model mDg can be represented as follows:

$$\begin{gathered} \text{mDg} = \{ \text{TD, LD, SbD, PEC, MacroD, MicroD} \}, \text{TD – Type of Dialogue, LD – Language of Dialogue,} \\ \text{SbD – Subject (topic) of Dialogue, PEC – Purpose Entities Communicate, MacroD – Macrostructure of} \\ \text{Dialog, MicroD – Microstructure of Dialog} \end{gathered} \tag{18}$$

3.7. Models of Languages and the World Model

As the communication is conducted in a language (or several languages, if an Interlingua is used) we have included in the interaction model **models of languages** mLgs. As the volume of this paper is very limited, we will

not analyze these models in detail. For the discussed ITS BFL the model of Belarusian is both a studied **domain model** DM (Domain Model) and **an Academic discipline model** (mAD). Obviously modelling a language both for natural language human-computer interaction and for the teaching of the given language requires a particular approach. However primary researches impose that hierarchical levels distinguished by the linguists need to be reflected within the given model. Additionally, a language model as well as an academic discipline model needs to include various levels of complexity of language components and show the frequency of usage of particular patterns and the importance of a given element for the overall learning process (i.e., whether a topic is an absolute must for learning or just an additional element and thus can be omitted). Thoroughly formalizing at least the most common rules of language seems to be a good idea, because it will enable the system to analyze or generate natural language utterances in the course of dialogue with the user as well as for explaining these rules to the learner. Besides these rules must be used for automatic generation of various exercises and the correction of mistakes made by the learner (ranging from grammar to grammar and stylistic-related mistakes).

The last component of the interaction model in question is **the world model** mW. This component of the ITS BFL is probably the largest and the most complicated in terms of formalization, because the main goal of foreign language learning is, as we have stated above the acquisition of speech competence within a wide range of topics. Therefore when discussing the creation of an all-purpose system, in our conception the surrounding world model mW will be a set of models of various subject areas (domains). Depending on the level of the learner or on the subject area in which he wants to use the language, the ITS should activate the model of a relevant **subject domain** (DM).

Learning Process Structure Model

Thus the components of **learning process structure model** mSLP, **learning activity forms models** mFLA, **academic discipline models** mAD depend directly on the goals and tasks set within **the tutor model** mT, **the learner model** mL and **the interaction model** mI. For example, the above mentioned learning goals and tasks already contain corresponding learning stages and elements of the content of the learning material

Within **the learning process structure model** mSLP it is reasonable to consider the time frame of the learning process, split up in terms (terms - Tr) with corresponding goals and tasks:

$$\begin{gathered} \text{mSLP} \subset \{ \text{Tr} \subset \{ \text{Gtr} \to \text{Ttr} \} \},\ \text{Gtr} - \text{Goals of term},\ \text{Ttr} - \text{Tasks of term}, \\ \text{Tr} = \{ T_j \}, j=1, \ldots, \text{Qtr},\ \text{Gtr} = \{ \text{Gtr}_{ji} \}, i=1, \ldots, \text{Ntr},\ \text{Ttr} = \{ \text{Ttr}_{ji} \}, i=1, \ldots, \text{Ltr} \end{gathered} \tag{19}$$

The time frame of each term are set as exact intervals within a certain calendar system (absolute system) or, in the case of remote learning, as sets of start and end points (relative system). In the second case the start and end points are assigned a set of academic requirements relative to the learner's current level of competence. Depending on the type of the learning process organization, additional parameters could be added, e.g., the criteria of competence evaluation and/or the duration of the term.

The model of an academic discipline mAD, as stated above, is, within the ITS BFL closely connected with the model of Belarusian language mBelLg (model of Belarusian Language) and is based on the subject domain model DM. However all the elements of the learning material, its structure as well as their appropriateness for various levels and stages of learning are just as essential for the academic discipline model.

Conclusion

Unfortunately, due to volume constraints we cannot describe all models in more detail in this paper. However we dare to hope that at least at the conceptual level we have managed to analyze the model of learning process within the ITS for learning Belarusian as a foreign language. We must mention that the system is described here as an idealized project. This is done in order to define the most interesting ideas and to explore alternative solutions for complex problems. We do not affirm that this conceptual description of a ITS BFL is complete nor flawless. It is clear that many of the above mentioned ideas need to be refined and some of them are highly debatable.

In conclusion we need to add that in order to embody this concept of an ITS BFL we need to elaborate a set of knowledge representation languages for various purposes. But the use of different languages that are incompatible with each other is not acceptable, because by analyzing the above described models one can easily understand that many of them are closely related to each other. Therefore the choice of the knowledge representation languages should be determined by one base. For this purpose we can use the basic semantic language of knowledge representation SC (Semantic Code), which has been created and is being developed within the open source project OSTIS (Open Semantic Technology for Intelligent Systems, http://www.ostis.net) at the Belarusian State University of Informatics and Radioelectronics in Minsk.

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Authors' Information

Olga Yeliseyeva *– PhD, associate professor of the Department of Applied Linguistics, Faculty of Philology at the Belarusian State University, 39/1 Logoiski tract street, appt.261 Minsk, P.O. Box: 220090, Belarus, e-mail: olae@yandex.ru*

Major Fields of Scientific Research: E-learning, Artificial Intelligence, Natural Language Processing

Kim Yury *– postgraduate student at the Belarusian State University, 28 Tikotskogo street, appt. 83 Minsk, P.O. Box 220119, Belarus e-mail: 6rikim@gmail.com*

Major Fields of Scientific Research: Natural Language Processing

THE EDUCATIONAL TECHNOLOGY FOR LEARNING FOREIGN WORDS

Andrey Dukhovny

Abstract: *German psychologist Hermann Ebbinghaus, the first person studied a memory, experimentally publishes his forgetting curve, which characterized the ability of a human brain to remember the information. He proved experimentally that during the first hour of learning process 60 percent of information is forgotten and after 10 hours of workload our memory abandons 35 percent of information. Then forgetting process become slower and after six days our memory abandons near 20 percent of the learning material. As a result of the research Hermann Ebbinghaus has suggested the algorithm of the effective learning. Based on the modification of the algorithm we have created a special service for learning foreign words called WordSteps. It allows to learn more than 97 percent of new information even in a year after the first training.*

Keywords: *Memory, natural language processing, learning words*

ACM Classification Keywords: *I.2.7 Natural Language Processing*

Introduction

There is an effective method of learning new foreign words. Person just must devote 15 minutes a day to learning. This project has special algorithm, that helps to learn foreign language systematically and efficiently. As we can observe from different linguistic researches and studies, learning new information will be effective if the information we have to learn would be refreshed in our memory at the right time intervals. WordSteps offers a big collection of dictionaries available on the website in 30 different languages: English, Russian, French, Spanish, Chinese, German and others. Project gives an opportunity to find a dictionary or create a new one. Every dictionary could be rated by users. Such system allows members to choose a dictionary of required quality and difficulty level. Next step is to repeat the words person has learned a few days ago. So we can observe a spacing effect in psychology which means that information learned during a long period of time is much better retained than information which is intensively learned during a short period of time. Thus the basic way to success is determined by repetition and regularity.

The list of competitors:

- SuperMemo is a method of learning the information. Their slogan is “everyone can learn effectively” and “forget about forgetting”.
- Smart.fm -> iKnow.jp is a service for learning words. This project has one of the best algorithm of learning. The attendance of this web site is about 60 th/day.
- Quizlet.com- quite old service for learning a new words. It has an open API, Android and iPhone applications. Monetization- is a paid subscription for expanded possibilities.It is not so good at algorithm and simplicity of using, but it is quite popular. The attendance is near 45 th/day. More than one million of registered users.
- Livemocha.com- is one of the biggest social language network. It has the same principle with a busuu.com, with a sale of thematic courses. More than 8 mln of registered users, the attendance is near 200 th/day.

- Rosetta Stone- is a company that produce on-line and soft services for learning foreign languages. It has their own methods of studying. It uses only pictures without translation.

Our project has a number of advantages:

- The best algorithm, based on experimentally proved methods;
- Simplicity in use;
- Availability on web and mobile applications;
- Presence of only base of knowledge and pass-rate.

Project Description

In psychology, the spacing effect is the phenomenon whereby humans more easily remember or learn items in a list when they are studied a few times over a long period of, rather than repeatedly in a short period [Shaw, 1995].

According to Fig.1, this algorithms work by following principle: you are offered to remember a number of words, if you manage with it successfully, the time of future repeating increase [Ebbinghaus, 1885]. But if you forgot the words and you can't remember them ,repeating interval sharply decreases. To learn the words successfully you should use them in different ways such as: reading, writing, listening.

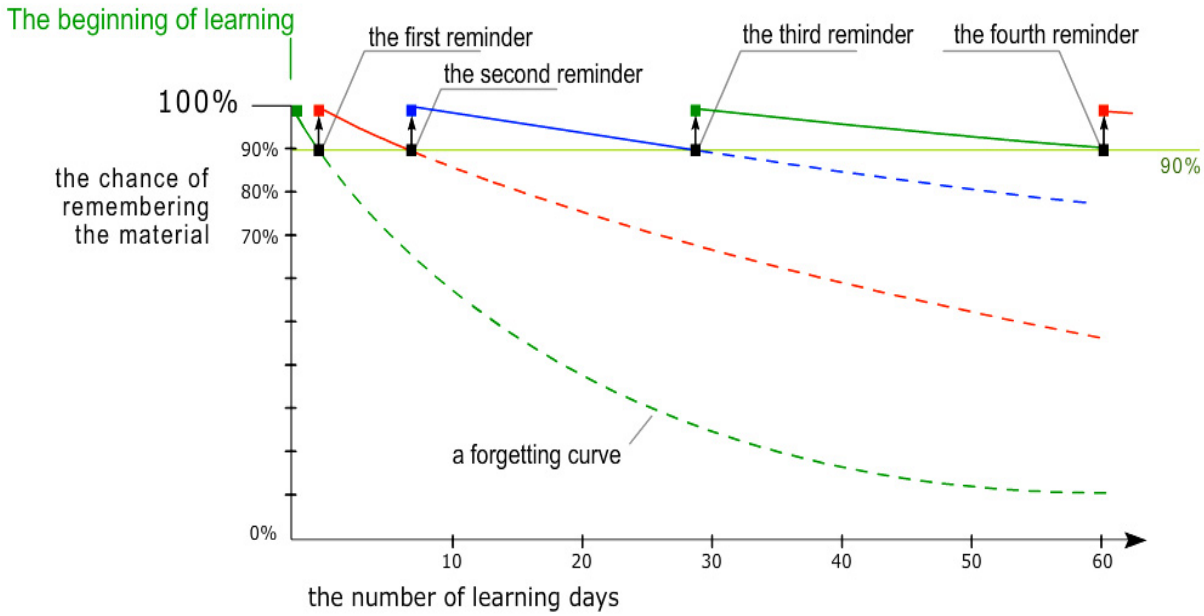

Fig.1. Forgetting Curve

WordSteps - personal vocabulary manager with a quite simple idea: invest 15 minutes a day visiting this website and in return get about 20 new foreign words remembered. It appears that, according to linguistic researches and studies, the most efficient way to learn foreign words is by memorizing not more than 20 words a day. Multiply this number by 365 days and get more than 7000 words in one year. Taking in account that normally no one wants to study every day and the best scenario is once in two days, we get a little more than 3000 words. According to statistics that amount of words is enough to understand 80% of all foreign books, newspapers and movies, and this is more than enough to hold day to day conversations with foreigners.

Methodology

To learn new things you should plan your lifetime capacity. The following information has some scientific aspects concerned learning words.

The number of words memorized in consecutive years when working one minute per day can be approximated with the following equation [Wozniak P. A., Gorzelanczyk E. J., 1994]:

$$NewWords=r*(3*e- 0.3*year+1)+1) , \quad (1)$$

where :

- NewWords - words memorized in consecutive years when working one minute per day,
- year - ordinal number of the year,
- r - asymptotic acquisition rate, i.e. the minimum learning rate reached after many years of repetitions (usually about 150 words/year/min).

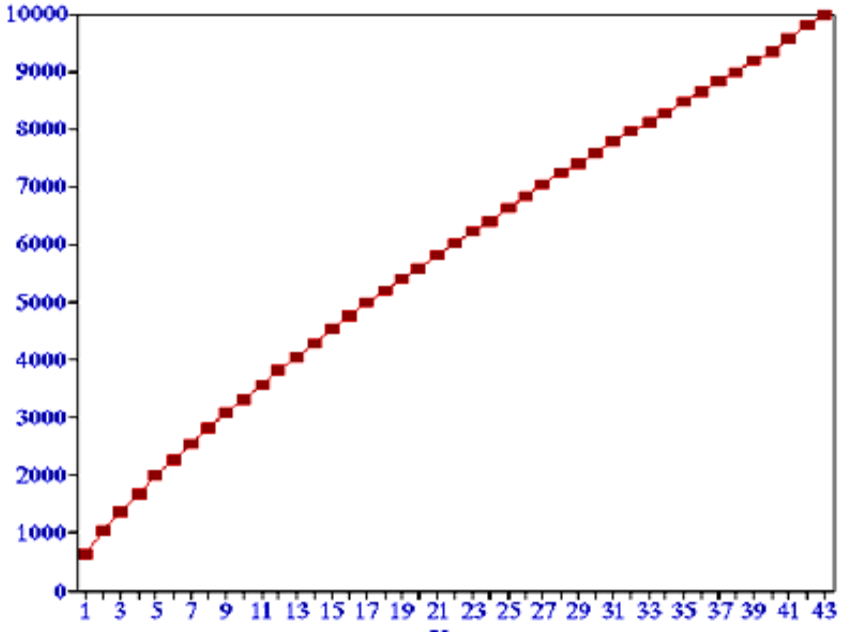

Fig. 2. Learning curve for a words, forgetting index equal to 10%, and daily working time of 1 minute
**Axis of abscissae is a year; Axis of ordinates is a total number of memorized words.*

For a generic material and the forgetting index of about 10%, the function of time required daily for repetitions per word can be approximated using the formula [Wozniak, 1994]:

$$time = 1/500 * year-1.5 + 1/30000, \quad (2)$$

where:

- time - average daily time spent for repetitions per word in a given year (in minutes),
- year - year of the process.

For example, the total time for a 3000-words collection in the first year will be

$$3000/500*1+3000/30000=6.1 \text{ (min/day)}$$

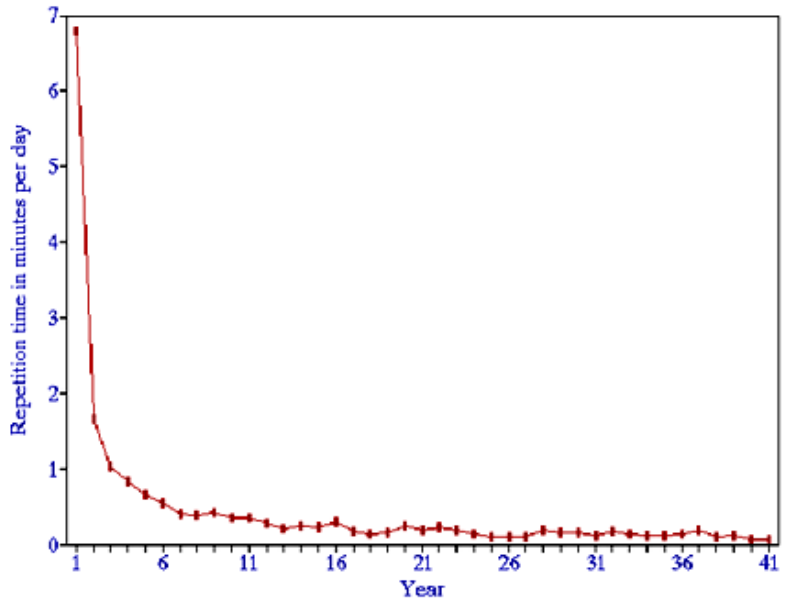

Fig. 3. Time, in minutes per day, in a generic 3000-words learning material, for the forgetting index equal to 10%

The forgetting index and knowledge retention can accurately be described using the following formula:

$$Rt = -in/\ln(1-in) \quad (3)$$

where:

- Rt - overall knowledge retention expressed as a fraction (0..1),
- in - forgetting index expressed as a fraction (forgetting index equals 1 minus knowledge retention at repetitions).

The above formula can be derived from the formula for the exponential decay of memory traces (R=e-d*t where R - retention, d - decay constant, t - time).

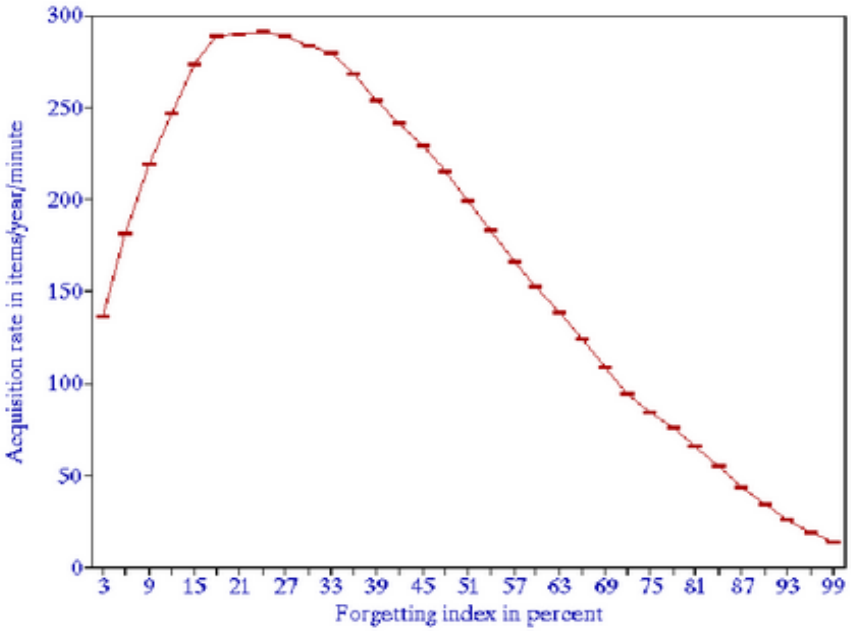

Fig. 4.- Dependence of the knowledge acquisition rate on the forgetting index

The recommended value of the forgetting index used in the practice of learning is 6-14%.

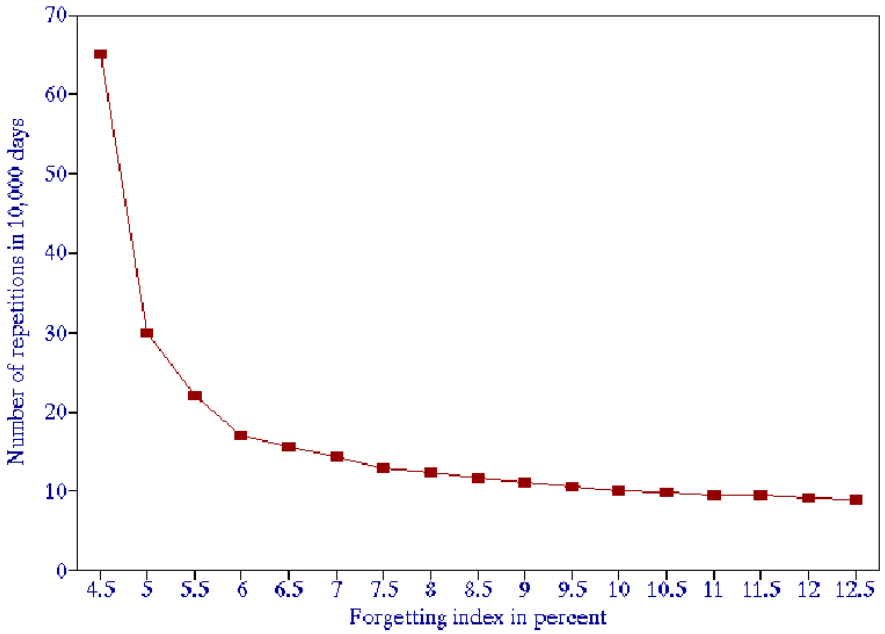

Fig.5. Trade-off between the knowledge retention (forgetting index) and the workload (number of repetitions of an average item in 10,000 days)

As compared with equally spaced repetition schedules, for the forgetting index equal to 10%, in the period of 50 years, the discussed model produces an about 50-fold increase in the speed of knowledge acquisition (i.e. speed of learning)

The following table illustrates the proportion of time spent on repetitions of material characterized by a different number of memory mistakes:

Table 1. Proportion of time spent on repetitions of material characterized by a different number of memory mistakes

Number of mistakes	Percent of words	Percent of time
0	62%	42%
1	16%	16%
2	9%	15%
3	5%	9%
4	3%	6%
5 and more	5%	12%

Conclusion

Today WordSteps offers more than 40.000 dictionaries and 30 languages to learn. Such a great amount of UGC (User Generated Content) is available because people really get the great results while learning process and the reminder system via e-mail get the motivation on a high level. Users can also use mobile apps to learn words on the go. Now iPhone, Android and Bada Apps are available. WordSteps offers the special e-learning platform for teachers, who can share dictionaries with students and check their mistakes.

Nowadays people have so little time to spend it for learning languages and the WordSteps project is aimed to solve this problem and make the process effective.

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Authors' Information

Dukhovny Andrey *– Bachelor; Academy of national economy and civil service under the President of Russia; Petra Romanova 2 , Moscow, 115193, Russia*

e-mail: aduhovnyj@yandex.ru

Major Fields of Scientific Research: mathematical modelling, data mining

SOFTWARE ENGINEERING
INFORMATION SYSTEMS

INFORMATION SYSTEMS OF ADMINISTRATIVE JUSTICE – AS SOCIAL TOOL FOR IMPLEMENTATION OF PUBLICITY PRINCIPLE

Tatjana Bilevičienė, Eglė Bilevičiūtė

***Abstract**: Today in Lithuania understanding the principles of administrative justice is aggravated because of complicate system of institutions dealing with pre-trial procedure of administrative offenses and the administrative judicial system, and the imperfection of the current laws. For Lithuanian citizens are difficult to orient in administrative law norms. At the same time with the administrative law violations often every citizen is faced. Therefore, public awareness and legal education serve for formation of civil society. Information and communications technologies in today's society are perceived and practical sensed as background of any the modern organization and public management environments model. It can be argued that public education on matters of basic justice administrative measures should be applied in the information space. The first steps in usage of public relations and information technologies activities in courts have to go. Lithuanian administrative courts apply the public information activities on the court web sites. However, the authors' studies show that public authorities and administrative courts websites provide information mainly oriented to publicity of proceedings the trial. Information about the administrative features of the infringement is almost unavailable. The article deals with public information policies and implementation of the accessibility of administrative justice in Lithuania in cyberspace.*

***Keywords**: administrative justice, principles of public information, the information society.*

***ACM Classification Keywords**: J.1 Administrative Data Processing - Law*

Introduction

Administrative disputes are the conflict with public administration entities, or conflicts between independent public administrations' subjects [Lietuvos Respublikos..., 2000]. Administrative adjudication has two main objectives: to provide any personal administrative rights (protection of human rights of the public administration bodies of illegal actions of public servants of redress against administrative arbitrariness and self-government institutions of redress against unlawful acts by public authorities) and to ensure the legitimacy of public authority. These objectives can be identified with the main purpose of the administrative justice [Teisės institutas, 2004]. The purpose of the administrative courts and the goals are to ensure the implementation of the constitutional provision that public institutions serve the people, to solve conflicts between state and individual, as well as the decisions taken by management to promote the progress of administrative capacity.

Based on Law on Administrative Proceedings and other laws, now in Lithuania the first instance in administrative disputes is the regional administrative courts and for appeal - the Supreme Administrative Court. As well as some cases the Supreme Administrative Court considered as the first and final instance. Administrative Court does not deal with cases classified as of general or other specialized competence. However, in some cases the jurisdiction of the Administrative Court and other courts overlaps. Often there are problems of jurisdictional cases between courts of general jurisdiction and institutions dealing with the administrative law governing the relationship between extra-judicial procedures. Administrative proceedings versatility due to the fact that the individual principles of the administrative process in a variety of different extent in administrative matters [Valančius, Norkus, 2006].

Today, not any Lithuanian citizen is aware of his rights at all to build up basic knowledge of legal issues and is familiar with operating in the country's legal framework. Understanding of the principles of administrative justice is also aggravated by the activities of pre-trial organizations and the courts' system, and the imperfection of the current laws. Current Administrative Code was adopted in 1985, since then he has been constantly changing. From 2012 05 01 the new version of Administrative Code came into force [Lietuvos Respublikos..., 2012], but again it was only made the changes of the old version.

Algimantas Urmonas [2007] argues that the insularity of administrative law, the search for solutions just in to the legal environment in view of social technologization restricts its ability to enrich it by social information of other sciences. Developing an optimal institutional framework of administrative justice and the governing it legal framework, it is necessary to take advantage of the latest social technologies. Social technologies are the whole of efficient or less productive permanent ways of management and solutions of social problems that help achieve the default action (outputs) on the social effects of human, social groups, hierarchical social structures (such as public administrations, local authorities, non-governmental organizations and etc..) behaviour. Expression of social technologies in law is relating to the social and legal status of scientific knowledge (scientific factors) and social efficiency of the legal action arising from both the social and legal conditions and the objectives pursued by means of decisions in society (social factors in legal practice) [Urmonas, 2007].

Arūnas Augustinaitis ir Rimantas Petrauskas [2010] states that information and communications technology (ICT) in today's society are perceived and practical sense as the base of any managemental model of modern organization or public in complex of changing environment. Social technologies actually express forms of the civil knowledge, information's metabolism, organization and interoperability, which is in communication processes of various forms of civil communication models, communication as well as enforcement mechanisms. It can be argued that public education on matters of basic justice administrative measures should be applied in the information space. However, the author studies show that public authorities and administrative courts website provides information mainly focused on litigation trial publicity. Information on administrative infringement features almost unavailable.

The principle of publicity and social technologies in the administrative justice

An essential function of administrative justice in the legal state is by legal means to protect a person from the illegal acts or omissions of public administration bodies [Kurpuvesas, 2007]. Constitution of Republic of Lithuania and other laws defining freedom of speech and freedom of the media rules are based on the same principles: priority of individual rights against the state, freedom of expression, the right to correct information which is harmful to the information and the prohibition of restrictions on ownership, diversity of opinion [Aleknonis, 2010]. Birutė Pranevičienė [Pranevičienė, 2007] states that the system of fundamental (or otherwise known as generic) Lithuanian administrative law principles consistes of the rules of rightness, justice, rationality, openness, control and responsibility. Studies of modern administrative law increasingly emphasize the importance of social

relationships of the administrative process and procedures [Kargaudienė, 2007]. Social changes affect the Lithuanian legal system and activate a new stock of administrative law and regulatory changes. Because of the qualitative transformation of social relations, there is a need to look for new administrative regulatory environment models. The search of it through legal and non-legal forms (or technology) consistently helps to achieve the main objective - the protection of human rights and legal interests [Deviatnikovaitė, Kalašnykas, 2007]. Administrative case law assumes that the public interest, under the Administrative Proceedings Act, should be seen as what is objectively relevant, necessary, useful to the public or part thereof [Trumpulis, 2010].

Administrative law is based on common law principles. One of them - the principle of transparency, which is understood in the context of administrative law as a legal obligation to publish consolidated laws and regulations adopted by the management regulations, public awareness and information provision, the publicity of already adopted administrative decisions. Public Information Act of Republic of Lithuania [Lietuvos Respublikos..., 2006] determines the order of public information's collection, compilation, publication and distribution, the rights, duties and responsibilities of public information's producers, disseminators, participants, journalists and the governing it bodies.

About technologies of social law or the law as a social technology, the Lithuanian legal science has little said. Often referred to themselves the right away from the man (this time not everyone is aware of the legal text, let alone his spirit), and the legal authorities accused business is closing. Given the right role and authority of each state (including legal) duty to serve the people, the situation is seen as problematic and requires quick and smart decisions, not only through legislation, but also other sciences opportunities. Gap, on the other hand, the right technology and social interaction, of course, exist. Both the law and the social purpose of technology - affect the social environment [Kurpuvesas, 2007].

Social technology is a tool for constructing the model of public communication and for the creation of its management mechanisms in complex and multi environments, where is the growing impact of technological factors. Social technology is a phenomenon of information epoch and it can not exist without the ICT-based development [Augustinaitis, Petrauskas, 2010]. Implemented sally by Social technology can be described as a used algorithm of social control. The perceived social technologies are a set of cyclic target practices connected with solutions of social and legal problems in an effort to change the social and legal status of the object. These social and legal changes are implementing seeking the expected results of activities, using the methods and techniques as a whole. It helps to reveal and use the unrevealed and the unused potential of social legal system hitherto of their development objectives, social norms and legal standards [Urmonas, 2007].

Modernised solution of social legal problems should be based on the development methodology of social technology. Social technologies development methodology includes theoretical, methodological and procedural static modeling aspects of activities' entities. Dynamic modeling aspects of social technologies are revealed by technologization phases [Urmonas, 2007]. In activities of administrative justice institutions we need to increase the use of relations with public and information technology. Free access to any information that person is interested in, free use of information resources in his activities (without prejudice to other rights and freedoms) must be provided for each person [Kurpuvesas, 2007].

Peculiarities of the Administrative Justice System

Administrative law deals with cases of violations by the Administrative Commission of the municipal councils, municipal townships in rural areas, elders, district (city) district courts (district courts), the police, the State Inspectorate of the Republic of Lithuania and other laws to authorize the bodies (officials) [Lietuvos Respublikos,… 2012]. Lithuanian administrative courts entrusted with the consideration of several kinds of administrative legal nature cases. Administrative Courts according Lithuanian law examine the litigations in the

field of public and internal administration, and the cases of legality of administrative regulations, and the administrative offenses cases. Those cases are regulated by a single Law on Administrative Procedure of the Republic of Lithuania [Lietuvos Respublikos..., 2000], in which different categories of cases are considered by some features. It is obvious that legal nature of these kinds of cases is very different. Particularly procedure of administrative offense cases is striking [Valančius Norkus, 2006].

Administrative courts of Lithuania are a two-tier: 5 regional administrative courts (in Vilnius, Kaunas, Klaipeda, Panevezys and Siauliai) and the Supreme Administrative Court. Administrative courts of Lithuania deals with disputes between civil servants as well as disputes in the environmental, agricultural, health, communications regulation, consumer rights and competition. Can be distinguished, and one quite specific areas of dispute - disputes arising out of tax relations. In summary, one can say that the administrative courts deal with disputes in which at least one of the parties is a State, municipality or state or local government, institution, office, and those who are subjects of public authority functions [Valančius, 2007].

County Administrative Court is the tribunal which was set for hearing complaints (petitions) for public and internal administration bodies of administrative acts and acts of commission or omission (failure to perform duties) for consideration. It dealt with disputes involving public sphere, the normative question of the legality of administrative acts, tax disputes, etc. T. Before applying to an administrative court, the law provided for public administrations to adopt individual acts or actions may be challenged pre-trial procedure. Regional Administrative Court of first instance as well as dealing with complaints (applications) on the municipal and county administrative disputes commissions and the laws of the cases and the other pre-litigation out of court by the Authority. The Vilnius Regional Administrative Court of first instance as well as dealing with complaints (applications) on the Chief Administrative Disputes Commission, the Tax Disputes Commission, and the cases provided by law and other pre-litigation out of court by the Authority. Lithuanian Supreme Administrative Court is the first and final instance for administrative cases assigned to the laws of its jurisdiction, and the appeal court for cases concerning the administrative county court judgments, decrees, orders, as well as administrative offenses and cases of district courts. In addition, laws in the cases it deals with requests for the reopening of completed administrative proceedings, including the administrative offenses. Lithuanian Supreme Administrative Court as well is forming a uniform practice of administrative courts in interpreting and applying laws and regulations [Lietuvos Respublika, 2011].

Under the valid Administrative Offences Code (AOC) [Lietuvos Respublikos…, 2012] and the Law on Administrative Procedure [Lietuvos Respublikos..., 2000] the administrative courts by themselves can't constitute penalties for administrative offenses (it is appointed by the authority institutions and district courts of general jurisdiction), however, deal with complaints about these penalties or other decisions in these cases.

Such administrative justice system is complicated and difficult to understand for non-specialists. At that time, residents encounter with the administrative law violations most often. In September' 2008, by the Lithuanian Supreme Administrative Court order, the company *Baltic Surveys*, conducted a survey of the Lithuanian population [http://www.delfi.lt/news/daily/law/beveik-puse-gyventoju-nezino-kokias-bylas-nagrineja-administra-ciniai teismai.d?id=19138285]. 1020 people were interviewed from different areas in Lithuania. The survey showed that 45% of Lithuanian residents do not know what cases are judged by the administrative courts, while 10% of people believe that the judges in such courts deal with criminal law. Only 38% of respondents knew that the administrative courts judge disputes with state authorities. However, approximately 17% of the population felt that the administrative courts judge cases relating to legal persons. This shows that in Lithuania, it is essential to resolve the administrative justice accessible to citizens.

Lithuanian law enforcement information systems

The first steps in using public relations and information technology activities of the courts, has to go. According to *Court decisions, judgments, decrees and orders publishing online order* [Teismų taryba, 2005], court proceedings shall be published on the Internet to inform the public about the interpretation of the law and the practice of Lithuanian courts. Judicial decisions and related information are published online by the *Lithuanian courts information system* LITEKO [Teisėjų taryba, 2011].

LITEKO's goal is to create for the courts an automated way to collect, organize and provide for users data, related to the courts' received documents and other documents in the filed of justice functions' implementation process, judicial decisions, judicial performance statistics, as well to exchange of data with state and departmental records and information systems, to improve implementation process of justice administration functions, to increase transparency of the judicial system, to ensure information system of high-quality and convenient for LITEKO users, to save users time and other resources enabling users to receive public services electronically. The structure of this information system is shown in Figure 1.

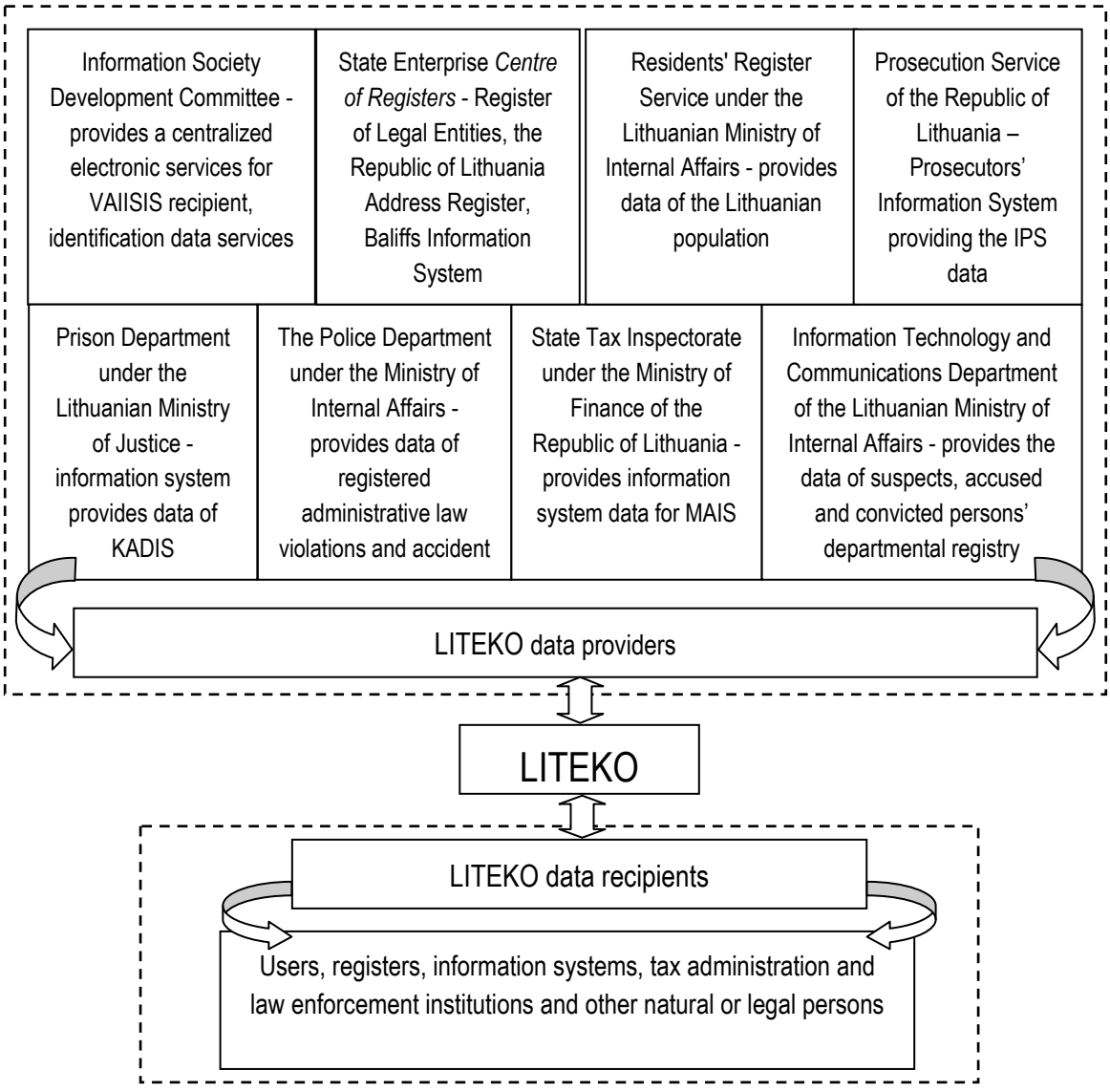

Fig. 1. LITEKO information system structure

It should be noted that LITEKO have a relationship with the public administration interoperability information system VAIISIS, which consists of two main parts: a data exchange platform and the central E-government portal gateway for electronic services [www.epaslaugos.lt, www.evaldzia.lt, www.govonline.lt]. This portal is designed that the citizens of Lithuania would be able to find in one place and receive the desirable public services and to get needed information [Viešojo administravimo..., 2008].

According to *Order of the place online the court decisions, judgments, decrees and orders* [Teismų taryba, 2005] such solutions of administrative proceedings are publishing online - all valid regional administrative courts' procedural decisions, then the administrative case is solved in principle or discharged without trial decision, the Lithuanian Supreme Administrative Court's procedural decisions adopted in principle by the proceedings in the appeal or separate appeal, the procedural decisions taken in the proceedings on the legality of normative administrative act, the election case and other cases, that are examining in a single instance procedures, procedural decisions, which terminates the proceedings without trial, and proceedings decisions made after the request for renewal. By procedural decisions adopted judge's, by college of judges', as well as by the president's of the court, the vice-president's or a authorized person's decree the procedural decisions of a court in which resolved the special procedural issue may be published on the Internet (for example, the appointment of an examination, the requirement of collateral, the suspension, removal of case, etc.), if it is necessary to ensure public awareness of legal interpretation and application of the law in the administrative courts.

The court order of the electronic booking system TIEUS [http://liteko.teismai.lt/tieus/] allows natural and legal persons to submit an application for a court order for electronic (online). This system facilitates lenders' access to justice; the court is to examine the possible cases of this type. The system is available only to legal entities and natural persons who are qualified electronic signature certificate. The certificate is necessary because without it cannot connect to the system and sent documents to sign.

In March' 2012 Lithuanian Ministry of the Interior presented the project *Electronic Service Information System for administration of non-contentious fines for natural persons and legal persons* [http://www.ird.lt/print.php?type=N&item_id=63]. Lithuania currently has about 80 institutions, which sets and administers fines under the Administrative Offences Code. The e. fine project is planned to meet three key changes: to reorganize the Administrative law violations and accidents register to the Administrative offenses register, gradually adding to it the institutions controlling and recovering the administrative penalties, administrative fines and the recovery functions transfer to tax services to develop electronic services to residents. Using the created system residents can easily and quickly paid the fine in cyberspace and to receive confirmation of payment - as well as reminders about upcoming payment of a fine time. The process will be automated and standardized, the created system will reduce the false number of cases referred to bailiffs, because the information about the appointment and payment of fines will be obtained and stored in information system. [Lietuvos policijos..., 2011].

Research methodology

Document analysis method was applied to examine the legislation governing the Lithuanian administrative justice and public entities in the principles of communication, scientific and legal literature in other fields. The study was used a systematic method of analysis. Application it was looking for links between law and social technology, looking for opportunities for administrative justice issues bring new, innovative ways - social technologies. The analytical method was considered for particular social technologies that could be adapted to the administrative justice institutions. Comparative method was used in analysis of public conveyance of the principles of administrative justice Lithuania methods, these techniques on the Administration of Justice entities closure for disposal in the information society. Tracking method applied to the administrative courts and public authorities

web survey to determine the details of administrative and legal cover. Statistical methods applied to the administrative courts practice of statistical analysis.

Results and findings

Lithuania officially publishes the caseload statistics of the administrative courts. The analysis of statistical data shows that the amount of administrative cases in administrative courts is growing constantly. This means that citizens better recognize their rights and understand them. Non-governmental organizations help a lot citizens, the community become more active, increasing the legal knowledge dissemination media. People are beginning to realize that they have certain rights and opportunities, and which is very important – they begin to use them for defence them.

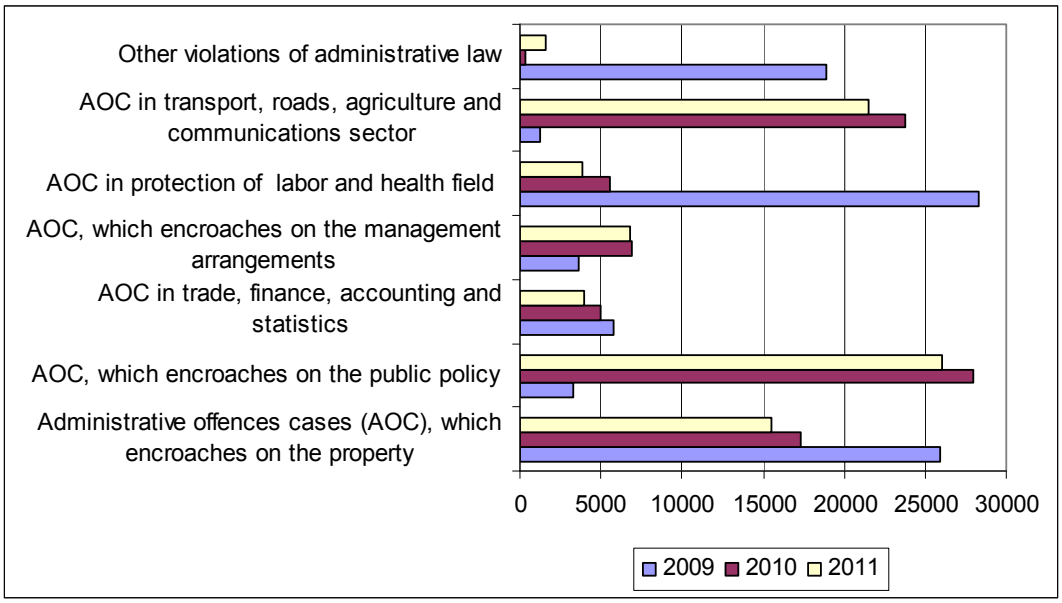

Fig. 2. Finished administrative law procedures of District courts

Finished and examined the administrative law proceedings of District courts are presented in Figure 2 [Lietuvos Respublikos teismų..., 2012]. We could predicate that these cases reflect a wide range of topics of economic and managerial performance range.

Figure 3 presents the dynamics of cities, the district courts' closed cases of administrative violations and the dynamics of regional administrative courts (administrative examinations and cases of administrative violations) [Lietuvos Respublikos teismų..., 2012]. The study shows that the overall administrative violations cases' amount is steadily increasing, but there is inverse dynamics of the Cities, District Court closed cases of administrative violations and the county administrative courts' examined administrative and cases of administrative violations (Pearson correlation coefficient $r = -0.89$, $p = 0.001$). Courts aren't able effectively examined such amount of cases. It may be noted that the overall administrative offense cases' amount decreased in 2011 because of administrative law and administrative proceedings legislative changes that led to a reallocation of general and administrative jurisdiction of the courts, cashing it and allowing the courts consistently specialization [Lietuvos Respublikos teismų..., 2012].

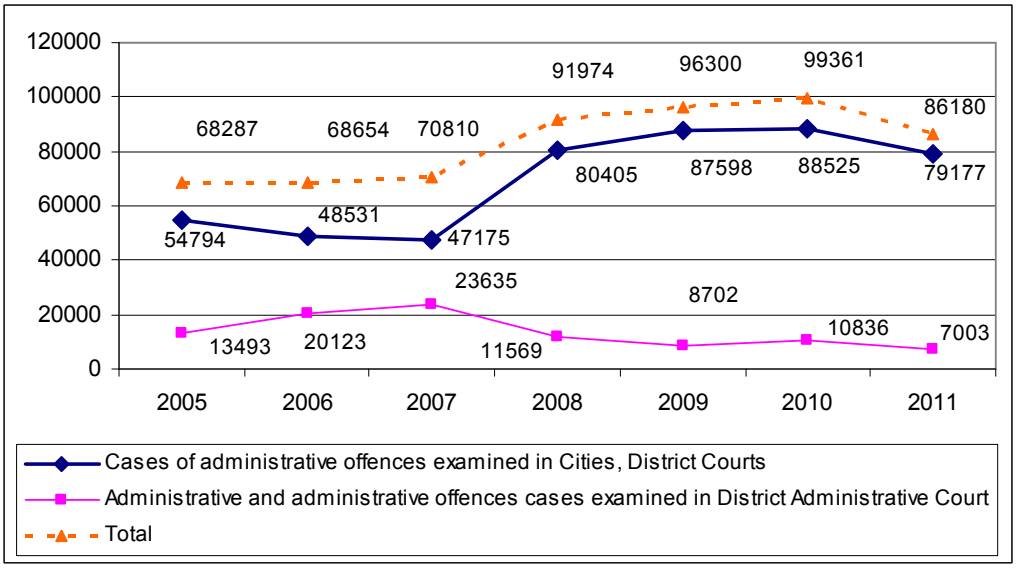

Figure 3. The dynamics of closed cases of administrative violations in cities, district courts and dynamics of regional administrative courts dealing with administrative matters of administrative law violations

Lithuanian Supreme Administrative Court is the court of appeal cases firstly examined by the administrative courts of first instance, the only and final instance in matters of the legality of administrative normative acts adopted by the central state administration bodies, the final court of appeals for proceedings under the Central Electoral Commission decisions or omissions [Lietuvos Respublikos..., 2000]. In 2005 -2010, number of received cases of the Lithuanian Supreme Administrative Court has steadily increased (see Figure 4). Already in 2008, to all types of cases has increased very significantly - by nearly 40% compared with 2007, the number of cases received. In 2009, the court received 8,448 cases; it is still 3%more than in 2008. In 2009, the number of cases increased by a further 11% [Lietuvos vyriausiojo administracinio..., 2012]. This again shows the complexity of administrative justice and importance.

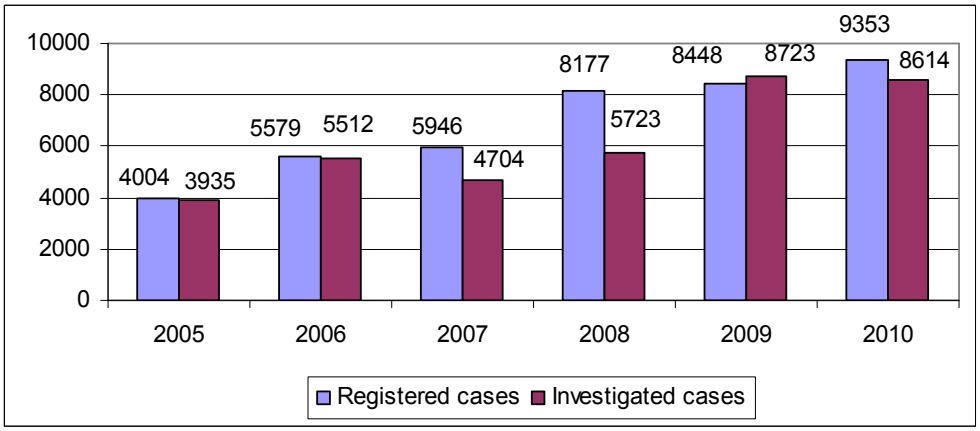

Figure 4. The number of received and examined cases of the Lithuanian Supreme Administrative Court in 2005 -2010

Lithuania Government Resolution *On general requirements for state and municipal institutions and Web sites describe the approval* [Dėl bendrųjų..., 2003] provides that each site should be menu *Legal Division*. However, after analysis of the Lithuanian ministries' web sites, we can notice that the legislation acts contained in this section aren't associated with an administrative proceeding. There are no references to the Code of Administrative Offences, Administrative Proceedings Act; there is no case law under the topics of ministry.

Public confidence in the law, democratic values, independent courts, it is necessary condition of survival of the state. Principles such as transparency, openness, openness will help to renew the administrative court system, to restore the population's faith in justice, in the belief that justice is administered, transparent, open and professional courts, that citizens are guaranteed the constitutional right to a fair trial [Piličiauskas, 2011a].

The Judicial Council ruling on information about the judiciary, the general public and the media rules [Teisėjų taryba, 2007] establish a procedure whereby, in accordance with the laws of the Republic of Lithuania and other laws and judicial activities in order to ensure transparency, all the courts in providing information to the public and the media measures of judicial performance Publishing information on courts websites about court activities related to the personal data (court meetings' schedules, others court proceedings and decisions) it must be guided by expediency and proportionality principles and it should be to ensure the data protection, the confidentiality and security of sensitive personal data. These rules are mandatory for all general and special jurisdiction courts of the Lithuania Republic. The Vilnius Regional Administrative Court on its website presents the rules of Vilnius Regional Administrative Court information reporting in the public and the media (Vilnius Regional Administrative Court Order No. T-25 on 4 March 2010 [http://www.vaateismas.lt/lt/aptarnavimo-tvarka/informacijos-teikimo-taisykles.html]). Vilnius Regional Administrative Courts' rules of the allocation of cases to judges using information technology [Vilniaus…, 2010] regulate the assignment of cases of administrative violations and others cases to judges using information technology in Vilnius Regional Administrative Court. Rules regulate the automated assignment of cases to judges and judicial colleges award process so that the judge would be awarded according to the specifics of the court, the rules of procedure, the different types of cases and their characteristics (eg, different number of judges in administrative matters - considered individually or collegially, and etc.) to the current legislation. Rules have been prepared in accordance with the Judges Council Resolution of 10 October' 2008 [Teisėjų taryba, 2008].

In order to increasing openness to the public court to the Supreme Administrative Court of Lithuania has been installed and there is actually a computerized distribution of cases judges and objectively, without exception, the distribution of all administrative matters. Access files with a particular specialization of judges determined by a judge and a computer to choose random numbers. This ensures complete transparency in the allocation of cases to judges. Taking into account the wishes of the population, and has a launched a new website of the court. This site has all the regular information on court operations [Piličiauskas, 2011a].

All these methods increase the openness of the courts, but do not perform the tasks of legal education of citizens. The analysis of Lithuanian administrative courts' websites showed that legal information is presented deeply and sufficiently and it is convenient not only for professional lawyers, but also for ordinary citizent, who are defending or intends to defend their interests in court, for example the Vilnius Regional Administrative Court's website [http://www.vaateismas. com]. This site contains not only the necessary information about the court structure, jurisdiction, functions, history, statistics and business area, working judges and court's staff contacts, but also useful advice on claim time, on the form of complaint, what is the accessing to the case file order and so on. The proposed section *Questions - Answers* is designed for citizents who would like to ask about court procedures. The site provides web links to other Lithuanian courts, state agencies, pre-trial institutions and court work regulated legislation. Web site may be used by people with disabilities – there is adapted the special version for them. Home page information is available to foreigners - it is published in English.

Lithuanian Supreme Administrative Court, the practice that the public interest by the Republic of Lithuania Law on Administrative Procedure, should be seen as what is objectively relevant, necessary, useful to society or part of it. It should be noted that the public interest not to be regarded as any legal person or group interest, but one that reflects and expresses the fundamental values of society, which lays down, protect and defend the Constitution of the Republic of Lithuania. Of the Administrative Courts of Appeals shows that people who apply to the court, not

always correctly interpret the nature of public interest. In this case, an individual duty of courts to assess whether a particular interest should be considered public, as well as proper reasons for its decision. Public participation in decision-making in the public interest, the objects is closely related to the rule of law, good administration, and transparency principles. For many people the opportunity to be informed, to participate in decision-making and to challenge them in accordance with the fundamental issues of justice. Among other things, it should be noted that transparency, public participation and the right to challenge unlawful decisions of an independent and impartial court action to reduce corruption and arbitrary decision-likelihood. The public must have some assurance that the proper authorities to comply with the public interest. Therefore, the administrative courts actively advocate for greater public involvement in government decision taken by the review process [Piličiauskas, 2011b].

In order to obtain the opinion of the Lithuania people concerning necessity of public participation in the examination of administrative cases, the Lithuanian Supreme Administrative Court (LSAC) has fulfilled a public online survey of residents concerning the implementation of public representatives' institute at the administrative courts in Lithuania. The survey was on LSAC's website from 19th of August'2011 till 16th of October'2011. 689 people completed online the questionnaires, which consisted of 10 questions [Visuomenės..., 2011]. The survey showed that 65% of respondents believe that there is need of public representatives in the examination of administrative cases, 67% of respondents think that it would increase public confidence in the Lithuanian administrative courts. 41% of respondents believe that the public representative in administrative cases should be called the assessor, 24% - public judge. 34% of respondents have the opinion that public representatives should be appointed (from several candidates), they should be specialists in the certain field according to what category the file will be examined, 27% - selected at random. The analysis of survey results shows that in public participation in administrative proceedings it is needed the public legal education.

Conclusion

Administrative jurisdiction issues are the complex of classification problems of the administrative violations; a separate administrative process's principles are differently implemented in a variety of administrative matters, there is lack of the rule base level. Lithuanian citizens have the right to full and truthful information about administrative law and administrative process. Expression of the social technologies in law is impossible without the use of ICT. The first steps in using public relations and information technology activities of the courts have to go.

Lithuanian administrative courts employ for public conveyance the web site tools. However, the focus on procedural information: the distribution of cases, introductions to the work of the court schedules, files, etc., but very little there is known about the characteristics of administrative justice.

Ordinary person hardly could use the presented information; such presentation of specialized information is useful mostly for advocates or other types of lawyers. The researchers showed that public opinion believes that in the administrative cases should be involved public representative called the assessor or public judge. Such social technologies could ensure the effective interaction between administrative courts and public.

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Authors' Information

Tatjana Bilevičienė *– Mykolas Romeris University, Faculty of Economics and Finance Management, Department of Business Economics PhD, Assistant Professor, Ateities 20, LT-08303 Vilnius, Lithuania, e-mail: tbilev@mruni.eu*

Major Fields of Scientific Research: Mathematics (statistics), IT, management and administration, knowledge management

Eglė Bilevičiūtė *– Mykolas Romeris University, Faculty of Law, Department of Administrative Law and Procedure, PhD, Professor, Ateities 20, LT-08303 Vilnius, Lithuania, e-mail: eglek@mruni.eu*

Major Fields of Scientific Research: research management and law, environmental law, administrative law and procedure, law informatics and IT law, criminalistics, criminal procedure

USING REAL-TIME SYSTEM TO MANAGE PRODUCTION DATA IN A DISTRIBUTED SYSTEM

Magdalena Dobrzańska, Paweł Dobrzański, Artur Łopuszyński, Łukasz Kurowski

***Abstract**: The article presents the design and construction of data acquisition module, which allows read and write data counted by the data acquisition board. The acquisition was controlled using a program that was created in the QNX Momentics development environment, based on the architecture of the RLP. It involves the measurement card control directly by the read and write to memory registers. Data acquisition was performed on a computer running a hard real-time system QNX6 Neutrino. With the use of available tools QNX Neutrino RTOS was realized network communication process for managing production data in a distributed system. The article presents also industrial networks such as Profibus and Ethernet. Discusses the characteristics of distributed systems and the requirements for real-time systems.*

***Keywords:** real-time system, data acquisition, distributed system*

***ACM Classification Keywords:** J. Computer Applications, J.2 Physical Sciences And Engineering, J.7 Computers In Other Systems,*

Introduction

Real-time systems belong to the specific areas of modern computing. They are used in places where it is necessary to present the response to external signals. Real-time systems operating continuously since the implementation of the removal phase. They are designed to generate responses in parallel with the course and changes in the external process. They are found at almost every stage of human life, starting with simpler systems for applications such as audio equipment, the high-class nuclear power control systems, anti-aircraft weapons, serving the airport. Their use requires the timely fulfillment of critical tasks, because their failure could lead to danger for human life or significant property damage. Recently, real-time systems are becoming increasingly important and high conversion are increasing their functionality, so that they can meet the new standards of safety and security requirements. Significant impact on this have the rapid technological progress, decreasing costs and increasing capabilities of microprocessors.

The phenomenon of data acquisition presents a very important topic in real-time industrial systems. It's successful implementation allows to optimize the manufacturing process. The data obtained in the acquisition process is the main source of information for management support systems. Modern real-time systems can meet the demands posed consists in continuous operation, safety and reliability. Perform measurements, together with their development in an automatic cycle, according to the prepared algorithm. Computerization greatly reduces the time of measurements, allows them to make them in dangerous locations, difficult to access for a man. A large amount of data also allows to perform various analyzes and statistics. Real-time systems are the basis for control of complex technological processes in many industries, and in many areas of human life can play an increasingly important role over time.

At present, there has been considerable progress in measuring and control systems. Leaves from centralized systems toward distributed systems. This phenomenon is a consequence of the development of computer and electronics. Currently, the underlying elements of distributed measurement systems are the nodes that have the

ability to process data and provide two-way communication with other elements forming the system. Network nodes allow direct control of objects, performing the functions of measuring, control or measuring and control, thereby, the primary source of data that must be sent in a reliable and efficient manner. Providing access to the advanced electronic systems equipped with multiple communication ports and a number of development tools, enables the distributed data processing. Distributed data processing is related to the performance of several tasks that are interdependent which affects their sequence, are also often asked time thresholds, defining the maximum response time to events occurring in the system. Ensure compliance with these requirements can use the industrial network of real-time operating system to control operations, that provides the tools and features to ensure compliance with restrictive time constraints, and efficient management of available resources and the tasks undertaken.

This article presents the commonly used network communication mechanisms used in distributed measurement and control systems, industrial networks and the principles of real-time systems in this context. In addition, the process was carried out data transmission between the node responsible for the acquisition of data to another node, which are based on client-server.

The features and types of real-time systems

Real-Time System is a computer system in which calculations are carried out in parallel with the course of an external process, they have to supervise and timely responses to the ongoing events in this process [Ułasiewicz, 2007]. It's correctness depends not only on the logical correctness of the calculations themselves, but also on the time in which the result appears. Real-time system corresponds predictably to external signals flowing in an unpredictable manner [Lal, 2003].

The time factor is present in every system. However, in some systems it is very important and in others less important.

Defines two main types of RTS systems in connection with the different effects of non-compliance with time limit:

- a rigorous real-time system (a system of hard time limits) - this is a system in which the time limit must always be met. These include control systems, missiles, nuclear power plants, aircraft, missile defense systems. Exceeding the limit of the response time could lead to danger to life or health, or in substantial property damage, and not a significant amount of time limit for answers, just the mere fact of his crossing. Hard real-time system must therefore ensure timely fulfillment of critical tasks, otherwise it becomes useless.
- Mild real-time system (a system with soft time limits) - this is a system in which time limits can sometimes be exceeded. The tasks are executed as soon as possible, but need not necessarily be completed within the specified time, because it does not cause material damage and does not threaten human health. Used in equipment such as multimedia.

In addition, another kind of RTS can be represented by systems with strong real time constraints - the delay in the response causes the result generated by the system becomes unusable, but it causes no danger to humans or equipment.

Real-time systems must be characterized by high reliability, ensuring that users have confidence in the services they provided. The quality system is determined by the attributes of reliability [Ułasiewicz, 2007]:

- availability - the system continuously provides its services;
- reliability - is working for a long period of time without occurrence of defects;
- security - an instance of a system failure can cause a catastrophe;

– integrity - no unauthorized changes in system are allowed;
– maintainability.

Real-Time System includes all necessary components to meet specific requirements such as: hardware (CPU, memory, peripherals, etc.), operating system and applications. Contrast, real-time operating system (RTOS) is one component of a complete system of RTS, which is usually supervises the whole system. Provide appropriate functionality that makes the whole system can meet the demands facing it.

His ability to respond to interrupts is very high, and applies expropriate scheduling strategy. It consists in the fact that at any time, may receive a process or thread that has a higher priority than currently executing. It expropriates the process and goes into the exercise, while the lower priority process is suspended. RTOS should work as planned by the user, to support different hardware platforms, be well documented and free of errors.

Acquisition of data in measuring systems

Data acquisition means the collection of electrical signals from the sensors, the measurement of their parameters, and transfer to computer for testing and processing. The signals are collected from the environment, then stored on computer and instantly analyzed to obtain relevant information and results. Physical quantities are measured by sensors equipped with a microcomputer, then the resulting signal is converted to digital form, which is sent to computer. The computer makes the analysis, visualization and documentation of the data obtained.

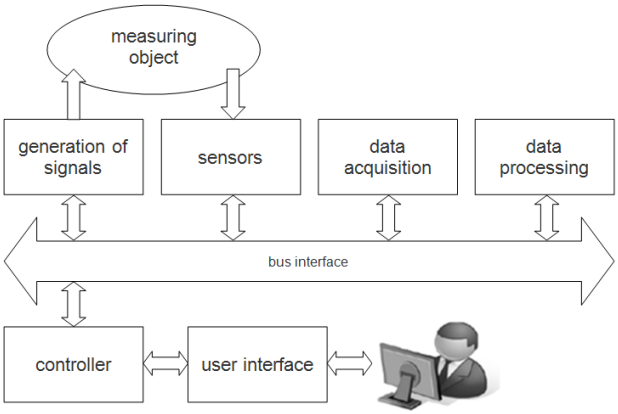

Fig. 1 Traditional measurement system [Rak, 2003]

The traditional measurement system is a set of basic elements coupled together. It contains the following function blocks (fig.1):

1. Sensors - allow receiving information from the test object, used to convert physical quantities (in example temperature, pressure) into electrical signals.
2. Data Collection - to read the signals from the sensors.
3. Data processing - processing of the measured signal.
4. Controller - responsible for controlling the entire system, and managing the flow of information. Frequently it is the role of a computer or microcontroller.
5. User Interface - provides user interaction with the measuring system.
6. Bus interface - connects the individual blocks measuring system ensuring the flow of data between them.
7. Signal Generation - responsible for generating signals in the measurement and control systems.

Successful implementation of the data acquisition process to optimize the production process in real-time industrial systems. The dynamic development of computerization linked with support for industrial processes resulting in an increase in the information provided, the processing of which is a challenge for modern systems. Computerization greatly reduces the time of measurements and allows to measure in dangerous and inaccessible to man. A large amount of data also allows to perform various statistics. Data taken from the microprocessor control systems are a major source of information for management support systems.

Transferring data in a distributed production control system

Continuous development of computer networks and increase their reliability led to the expansion of distributed systems in the control of the production process, thereby displacing centralized systems. Individual tasks can monitor a single computer or programmable logic controller (PLC), which manages real-time system, and communication between the components of the measurement system provides a communication network. The development of distributed control systems stimulate such factors as the continuous increase in the number of sensors and actuators, resulting in an increase in network cabling industry, increasing demand on communication media, security and flexibility and reliability solutions. Real-time systems, along with a computer network should ensure compliance with these requirements and be the guarantor of a certain time of the tasks related to the technological process.

Consisting of four layers of enterprise information model in a hierarchical method presents the informatics structure of the industrial system.

Starting from the lowest it includes the following levels:

I. Control in real time
II. Visualization and supervision over the production process
III. Tracing the production and material, optimization
IV. ERP/MRP

Control in real time includes equipment, whose task is to gather information about the process and control it. The first level provides the link between man and machines and technological devices. The most commonly used devices in this layer are microcomputers, programmable logic controllers, remote transmission devices and multifunctional controllers and local workstations. Visualization and supervision over the production process, the second level is used to configure measurement and control devices and monitoring of the technological process. To accomplish these tasks requires a dedicated application programs. The main function of this layer is to provide an interface between human and machine (MMI - Man Machine Interface). Thanks to him it is possible to influence product quality and the quantity of waste materials and energy. Levels outlined above are closely related to each other and their functions are sometimes intertwined. Production and material tracking, and optimization are the third layer of the model. It is the interface between layers I and II and ERP systems. Its main tasks include: visualization and monitoring of production, creation of documentation and reports, quality management, controlling the flow of materials and means of production. Provides the ability to modify the production plan on an ongoing basis depending on the circumstances arising. The introduction of level III results in takeover by him of the functions performed by the lower levels. Fourth level systems include information systems planning and management of the production process. Enable management resources such as procurement, finance, costing, planning, forecasting and optimization of the process in terms of improving quality and reducing costs. The boundaries of the above-mentioned layers are contractual and depend on the implementation of the system. Therefore, certain features may be implemented at different levels. Communication

between the different layers can be realized with the industrial networks and computer networks and their integration provides lower costs and improves management of the company and the production process.

The smooth operation of the measuring system and it meets the requirements assigned to it is possible by providing communication between the various components of the system. Communication is not only data transfer but also transfer timing of commands and time synchronization operations. To the process of communication is needed: hardware combination and adaptation of the system and for the efficient management is the responsibility of the software. Interfaces are called standardized communication systems, which combine elements of the measuring system. Mechanical, electrical and functional system and cables, connectors, controllers and software create an interface system. Communication path between the elements of the measuring system called the bus interface, which consists of a set of rails. As we understand the set of bus-rail lines designed to transmit specific information [Tumański 2007].

There are two basic ways transmission of measuring data, they are: serial transmission and parallel transmission. In the serial transmission bits are sent sequentially on a continuous basis, bit by bit at the specified frequency, while the parallel transmission bits are transmitted sequences of defined length, word for word. The way of data transmission is the basis for division of the measuring network, which can use a serial interface or parallel interface.

Overview of selected methods of data transmission in industrial automation

Requirements for industrial networks are different from those which are placed before the local networks used in offices, public facilities, universities and schools. This is largely due to the need to work out the network in widely different circumstances. The basic requirement of industrial networks is the timeliness of communication, which is the guarantee of the proper conduct of the controlled process. These networks, in contrast to local, provide connectivity between sensors, controllers and actuators.

In addition, industrial networks should ensure high data transfer efficiency, which are usually short communications, high reliability and safety. In the measurement and control system, we can distinguish three groups of networks:

- sensorbus, includes sensors and actuators
- devicebus associated with level control
- filedbus on the department level

Each of these groups can be assigned to the individual, the previously discussed levels, from the first, showing the structure of the information system. The OSI model, which describes the structure of communication network consists of the following seven layers: physical, data link, network, transport, session, presentation and application. The measuring and control systems most often used as three of the seven layers are: physical layer, data link layer and application layer. This is due to the fact that the network requires good communication parameters, reduce costs and simplify the communication structure.

Profibus among the most popular industrial communication solutions. They are often used in measuring and control systems, in which we can distinguish the level of sensors and actuators, the level of production and the level of faculty. At the level of production, data is transmitted periodically. Devices occurring at this level are: I/O modules, valves, transducers, and pre-setting engines. Profibus includes recommendations and standards for the three layers of distributed systems, these are the applications layer, communication layer and physical layer. In the communication layer, we can distinguish three protocols: PROFIBUS-DP (Decentralized Periphery), PROFIBUS-PA (Process Automation) occurring at the level of sensors and actuators, and PROFIBUS-FMS (Fieldbus Message Specification) is used to communicate with these devices. PROFIBUS-DP protocol is used in

systems with distributed actuators. It is characterized by a high speed and resistance to interference transmission and low costs and high efficiency. This is the most widely used protocol. PRFOIBUS-FMS protocol is now supplanted by TCP/IP. Profibus system sizes depend on the technology specified in the physical layer. It is recommended to use standard transmission lines such as RS-485, IEC 1158-2 and fiber. Profibus is a set of standards and regulations, which aim is to organize the production management both in the sphere of hardware and software, thus providing a common communication protocols, and compatibility and interchangeability of components. The communication structure of Profibus systems is a type of a master - slave.

Ethernet allows for the creation in the industry of a uniform platform for data exchange between computer systems and industrial automation systems. Has a high compatibility, versatility and flexibility of configuration. Allows connection of many thousands of devices with varied functionality, while providing them with direct communication. The continuous increase in transfer speeds and low costs of setting up a network, meant that Ethernet was applied in industrial networks. Figure 2 shows how the various devices can connect to an Ethernet network and to what extent covered the whole of manufacturing company. Forms the basis of Ethernet TCP/IP has four layers are: the data link layer, network layer, transport layer, application layer. Based on the Ethernet physical layer, numerous protocols used in the industry. Here are the most popular ones: Modbus/TCP, EtherNet/IP, Ethernet Powerlink, Profinet, EtherCAT, SERCOS III. Occurrence of so many varieties of Ethernet in the industry due to the need to preserve compatibility with older techniques, networking and with networks that enable real-time job. TCP is not designed to work in real time.

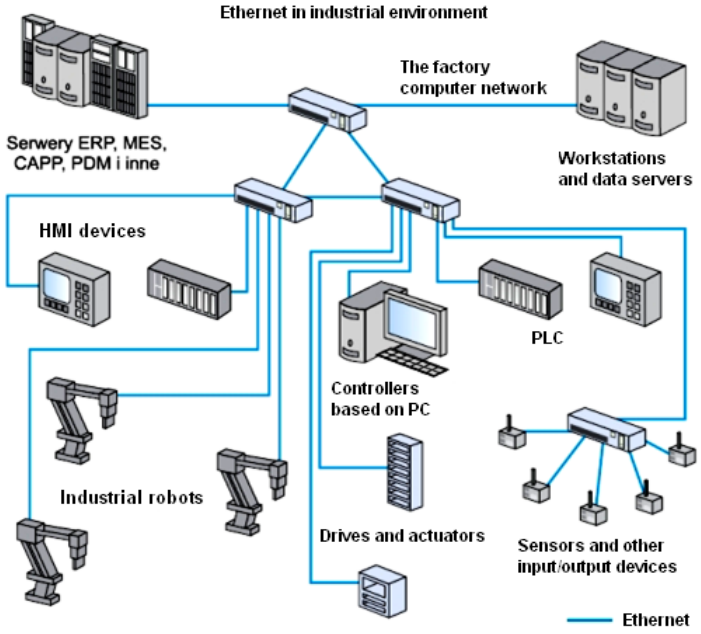

Fig. 2. Ethernet in industrial environments. Source [Automatyka B2B].

Wireless networks are used in a situation where because of the difficult physical conditions cannot use a serial cable or a data source object is in motion. Through the use of wireless technology, especially at lower levels of the hierarchy network pyramid can facilitate the work directly on the production line by using the portable control panels and remote measurement, particularly in endangered areas or hard to reach places. Wireless communication is a new trend in network industries. Frequently it is based on standard Ethernet, 802.11x (0,1, b, g), which is commonly used in office and public networks. Despite its universality, this standard is not fully suitable for use in demanding industrial applications, because does not provide an adequate level of data security and is not compatible with the communication interfaces of industrial automation equipment. They have been developing new communication protocols for industrial networks based on Ethernet for example, WirelessHART

(IEEE802.15.4). The popular and rapidly developing technology is Bluetooth, which is seen as an extension of the functionality of wireless networks.

Distributed systems in the control of production

Distributed control system is responsible for visualization and control of the production process having a common database. Individual components of the system communicate with each other using a specific communication protocol, so that they can work independently. The main objectives in creating a distributed system is to connect users and resources, transparency, openness, fault tolerance and scalability. Connecting users and resources means that the principal objective of the system is to facilitate access to remote resources and sharing them with other users in a controlled manner. This facilitates communication and exchange of information in the system. Transparency involves concealing the fact of the physical dispersion processes and resources. There are several types of transparency. Transparency of access is related to the differences caused by hiding data representation format and how to access resources. Location transparency is hiding information about the physical location of the resource. Transparency migration allows the transfer of resource to a different location without having to change how to communicate with him, and the change in location of the resource while using it to ensure transparency movement.

Transparency of multiplication is related to the of hiding information about the presence of multiple copies of the resource. The independent use at the same time by different users with the same resource allows distributed systems, and the concealment of this fact corresponds to the transparency of concurrency. It is important to split the resource remains in a consistent state. The hiding of failure is related to transparency failures. Information on whether the resource is in memory or in persistent storage hides transparent persistence. Openness is another goal of distributed systems. This property is associated with the ability to expand the system by adding external devices, memory, adding new communication protocols and resource sharing services without affecting existing services. The openness is related to the ability to work, which involves the cooperation of system components from different manufacturers due to the existence of a common standard. Features of a distributed system of openness aimed to ensure that such a system extensible and allow flexibility in the addition of different parts. Fault tolerance is associated with the possibility of completing the task started in spite of a hardware failure. For this purpose, the redundancy of hardware, which consists of allocating redundant hardware to perform the same tasks. In the event of failure of any of the equipment of the other takes over its task. Scalability is the last mentioned features a distributed system. It provides a possibility of increasing the scale of the system and software without the need for changes in them [Tanenbaum 2006].

Data acquisition module

Developed data acquisition module includes the following: NI 6601 data acquisition board, encoder, connector block, wiring necessary to connect the card with encoder, and the software controlling the operation of the card. Card is placed in the computer running the system QNX6 Neutrino, and also is connected with the connector block tape. The connector cables that are plugged in the analog signals generated by the encoder, which in turn are read and converted by the software-controlled data acquisition card. Connector block simplifies the connection of two different interfaces, data acquisition card and the encoder.

NI Measurement 6601 card was plugged into the PCI bus on the motherboard computer running QNX. The card comes with an NI-DAQmx driver. During the driver installation program is also installed Meauserement & Automation Explorer (MAX), which automatically detects all installed equipment and NI software installed.

If possible is recommended to use the driver, because it provides the greatest benefits of the equipment. NI DAQmx driver could not be used, however, because the Ni 6601 measuring card is not compatible with the QNX Neutrino system. In a standard situation, for example, under Windows or Linux, NI-DAQmx driver and other software supplied with it could be used, so that further work would simplify considerably.

When it is not possible to use an existing driver, you must use the architecture of RLP (Register Level Programming), which is used to control the device directly through reading and writing to memory registers without calling a function provided by the driver. To register a data acquisition board in the QNX Neutrino operating system is necessary to know about:

- Vendor ID (vendor ID device) - this number is identical for all devices NI (National Instruments) to be incorporated into PCI/PXI. This number can be found at the manufacturer's data acquisition card (www.ni.com), is it: Vendor ID = 0x1093.
- Device ID (Product ID device) - allows to identify a specific model. This number can be found in the NI documentation (ID = 0x2C60).

Using these two numbers, the system can identify the NI 6601 data acquisition card in system. Software controls the operation of data acquisition card, allowing to read and convert the pulses sent to the encoder. Software made in the QNX Momentics development environment, using the architecture of the Register Level Programming, available from National Instruments (NI). This architecture provides several functions to access measurement cards, on systems that are not supported by the hardware manufacturer, and facilitates communication between the hardware and the system.

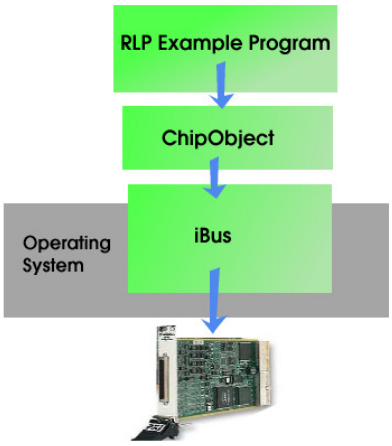

Fig. 3 Three-layer model of programming the memory registers [MHDDK]

No possibility to use the driver supplied with the data acquisition board forced its configuration under the control functions to read and write directly to the memory registers. The program configures the data acquisition card by setting the appropriate registers for its proper operation, and controls the data acquisition process.

In order to facilitate work on the created program or driver, the NI company divided RLP architecture into three layers, defined as osiBus, RLP ChipObject, RLP Example Program.

Figure 3 shows the three-layer model of RLP. OsiBus layer provides a simple interface between the PCI/PXI and running programs, also provides a simple I/O functions performed by ChipObject the memory registers. The supplied interface is designed in such a way as to be able to work with any operating system.

ChipObject an abstract reflection of Logic chip devices used, and thus consists of several registers and bit fields, using to their definition of logical names. This helps to avoid numerous errors and easy to use equipment on many different operating systems using the RLP. It is used for configuration and programming of the device by using the methods defined in C++ classes and functions osiBus layer. It may happen that the device will contain

more than one chip is responsible for control and configuration, then cannot avoid a situation where one counter is controlled by two systems, since it could lead to damage. ChipObject can prevent this situation by assigning to each chips separate address spaces [MHDDK]. The final element to facilitate the programming of the memory registers are RLP examples. They include the implementation of specific operations, which makes it possible to perform a specific device. Using for that purpose the basic functions provided by the previously described RLP layer. Knowing the construction of memory registers user can easily adapt the chosen example to suit your needs.

The acquisition software, first searches the data acquisition card in system. Then it initializes the interface MITE, in order to connect to the PCI bus. These activities allow access to the data acquisition card from the system. Then the program uses the registers function sets up the data acquisition board (counter mode, the value of the initial count, the internal clock of the card (frequency 20 MHz), and turns the counter). After configuring the card program performs the data acquisition process, which are displayed and saved to a file in real time.

Measuring card is to look at a bus address returned by the program ("PXI0::8::INSTR"). It is used for this function bus = acquireBoard("PXI0::8::INSTR"), which returns both the base addresses of the measuring card (BAR0, BAR1). Address BAR0 refers to the memory address register MITE, while bar1 to registers of the data acquisition card (TIO). Based on the addresses returned is the address space that allows access to the data acquisition card registers. Described function returns only addresses BAR0, BAR1. Functions are performed on registers address space address BAR1, and therefore it is necessary to provide the address BAR1 and to highlight its address space. On the basis of the returned basic addresses interface is initialized using the MITE function initMite(bus). It aims to make available, the connection address bar1 plate measuring board and gain access to the registers of data acquisition board.

After initializing the interface MITE main function is responsible for configuring and controlling measurement board (test(bus)). At the beginning of the function returns the address space of address BAR1 shared by the function initMite(bus), which provides registers of the measurement board. It is used for this function CardSpace = bus-> createAddressSpace (kPCI_BAR1). Function test(bus) consists of two main parts. The first of these sets contains the functions responsible for the configuration registers and control the measurement board: set the timer, the value of the initial count, counter mode, the gate signals, the internal clock (sampling frequency), and turns the counter. After setting registers and turn counter is done the second part of the function test(bus), which is responsible for the data acquisition process. The data is sent from the encoder. A measure of the encoder are two separate channels, the signals A and B of the measuring board (fig.4). Using the two signals (A and B) are offset by 90°, to distinguish the direction of rotation of the encoder.

The use of two offset signals is also used when determining the measuring board read the signals from the encoder and to add the pulse, and when subtract. In addition, there is yet another signal that serves as a marker to indicate when it was made a full turn. Set in the X1 mode (fig. 5) means that the values are counted in 0-2000 (with a value of 2000 will be made full rotation encoder).

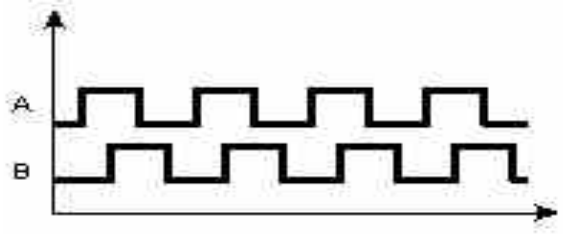

Fig.4. Signals offset by 90 °

Counter mode (set in the first part of the function test(bus)) can be changed using the register function: board-> G0_Counting_Mode_Register.setG0_Encoder_Counting_Mode (1); Changing the counting is done by changing the numbers passed as a parameter to the function:

- 1 - X1 mode
- 2 - X2 mode
- 3 - X4 mode

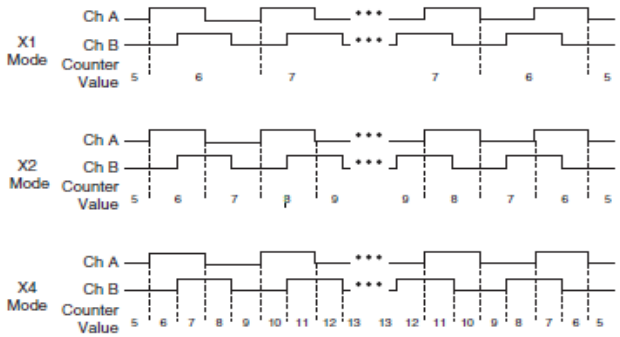

Fig. 5 Available counting modes [DAQ NI, 2002].

The second part of the function test (bus) performs the data acquisition process. Measure board compares the described signals transmitted from the encoder, and then using a timer, count them according to the mode of counting X1 shown in Figure 5. Counter values are displayed in real time on the console and stored in a file. Using a loop is set to the read counter value data which are read by the function:

board->G0_Save_Registers.readRegister()

After making number of counts the acquisition process was completed. It is still disconnecting the board from the bus, and releases the resources assigned to it. Counter disconnected by using the the board-> G0_Command_Register. writeG0_Disarm (1), system resources allocated to the start of the function test(bus) released by: bus->destroyAddressSpace(cardSpace)

The release at the end of base addresses (BAR) returned by the function acquireBoard ("PXI0 :: 8 :: INSTR") at the beginning of the acquisition, using releaseBoard (bus).

The data obtained in the acquisition process specify the position of the encoder at a time. Set in program counter mode X1 means that pulses are added in the range 0-2000, depending on the relative positions of the signals, according to the diagram counting mode. If the direction of rotation to the left encoder data is reduced in the range of 0 - (-2000). The data obtained in the acquisition process can be converted based on the algorithms, it allows the determination of position, displacement, distance, speed. The encoder can be combined with additional mechanics, allowing you to perform various measurements. If the direction of encoder rotation is to the left, data is reduced in the range of 0 - (-2000). The data obtained in the acquisition process can be converted based on the algorithms, it allows the determination of position, displacement, distance, speed. The encoder can be combined with additional mechanics, allowing to perform various measurements.

Today, encoders are used widely in industry. They are used for the implementation of various measurements, they are able to obtain specific information regarding such trading performed by the element in the machine or work piece to be treated. The data obtained in the acquisition process also allow you to improve the manufacturing process for industrial machinery.

Production data management module in a distributed system

The data transfer process for monitoring and controlling the production process is closely linked with systems of data collection and processing. These elements together form the measurement system, which can be a single position, e.g. the measurement system in an industrial laboratory, or may take the form of a distributed, while its range covers many areas and the distance between the devices is greater than the length of the interface cable. The basic elements of the measuring system is a computer or dedicated microprocessor controller, whose job is to control the transmission of data and their processing and archiving. Often specialized measurement systems are controlled using a computer operating system, which is the basis for launching programs, which enable the realization of tasks measuring system including the presentation of processed data. Distributed real-time system implemented in this article consists of two nodes, one acting as the position used for data acquisition, the other to a server to which the read data is sent (and which data can be visualized). These nodes are connected by an Ethernet network. For communication between nodes the Qnet protocol is used. In addition, the network is connected to the computer with the QNX Momentics development platform. Network nodes are controlled by the real-time operating system QNX Neutrino while application development is done on a remote host running on Windows. The position used for data acquisition consists of: data acquisition card from National Instruments PCI6601, PCI slot connected to the computer, dedicated to the card, data cable and connector R6868 CB-68LP, interface for connecting a source of signals. As the source signal encoder is used. Figure 6 shows a simplified diagram of a distributed measurement system using the previously described elements.

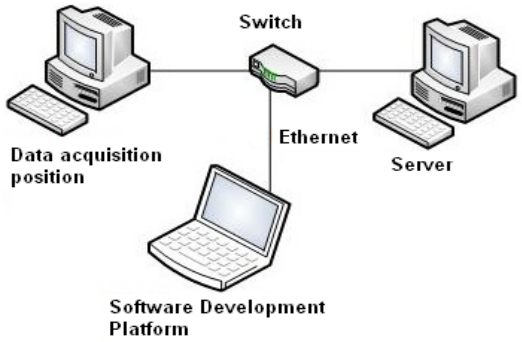

Fig. 6 Diagram of a distributed data acquisition system with software development platform.

In order to implement interprocess communication, provide the following parameters: the node identifiers and a process known as NID and PID and the channel known as CHID. The applied method of communication works very well when communicating processes run on one node. In a distributed system is the difficulty of the processes running on different nodes to provide access to information about the required IDs. The solution to this problem is to use the services of the global name server known as GNS (Eng - Global Names Service). It allows to connect to the server using for this purpose its name. In this paper, the communication between a client process running on a separate node, responsible for data acquisition and transmission and the receiving server process read from the data acquisition card is made using the GNS. To do this, follow these steps:

- check the operation of the network Qnet, whose correct configuration is required to use the GNS
- start the node used to data acquisition gns program in client
- start the server program gns running in server mode
- on the server, run a program that will receive the measurement data
- on the node for data acquisition, run a program that supports the operation of the measuring card and whose operation has been extended with features for sending messages.

Figure 7 shows the sequence to run the various server and client programs, and illustrates how it is sending the message and when processes are locked and unlocked.

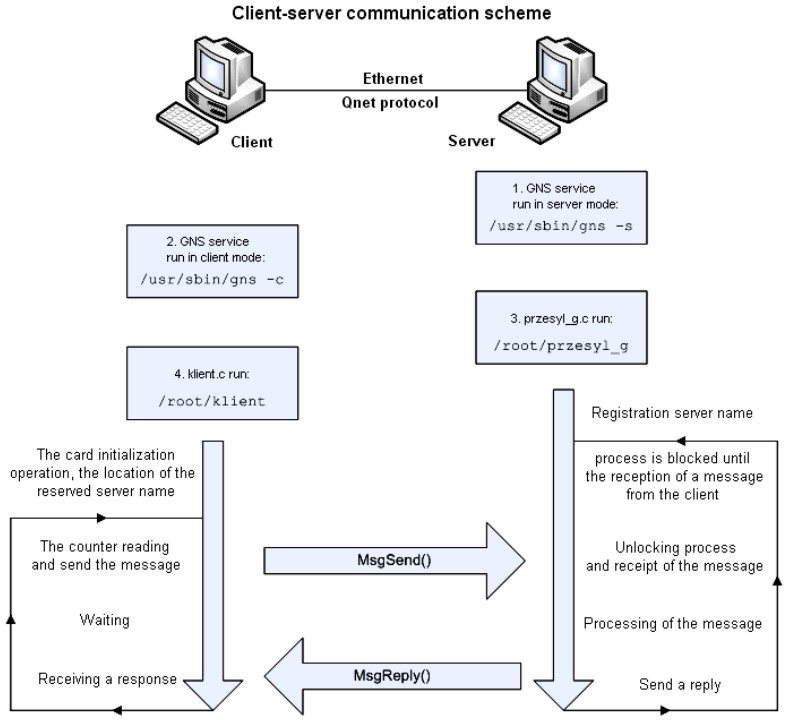

Fig. 7. Diagram of client-server communication.

GNS Running in server mode and client is possible when the user has administrator privileges. The GNS in server mode is responsible for maintaining the database of registered trademarks, and supports sent by the client process requests the name and location makes the connection. The gns when working in client mode transmit request location to the server and creates a connection to it. It is also possible run programs gns automatically at boot time by placing it in the INI file system. To start data transfer, run the appropriate program on the server would not otherwise be registered with the name of the server process and client program after running reports an error. Similarly to the server process data read from the encoder are saved to a file. The method of communication uses a simple interprocess communication mechanism using the GNS name administrator making it possible relatively easily create distributed measurement and control system.

Conclusion

Informatics company model can be illustrated by dividing it into four levels, ranging from the lowest level of sensors and control level, the level of faculty associated with the tracking of production and materials through to the level that includes planning and management systems using ERP/MRP. Now the aim is to integrate measurement and control systems with systems operating at higher levels of the presented model. This trend is caused by the desire to reduce the operating costs of the company and increase its efficiency. The basis of integration of the various levels of company information model is to ensure the proper flow of data and enable agile information processing. Therefore, there are many different interfaces based on the serial, parallel or wireless data transmission systems which design and functional parameters are strictly determined by the standard. Mentioned interfaces are used for industrial networking its various organizational levels. Profibus is used in measuring and control systems, whose working conditions are monitored continuously in real time. Ethernet network are used in the enterprise-level planning and management. May be noted that Ethernet-based networks provide coverage lower levels of the present business model, it is a consequence of the emergence of

market measurement and control devices, equipped with an Ethernet connector and adjusting these networks to meet the requirements posed in front of them real-time systems, and whose primary requirement is a timely response to changes in the controlled process. Companies typically provide coverage area in which to perform measurement and control processes, as well as management and planning processes, often carried out by individual network nodes, which work independently allow access to available resources, therefore such a network can be described as a distributed network. Real-time systems can be operated under the control of real time operating systems, which due to special design of the kernel and providing a number of tools to greatly facilitate the fulfillment of the requirements for control and measuring systems. System deployed to the process of sending data in this paper, is a system QNX Neutrino, which provides the user with a number of functions to support interprocess communication, which is characterized in that the communication between processes both in the area of one network node and between processes located on remote from each other nodes is possible to achieve using the same methods. Stage of the work involved in preparing the position for data acquisition showed that the major and how important it is to use measuring devices and operating system are compatible, which translates into effective use of the opportunities offered by the device to the system. Presented by the authors of the process of data transfer between two nodes includes simple, available in QNX Neutrino interprocess communication mechanisms. Thus, there is further development of the proposal to solve the problem or its improvements for more efficient flow of information in the network and a detailed analysis of the data transmission process using available in QNX Neutrino, mechanisms for meeting the requirements from real-time systems.

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Authors' Information

Magdalena Dobrzańska, PhD, Eng– *Rzeszow University of Technology; Department of Computer Science, ul. W. Pola 2 Rzeszow 35-959, Poland; e-mail: md@prz.edu.pl*

Paweł Dobrzański, PhD, Eng– *Rzeszow University of Technology; Department of Computer Engineering in Management, ul. W. Pola 2 Rzeszow 35-959, Poland; e-mail: pd@prz.edu.pl*

Artur Łopuszyński, Eng– *Student Rzeszow University of Technology, Poland*

Łukasz Kurowski, Eng– *Student Rzeszow University of Technology, Poland*

PREPROCESSING "RAW" DATA SETS AS AN IMPORTANT ASPECT OF INTELLIGENT INFORMATION PROCESSING

Sergii Konovalenko

***Abstract**: The paper highlighted the problems of selection methods for the preparation of the "raw" data for subsequent processing in the systems of intelligent information analysis. Each application domain contains a lot of different types of identification characteristics. Most algorithms are unable to work directly with all types and formats of data. Therefore, the preparation or the transformation of the input data set is an integral part of analysis system design. In the paper discusses methods of transformation of continuous and discrete types of data useful for analysis of the vector set. On the example of the domain "Information customs control" has been shown as configured training set for recognition of risks violation of customs legislation, based on a neural network the type multilayer perceptron. Were also considered methods of forming pseudographic patterns from the input sequence data initially did not a graphic of origin.*

***Keywords**: preprocessing, transformation data*

***ACM Classification Keywords**: D.2 SOFTWARE ENGINEERING – D.2.12 Interoperability – Data mapping*

Introduction

Building Systems intelligent information processing provides themselves stage of the preparing input data. Since in most cases, the information processing system receives the input data for analysis from various sources, there is a need to bring them to a suitable format for consideration. The primary source of data storage and may serve a database of commercial and government organizations, submitted documents, the Internet, i.e., as much as possible information that might be useful for decision making [Byuyul, 2005]. Given the fact that intelligent systems have the properties of learning, it is important to pay attention to the pre-treatment and preparation of input data sets. Failure to do so, we deteriorate the quality of information analysis system (pattern recognition, classification, etc.), and in some cases it will even make it impossible to adequately perceive the input vector data. For example, in order to train a multilayer perceptron (MLP) address a specific problem, the problem must be formulated in terms of a set of input vectors $x = [x_0, x_1, ..., x_i]^T$ and their associated reference output values $y = [y_1, y_2, ..., y_j]^T$ (standards) [Swingler, 1996]. Almost any set of domain identification characteristics of classes of information processed, is polytypic character which allows to allocate a for the consideration of actual problem as a choice of methods of preparation and transformation of its input data set for subsequent correct processing to the system analysis.

Problem definition

The purpose of this paper is consideration of the theoretical and practical application of methods of preparing input data for data mining systems, in connection with which there is a need in the following tasks:

1. To consider and to group the main methods and means of preparing the "raw" data;
2. Give an example in the domain of "information of customs control";
3. Identify possible methods for the preparation of data for training the neural network classifier.

Preprocessing of the "RAW" dataset

The functioning systems of intellectual information processing involves himself several important steps (Fig. 1):

1. Getting information from the external (internal) sources, e.g. reception;
2. Preparing Data (preprocessing);
3. Information processing;
4. Interpretation of results (postprocessing).

As mentioned above, preparation of input data, or the so-called training set (x, y) is one of the most important aspects in the creation of systems analysis. The quality of the training set has a strong influence on the model's ability to perform tasks (e.g. neural networks) [Swingler, 1996].

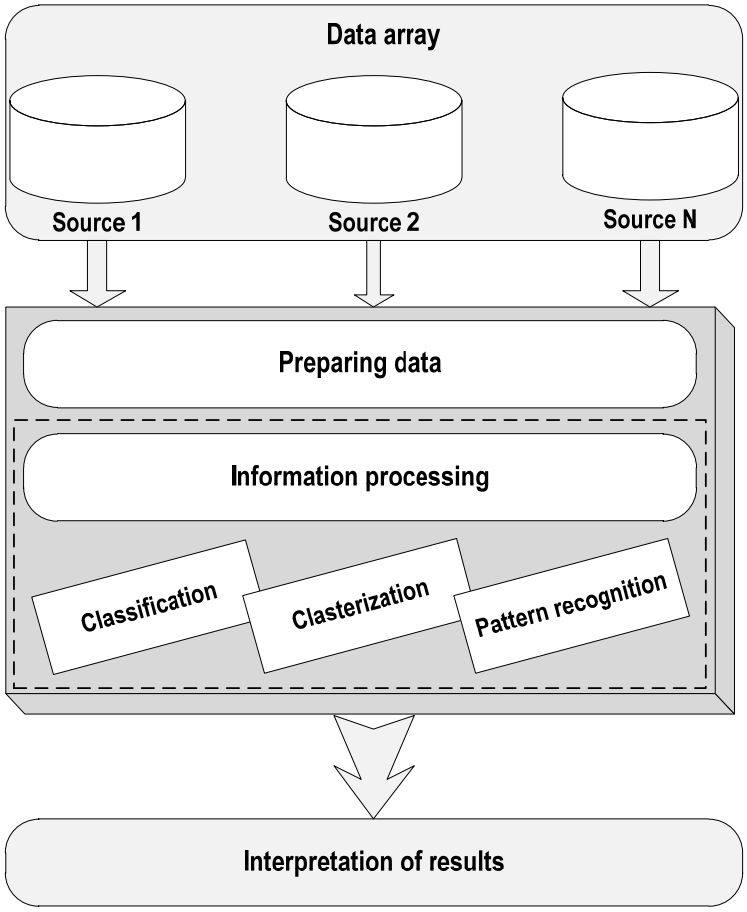

Fig. 1. Model of the information processing system

As seen in Figure 1 is the last stage of postprocessing of data, i.e. interpretation of the results. Different methods of analysis can provide information on various types of output data. In the simplest case – a set of digits (output vector), and more complex – models and rules. Therefore, it is also important to make the interpretation of this result is used in the context of the subject area. This stage performs the reverse conversion of data from the preprocessing task.

What represents the preprocessing of input data? Preprocessing is the process of preparing data for analysis, during which they are brought into conformity with the requirements determined by the specific problem to be solved (subject area) and use the model processing (analysis), the information received. As a rule, preprocessing of data includes two directions [BaseGroup]:

1. Cleaning and optimization;
2. Transformation and normalization.

Cleanup is performed to eliminate the factors that reduce the quality of data and hamper the work of analysis algorithms. It involves the processing of duplicates, inconsistencies, and fictitious values, restoration and filling gaps, smoothing and cleaning of data from the noise suppression and editing of anomalous values. In addition, the cleaning process restores violations of the structure, completeness and integrity of the data are converted incorrect format. Optimization of the data as an element of preprocessing includes reducing the dimension of input data, the identification and exclusion of irrelevant attributes. The main difference between optimization of the cleaning is that the factors that are fixed in the cleaning process, significantly reduce the accuracy of the solution of the problem or make it impossible to work analysis algorithms. Problems solved with optimization, adapting the data to a specific problem and increase the efficiency of their analysis.

Table 1. Methods of data preprocessing

Method	Problem	Solution
Cleaning the data	*Contradictory information*	1. Delete records; 2. Correct entries, selecting the most probable event.
	Gaps in data	1. Approximation (ordered sets of data); 2. Identification of the most verisimilar values (unordered information).
	Abnormal values	1. The value is removed; 2. The value is replaced by the nearest boundary value.
	Noise	1. Spectral analysis (cleaned frequently and marginal variations in some of the main signal); 2. Autoregressive methods (removal of noise from the signal describing function).
	Data input errors	1. Format-logic control
Optimization of data	*Reducing the dimension of input data (the identification and exclusion of irrelevant features)*	1. The method main components; 2. Multidimensional scaling; 3. Neural network techniques (Hopfield network, Kohonen network); 4. Using the analysis of the entropy; 5. Auto-associative networks.

As for the transformation and normalization of data, this step is necessary to bring the information to understand the terms used by the analytical model. This includes operations such as casting, quantization, coding, and so on. Each method of analysis requires that the original data were in any particular form. For example, neural networks only work with numeric data, and they should be normalized [Haykin, 1998].

Table 2. Methods of data preprocessing

Kind of information processing	Method	Solution
Data Transformation and Normalization	*Type conversion*	Convert a variable of one type to another type of value.
	Coding	It is used to encode qualitative data types or ranges of numerical types.
	Scaling	1. Decimal scaling; 2. Minimax normalization (2); 3. Normalizing the standard deviation (2).
	Quantization	1. The homogeneous (linear) quantization (3); 2. Quantization on the level

There are several types of data. Each of them is treated differently. Consider the basic data types (Fig. 2).

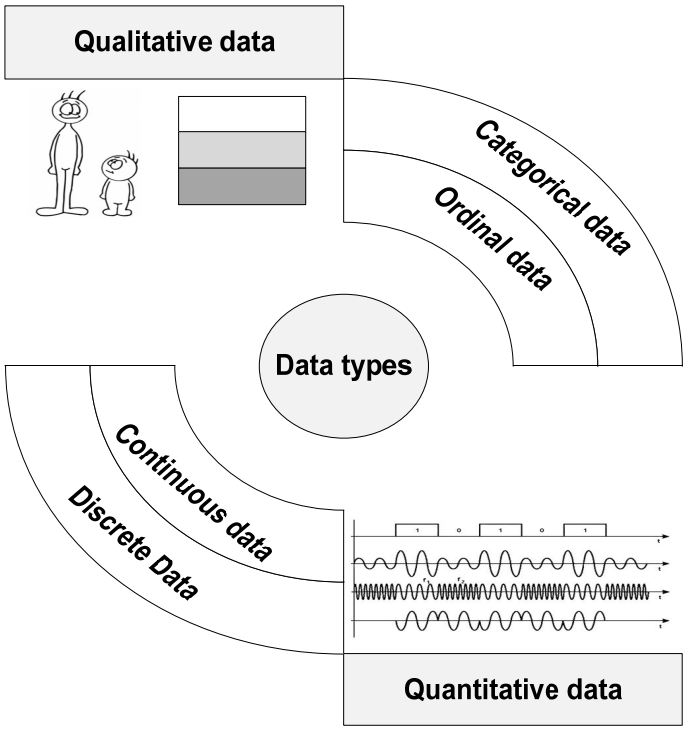

Fig. 2. Categories of the data types

The qualitative data. They represent some of the properties of objects that can't quantify (e.g., color, gender, person, etc.).

Quantitative data. They represent some of the properties of objects that take numeric values. Quantitative information in the analysis can be distributed on a scale, breaking it into equal intervals.

Consider using as a model for intelligent information processing neural networks, where there is a need to bring a training sample to the form that defines the activation function of computing neurons in the network [Bishop, 2006]. The choice of data for network training and processing is the most difficult stage of the solution. A set of training data must satisfy several criteria [BaseGroup]:

1. Representativeness – the data are intended to illustrate the true state of affairs in the subject area;
2. Consistency – is conflicting evidence in the training set will lead to poor quality of the learning network.

These criteria provide for himself the whole complex of actions preprocessing of different types of input data. As a rule, neural networks like multilayer perceptron using sigmoid activation function. That is, the input vector $x = [x_0, x_1, ..., x_i]^T$ must be brought to the range [0...1] or [-1...1] by (1) or (2).

$$x_i = \frac{x_i}{\max(X)}. \quad (1)$$

$$x_i = \frac{x_i - \mu}{S}, \quad (2)$$

where S – range $(\max(X) - \min(X)$ or standard deviation, μ – average value.

If you need to partition the continuous value into segments of equal length, the quantization can be performed as the initial value of the division by a constant value (quantization step) and the integral part of the quotient:

$$y_q = \frac{y - y_0}{h}, \quad (3)$$

where h – quantization step.

Qualitative data types shall be coded as can't be directly fed to the input of data processing systems. Typically, to each value is associated with a specific numeric value in the required range. For example:

Table 3. Example coding of the variable "Color"

Variable	Source value	Coding value	
		Decimal number	Binary number
Color	*Red*	1	00
	Blue	2	01
	Green	3	10
	White	4	11

Similarly, to encoded a vector output signal of the neural network.

In such a way, we examined the methods of preparation and transformation of the original "raw" data for systems analysts and data processing.

Preparing training sets "Information of customs control"

On the example of the domain "Information customs control" [WCO] will preprocessing training set for recognition of risks violation of customs legislation, based on of neural network the type multilayer perceptron [Moroz, 2011].

For example, the goods had been taken such a category as "Microcontrollers and Microcomputers" (8542 21 50 00 - Number of Classifier). An example of the process of forming the input vector is presented in the Table 4.

The components of the input vector are encoded by the following principle:

1. The variable X_0 is encoded binary numbers;
2. The variables X_1… X_5 are transformed by the formula (1) to the range [0 ... 1];
3. Variables X_6… X_7 take only three values, so we put them in compliance with three numeric values of {0, 0.5, 1}. These values match the level of risk {"Low," "Moderate," "High"} [ASYCUDA].

Table 4. Forming the input vector "Information of customs control"

№	Identification characteristics	Data types	Accepted values	Coding value
X_0	Country of Origin	string	Offshore	00 (bin)
			The EU countries	01 (bin)
			The EEA countries	10 (bin)
			other countries	11 (bin)
X_1	Product Code	integer	In accordance with the classifier	Range [0…1]
X_2	Customs cost	float	In accordance with the customs declaration	Range [0…1]
X_3	Quantity of goods	integer	Number of units or batches of delivery	Range [0…1]
X_4	Weight of goods	float	Weight unit of goods or the supply of the party	Range [0…1]
X_5	Invoice cost of a product	float	In accordance with the customs declaration	Range [0…1]
X_6	The difference gross and net product	float	no more 5%	0
			from 5% to 8%	0.5
			more than 8%	1
X_7	The history of the participant of foreign economic activity	string	black list	0
			gray list	0.5
			white list	1

In such a way input vector was transformed to a common format and range – [0 ... 1], which is suitable for the activation function. Now it can be input into the neural network used for training and classification.

Another way to prepare the input data is a representation of the input vector as a graphical image. Consider a vector X of 7 items and transform them into pseudographic dimension image of 7x7 (Fig. 3).

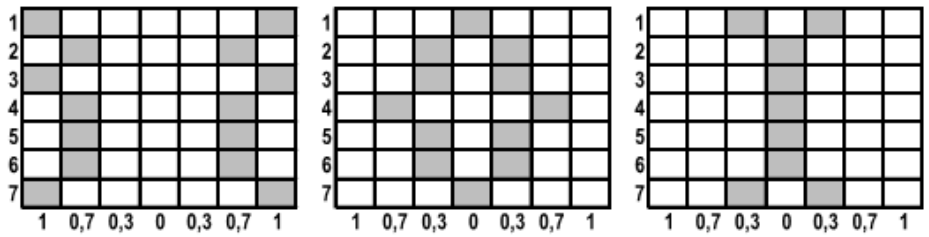

Fig. 3. Pseudographic patterns: {"High","Moderate","Low"}.

Graphic matrix is horizontally symmetrical range of risk levels (1; 0.7; 0.3; 0; 0.3; 0.7; 1), and vertically – the elements of our input vector (1...7). Each value is the input vector is estimated in accordance with the profile and level of risk (the anomaly) from 0 to 1. And then painted the cell at the intersection of the corresponding element

of the vector and its significance level of risk. The symmetry of the level of risk necessary for a better perception of the network image. In Fig. 3 shows examples of the formation of the input vector in pseudographic the first column corresponds to a “high” level of risk, the second and third – the “moderate” and “low”.

Then these symbols are the inputs to the neural network learning and recognition.

As a result of the creation of graphic images, improved quality and representativeness of the training set, both for neuroclassifier, and for the system designer analysis.

Conclusion

As a result of this work have been considered theoretically methods of preparation of input data.

The paper discusses methods for the conversion of continuous and discrete types of data suitable for analysis of the vector set. On the example of the domain "Information customs control" has been shown how a training set for recognition of risks violation of customs legislation, based on the type of neural network multilayer perceptron. Were also considered methods of forming pseudographic images from the input sequence data was not originally a graphic of origin.

Application of methods of preparation of the data allows you to turn "raw" data into high-quality training set, which is adequately and correctly displays the domain.

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Authors' Information

Sergii Konovalenko *– Ph.D. student, inspector of customs service of 3rd rank, head of the laboratory of information systems and processes in customs affair of the Ukrainian Academy of Customs, 2/4 Dzerzhinsky str., Dnipropetrovs'k, 49044, UKRAINE; e-mail: customslab@rambler.ru*

Major Fields of Scientific Research: computation intelligence, machine learning

SYSTEM MODIFICATION MODEL CREATING SYNTHESIS FOR ALGORITHM FORMULAS

Magdalena Niziołek, Volodymyr Ovsyak

***Abstract**: An analysis of the basic system for the synthesis of formulas of algebra algorithms was conducted The need for a construction of an expanded system for computer synthesis that would allow simplifying the notation of algebra formulas was demonstrated. Basing on functional criterion purpose a three-level model of decomposition was created. The model is recorded with the help of formulas of algebra algorithms. An implementation of the created model was made in the MS Visual Studio 2010 platform in C# programming language and samples are presented.*

***Keywords**: Algebra, algorithm, model, formula, subsystem, operations: formatting editor*

***ACM Classification Keywords**: F.2 Analysis of algorithms and problem complexity*

Introduction

The basic editor allowed operations only over two trivial uniterms. For more advanced algorithms the large amount of symbols led to surplus of form over content. A necessary for a new, advanced editor occurred. A new model of a computer system was created. As next, based on that model an actual editor was build. The editor assist in writing the algorithm's algebra formulas, saving it and loading exiting formulas as well as editing the data. It automatically compute the places for new elements, thus users don't need to manually correct the formulas, as it has place in the standard editors.

An example of the Euclidean algorithm written as block-diagram and as Ovsyak's formula written in the new editor is as given (Figure 1).

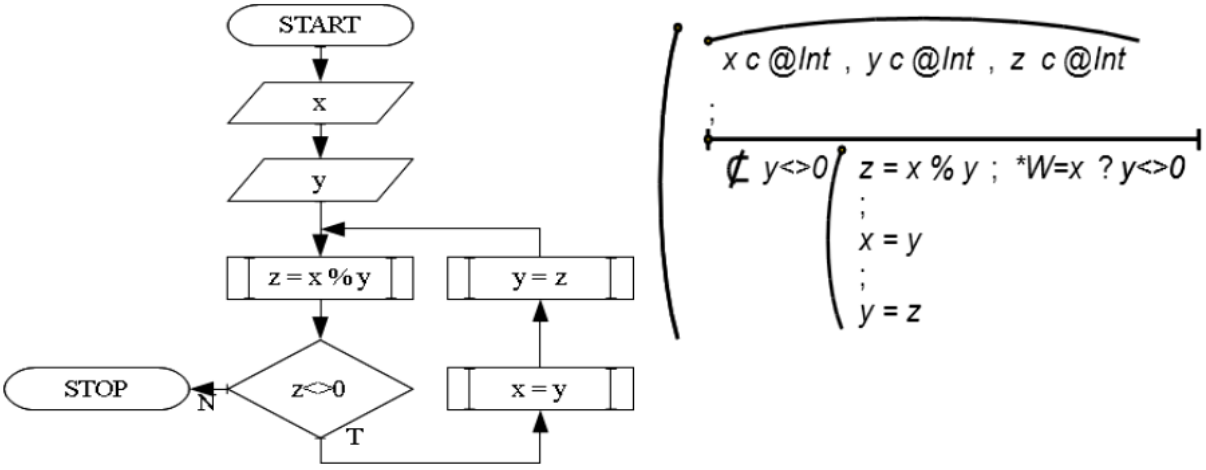

Fig. 1. An egzample of Euclidean algorithm in form of Ovsyak's formula

Where x, y are non-negative integers, z contains value of the modulo operation and *W is output message.

Computer system for creating formulas

Describing algorithms in the form of algebra forms allows not only the advantage of the formal description, it allows also to simplify transformation an algorithm into an actual computer data, thus an easier automatic optimization.

The new formula editor is written in Microsoft Visual Studio .NET 2010 with use of the modern languages XAML and C#. The actual algorithm is created and visible in the main editor in its graphic form, where a code that is easy for interpretation for a computer is at the same time written as an XML document. A description of creating complex uniterms was described in [Ovsyak, Niziołek, 2011], [Niziołek,Ovsyak, 2011]. This paper will describe the creation of operation in the above mentioned system.

Model

All models are shown as formulas of Ovsiak's algebra. The system's main model (@G) is as follow (Figure 2). The explanation of the operations and the symbols of the algebra are given in [Ovsyak, 2008].

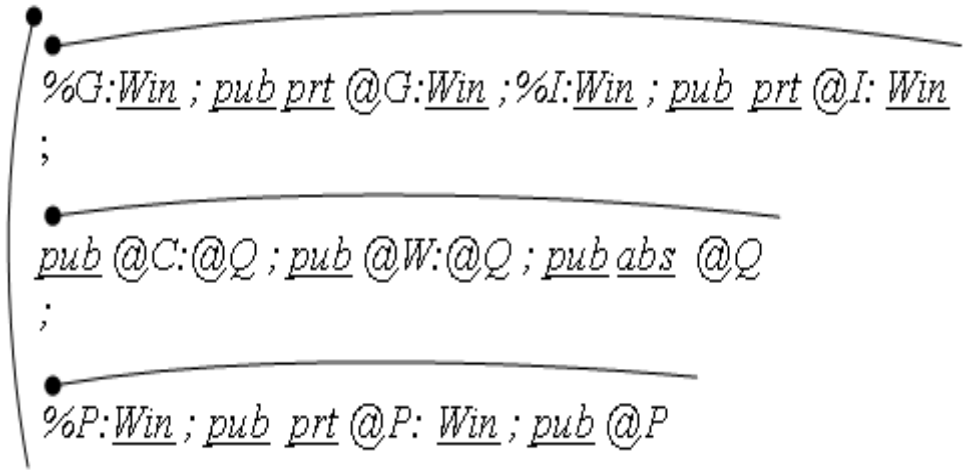

Fig. 2. Formula of the systems main model

where G is the main system, that is composed of two parts @G and %G, where @ indicate the functional subsystem and % indicate the graphic part of the system. The subsystem of creating complex uniterms is composed of @Q an abstract subsystem for terms, @W a subsystem for creating single uniterms, and @C that creates the complex uniterm. %I is its graphic part. Subsystem for creating operations is composed of @Q and %P.

The model of subsystem responsible for creating operations has the following formula (Figure 3), where:

- all the uniterms are given access method pub, which implements a well-known definition as public, with the exception of DrwCnt that has access method prv (private),
- Sprtr, Orntn and Drct are variables from the standard subsystem, enum holds information about the operation's separator, orientation and direction

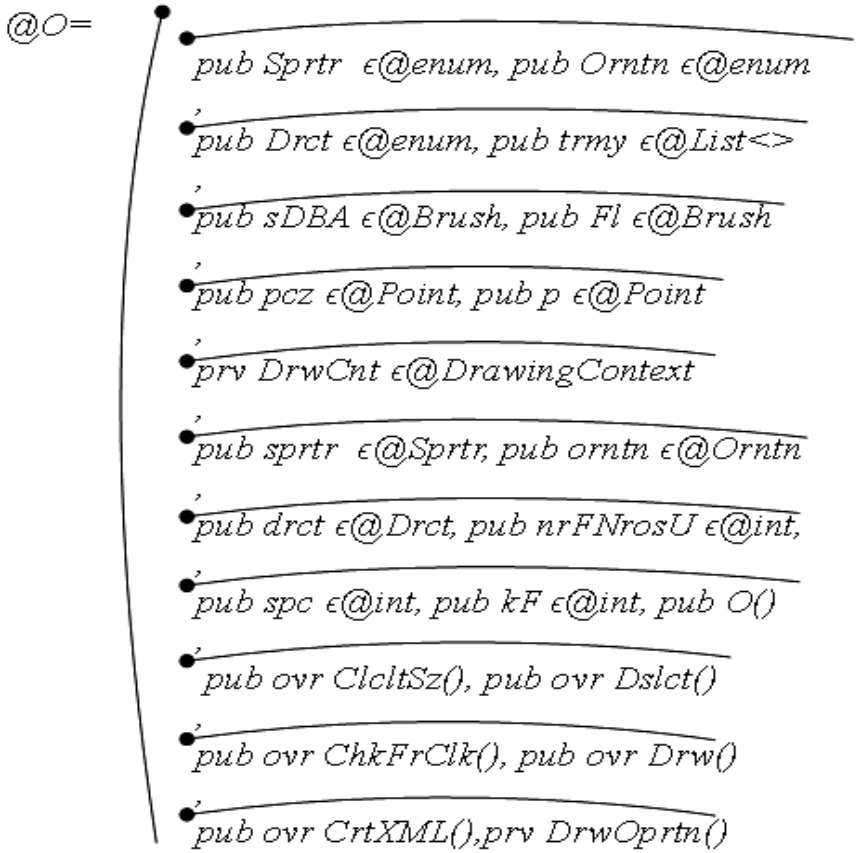

Fig. 3. Form of the subsystem for creation operations

- trmy variables from the standard subsystem List is a list of all uniterms that the operation will contain
- sDBA and Fl - variables from the standard subsystem Brush contains information about the main and second brush, that is used to paint the actual operation's symbol
- pcz and p - variables from the standard subsystem Point are uniterms that contain the beginning and current coordinate of where the operation should be placed in the main window
- DrwCnt - variable from the standard subsystem DrawingContext
- sprtr, orntn and drct - variables from the above mentioned enum type and are part of the operation that held information about the separator symbol, orientation and direction of the selected object
- nrFNrosU, spc and kF - variables from the standard subsystem Int and store information needed for creating the operation's object
- O() is the constructor, that create given operation
- ClcltSz() calculates the height and width for the new operation
- Dslct() deceselect the operation if it was chosen in the main window
- ChkFrClk() check if the operation was chosen
- Drw() draw the borders to indicate the choose of the operation, as well as others elements that are needed
- DrwOprtn() draws the specific symbol of the chosen operation
- CrtXML() creates a XML document basing on the editor nodes.

As an example of the functional uniterm a part (due to it's actual length) of the model of Drw() is shown (Figure 4).

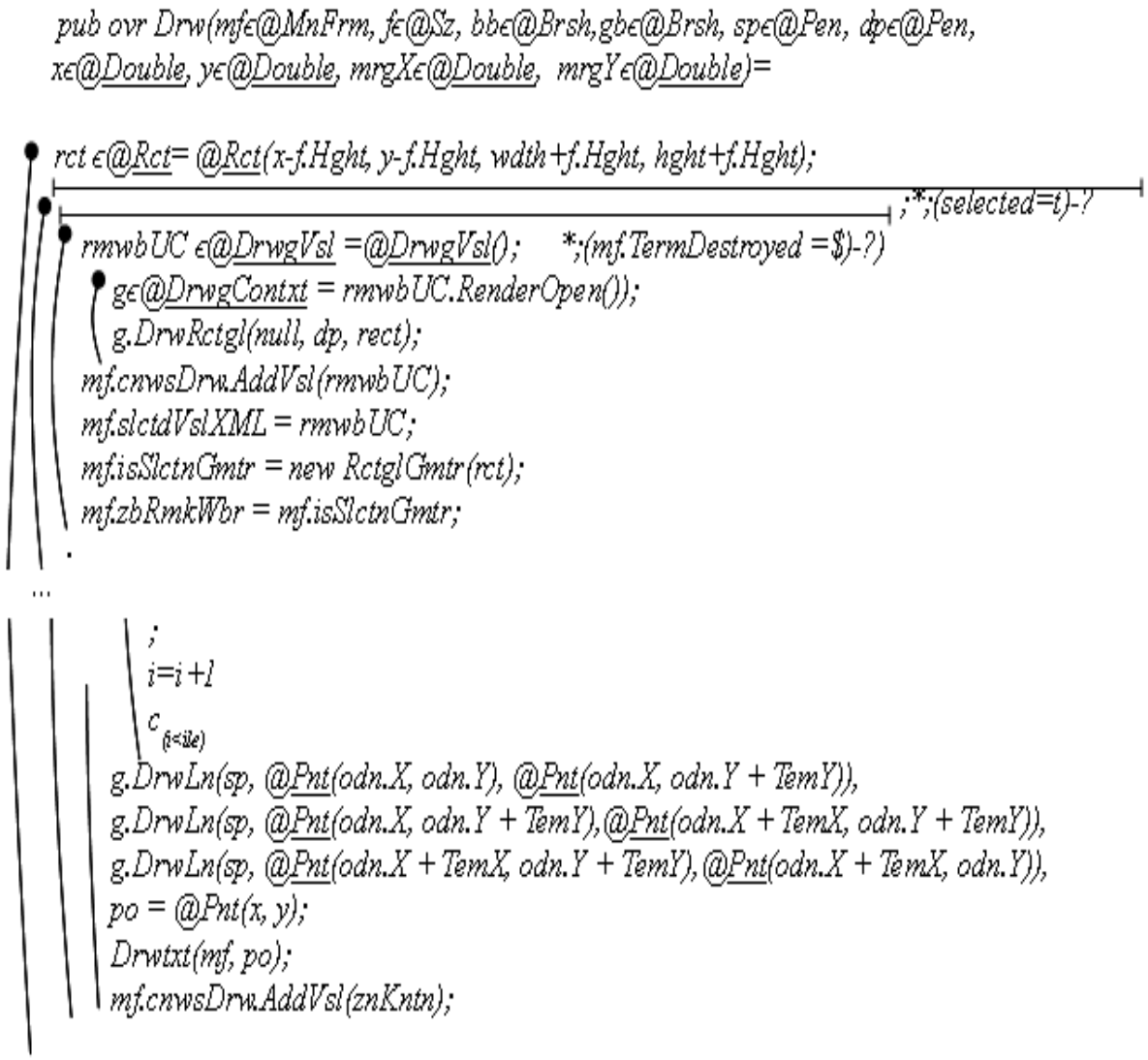

Fig. 4. The beginning and end of an functional uniterm

The model contain uniterms from the subsystem @Q and system @G, as well the standard systems.

Implementation

The main system contains classes that are system classes like MyCanvas or Form and those that were created based on the system model, like Uniterm or Sequence (Figure 5).

The model for operations is implemented for three classes: sequence, elimination and parallelization, as well partially for their cyclic counterparts. The class diagram for sequence is as follow (Figure 6).

Fig. 5. Classes used in implementation of the system

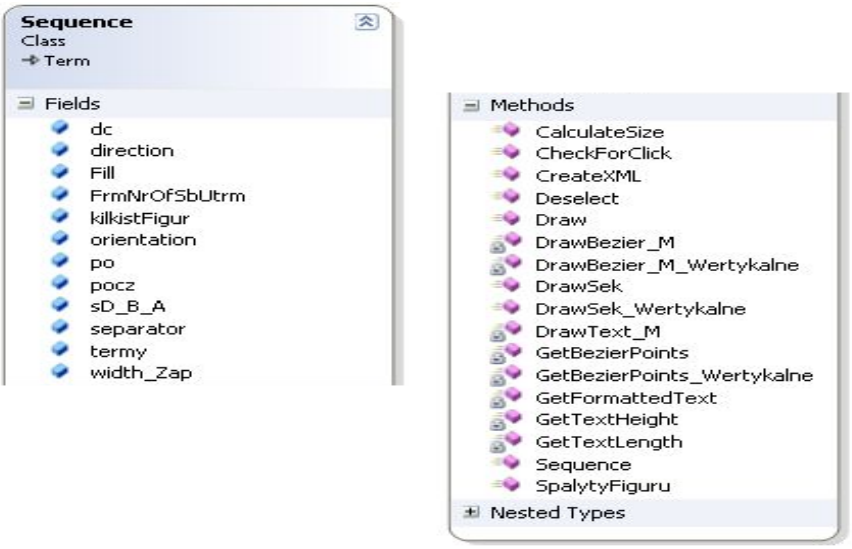

Fig. 6. Implementation of the operation's subsystem in the form of a class for creating sequences

To add an operation to the formula one has to choose an object in the main window and as next the operation symbol. The object (uniterm or operation) will be converted to the requested operation. A subsystem is called that call a graphic window for forming an operation. Next the constructor Sequence() is called and creates a new object with chosen parameters. The functional uniterm ChkFrClk() examine what part of the form was chosen. If it was uniterm, simple operation or complex operation. After receiving the information Dslct() is called. It deselect the chosen object. As next the functional uniterm ClcltSz() is calculating the size that the new operation will need in the main window (that is the size of all uniterms, separators and the operator sign size). The Drw() functional uniterm is drawing requested uniterms and call on the DrwOprtn(), that draws the requested operation symbol. At the end DrwCnt() redraws requested contents in the main window. The CrtXML() functional uniterm is called when the user saves his work.

Example

The editor showed has a tool menu divided in three sections. The first section shows button for the mostly used operations (Figure 7), that is sequencing, elimination, parallelization and their cyclic counterparts (the red frame). The second section show button for manipulating the data: creating complex uniterms, adding correct etc. of the data, connecting to database. The third section allows to customize the editor area.

To start working with the editor an uniterm or operation is need to be selected. Adding an operation to the formula is intuitively easy, by choosing the requested option from the main menu or toolbox menu. A new window will appear, that contains parameters for the new operation (Figure 8).

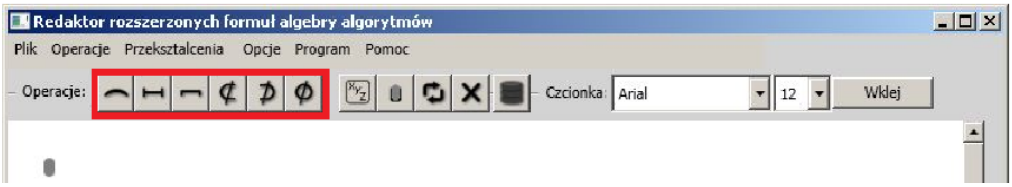

Fig. 7. Main window of the implemented system for creating Ovsyak's formuls.

Fig. 8. Windows (part of subsystem) for setting parameters for operation

The parameters are as following. The orientation of the operation can be horizontal or vertical, the separator can be a coma or a period. Accepting the parameters new operation is added to the editor **(Figure 9).** Now only data in the uniterms are need to be added.

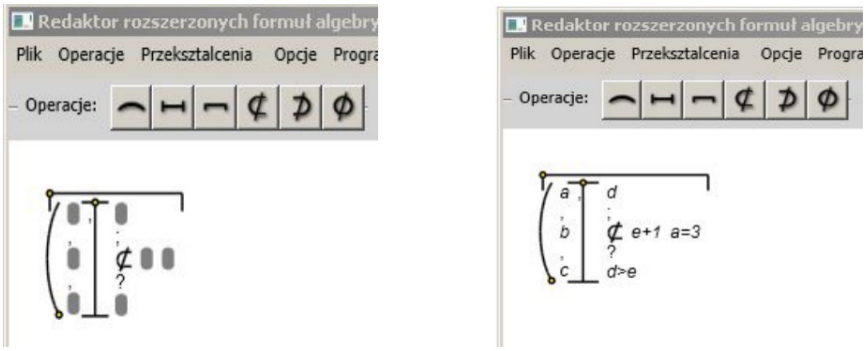

Fig. 9. Operations in the editor: a) without data, b) with data

The XML allows easy saving and loading the formula into the editor. Because of it's popular format it can be also easy imported and edited in another editors, like notepad, if the required structure is being preserved.

The example gives the following code:

```
<?xml version="1.0" encoding="utf-8"?>
<root>
 <parallelisation direction="beginning" separator="comma" orientation="horizontal">
  <sequence direction="ending" separator="comma" orientation="vertical">
   <uniterm nr=”0”>a</uniterm>
   <uniterm nr=”1”>b</uniterm>
   <uniterm nr=”2”>c</uniterm>
  </sequence>
  <elimination direction="beginning" separator="semicolon" orientation="vertical">
   <uniterm nr=”0”>d</uniterm>
   <cyclic-sequence orientation="horizontal">
    <uniterm nr=”0”>e+1</uniterm>
    <uniterm nr=”1”>a=3</uniterm>
   </cyclic-sequence>
   <uniterm nr=”2”>d&gt;e</uniterm>
  </elimination>
 </parallelisation>
</root>
```

The change in the notation between the basic and the extended editor are visible (Figure 10). In the extended editor only one symbol is needed for the same operation over more than two uniterms. The dot indicated witch uniterm shall be considered as a first. The extended editor has also an option for reducing the number of the symbols, that could appear while editing the algorithm or after optimization. At the same time the XML file is extended to cover the additional information.

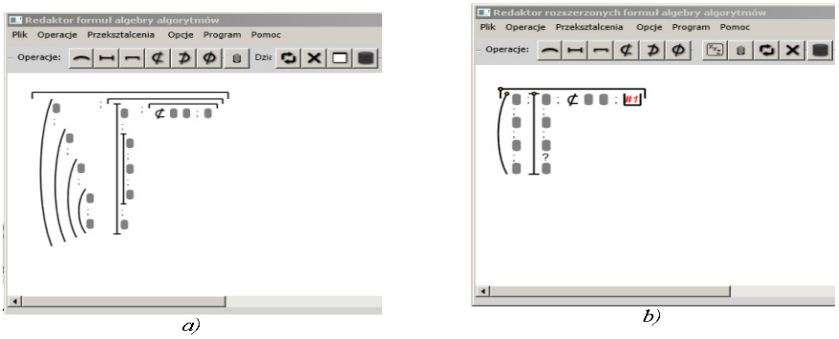

Fig. 10. Example of forms in: a) basic, b) the extended editor

Conclusion

Using algebra of algorithms allows algorithms to be described like a mathematical formula. The operations inform about connection between the parts. To help creating algorithm formulas a computer system was build, that allows easy edition of the formula and help to create computer friendly data for further use, in example optimization of the algorithm.

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Authors' Information

Magdalena Niziołek *– Opole University of Technology, Faculty of Electrical, Control and Computer Engineering, ul. Sosnkowskiego 5, 45-271 Opole, Poland; e-mail: m.niziolek@doktorant.po.opole.pl*

Major Fields of Scientific Research: programming, theory of algorithms,

Volodymyr Ovsyak *– Opole University of Technology, Opole, Poland and Ukrainian University of Printing, L’vov , Ukraine ; ovsyak@rambler.ru*

Major Fields of Scientific Research:Theoretical and applied computer science, theory of algorithms, programming, information systems, mathematical modeling.

Computer Aided Engineering and Simulation

RESEARCH OF ACCURACY OF GUARANTEED OPERAYTING TIME PREDICTION BY FRACTILE ZONES METHOD

Leonid Nedostup, Myroslav Kiselychnyk, Pavlo Zayarnyuk

Abstract: *This paper describes a method of forecasting the guaranteed operating time using the quantile zones. There are presented an equations and graphics for calculations of the guaranteed time operating error.*

Key words: *Reliability, guaranteed time, parameters' drifts, quasi-deterministic, quantile zones.*

ACM Classification Keywords: *B.8.1 Hardware - Performance and Reliability - Reliability, Testing, and Fault-Tolerance*

Introduction

It is known that among of the precision devices output parameters drift process a great part is non-stationary processes, which are variables not only the expectation and standard deviation of instantaneous values, but also dependent on the placement time interval correlation function. These processes are not ergodic is enough inertia in time irreversibility is determined by the gradual accumulation of changes, in turn, leads to smooth changes in the nature of mathematical expectation. The mean square deviation of a random component is much less than the tolerance field, because such processes are called kind of quasidetermined. Probabilistic prediction of parametric reliability of products can be made by prediction changes in the density distribution f[x(ti)] and determining on this basis since the possible options to achieve the threshold with some confidence probability. Known that to describe the drift of mathematical expectation use exponential or linear model, and to describe changes in standard deviation use linear model. Using these dependencies can build models of change over time fractile parameter values, and they help to make a prediction of the reliability with given probability of finding the parameter in the prescribed range. Guaranteed uptime T_{gar} and its variation is determined by the points of intersection of the functions of mathematical expectation m(t), upper fractile $\alpha_1(t)$ and lower fractile $\alpha_2(t)$ in setted tolerance levels Δ_1 and Δ_2. This T_{gar} is defined as the average time without a parametric failure, t_1 and t_2 respectively its minimum and maximum values. Dispersion since losing parametric reliability ΔT defined period between t_1 and t_2. This method is relatively simple and accurate, and allows to determine not only for 50% resource, but to other probability need only identify the fractile. But not always such processes can be processed using this method. In some cases, ΔT can be overwhelming, and sometimes altogether uncertain. As a result, it is necessary to study the method for its suitability in a particular case. Develop some criteria which would allow to check on the suitability of the method during the minimum number of calculations to statistical data processing. [Bobalo, 1996]

Describing of the method

If the experimental values of the parameter x_s, s = 1 .. k, in the intervals Δt_i, i = 1 .. n, then in each such period of products state is characterized by the density f[x(t_i)]. The probability of preservation efficiency is determined by the equations:

$$\mathrm{P}(\mathrm{t}_\mathrm{i}) = P\{x(t_i) > \Delta_1\} = \int_{\Delta_1}^{\infty} f[x(t_i)]dx\,. \tag{1}$$

$$\mathrm{P}(\mathrm{t}_\mathrm{i}) = P\{x(t_1) < \Delta_2\} = \int_{-\infty}^{\Delta_2} f[x(t_i)]dx\,. \tag{2}$$

x_{hr} = Δ is the limit (permissible) value of x(t); f[x(t_i)] - density distribution of instantaneous values of the parameter in the range Δt_i. Accordingly, the probabilistic prediction of parametric reliability of products can be made by changes forecasting in the density distribution f[x(t_i)] and determining on this basis since the possible options to achieve the threshold. Guaranteed uptime of T_{gar} and its variation is determined by the intersections of functions m(t), α_1(t) and α_2(t) tolerance in levels of Δ_1 and Δ_2:

$$\begin{gathered} T_{gar} = \arg\left|m(t) = \Delta_1\right|;\ \ T_{gar} = \arg\left|m(t) = \Delta_2\right|; \\ t_1 = \arg\left|\alpha_1(t) = \Delta_1\right|;\ \ t_1 = \arg\left|\alpha_2(t) = \Delta_2\right|; \\ t_2 = \arg\left|\alpha_1(t) = \Delta_2\right|;\ \ t_2 = \arg\left|\alpha_2(t) = \Delta_1\right|. \end{gathered} \tag{3}$$

Device guaranteed uptime error ΔT estimated by equation:

$$\begin{gathered} \Delta T_{1gar} = T_{gar} - t_1\,, \\ \Delta T_{2gar} = t_2 - T_{gar}\,, \\ \Delta T = \Delta T_{1gar} + \Delta T_{2gar}\,. \end{gathered} \tag{4}$$

[Nedostup, 1998]

The study of guaranteed operating time error depending on the slope coefficients

For linear parameter drift processes

For linear change of mathematical expectation and standard deviation of change construct the following equations.

$$m(t) = m_0(1 - k_1 t), \tag{5}$$

$$\alpha_1(t) = m(t) - u\sigma_0 - uk_2 t\,, \tag{6}$$

$$\alpha_2(t) = m(t) + u\sigma_0 + uk_2 t\,.$$

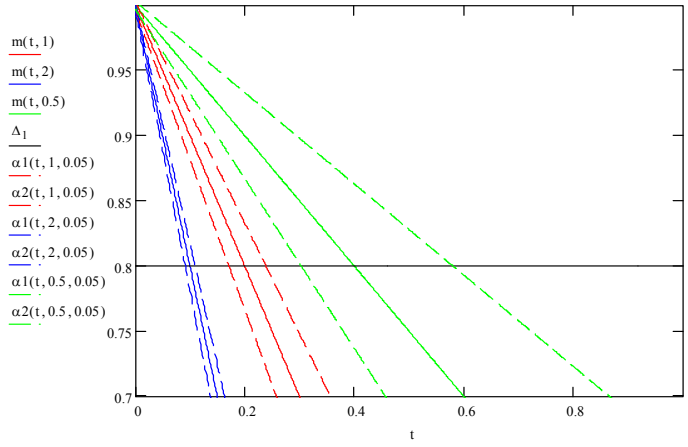

Fig. 1. Graph of the mathematical expectation and fractile for 3 different values of k_1 for fixed value of k_2.

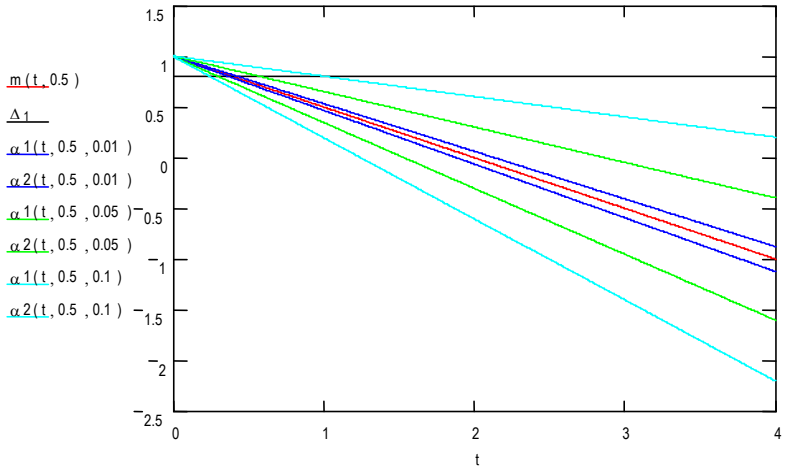

Fig. 2. Graph of the mathematical expectation and fractile for 3 different values of k_2 for fixed value of k_1.

From the pictures can be noted that the increased k1 do that the time difference between both fractile interception is reduced, with increased k_1 ΔT error decreases but decreases and guaranteed time (intentionally increase k_1 lead only to deterioration of circumstances). And there is another dependency k_2: increasing k_2 ΔT error increases and the value of guaranteed time is independent of k_2. Therefore advisable to try to reduce the k_2. Equating formed to determine the intersection points with the tolerance level T_{gar}, t_1, t_2.

$$m(t) = m_0\left(1 - k_1 T_{gar}\right) = \Delta_1, \tag{7}$$

$$\alpha_1(t) = m(t_1) - u\sigma_0 - uk_2 t_1 = \Delta_1,$$

$$\alpha_2(t) = m(t_2) + u\sigma_0 + uk_2 t_2 = \Delta_1. \tag{8}$$

And:

$$T_{gar} = \frac{m_0 - \Delta_1}{m_0 k_1},$$

$$t_1 = \frac{m_0 - u\sigma_0 - \Delta_1}{m_0 k_1 + uk_2}, \tag{9}$$

$$t_2 = \frac{m_0 + u\sigma_0 - \Delta_1}{m_0 k_1 - u k_2}.$$

Errors are defined as follows:

$$\Delta T_{1gar} = T_{gar} - t_1 = \left[\frac{m_0 - \Delta_1}{m_0 k_1} - \frac{m_0 - u\sigma_0 - \Delta_1}{m_0 k_1 + u k_2} \right],$$
$$\Delta T_{2gar} = t_2 - T_{gar} = \left[\frac{m_0 - \Delta_1}{m_0 k_1} - \frac{m_0 + u\sigma_0 - \Delta_1}{m_0 k_1 - u k_2} \right]. \quad (10)$$

Losing parametric reliability time dispersion ΔT determined by the sum:

$$\Delta T = \Delta T_{1gar} + \Delta T_{2gar}. \quad (11)$$

To determine the influence coefficients k_1, k_2 for guaranteed time prediction error construct graph family of the error depending for the first fractile and the second fractile (ΔT_{1gar}, ΔT_{2gar}).

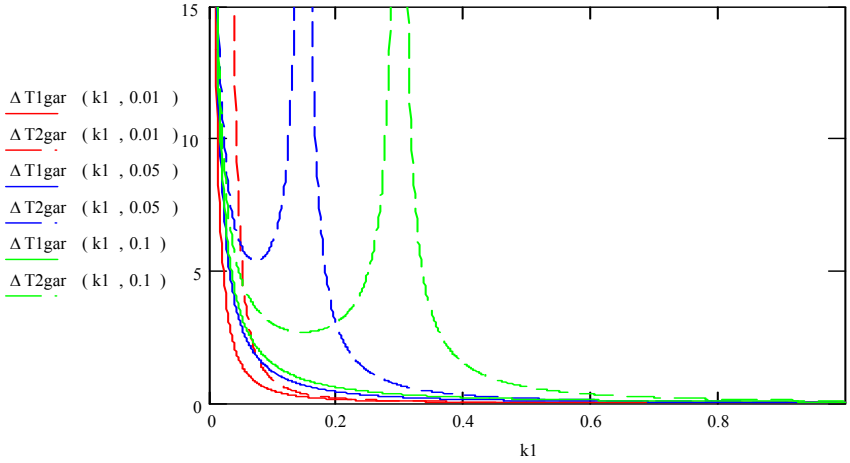

Fig. 3. Graph of guaranteed time error equation on k_1 factor.

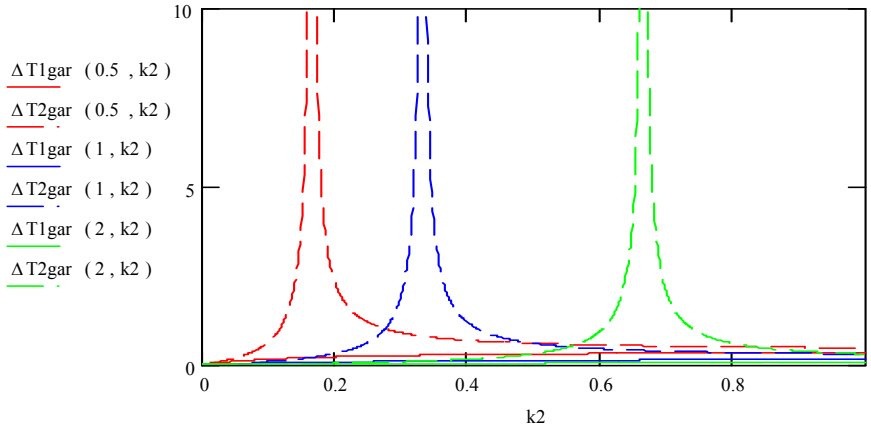

Fig. 4. Graph of guaranteed time error equation on k_2 factor.

Graph in fig. 3 show that for certain values of k_1 error ΔT_{2gar} behaves unclear due to the fact that in this case ΔT_{2gar} is unclear and since a value of k_1 error starts to decrease from infinity. That can be determined that an increase in the coefficient k_1 decrease error but the decrease a guaranteed time to, in addition there is the extent to which k_1 less error is uncertain, this limit is lower at lower values of k_2. The graph in fig. 4 illustrate that an increase of the coefficient k_2 increases measurement errors ΔT_{1gar}, ΔT_{2gar} so that ΔT_{1gar} tends to t when m(t)=Δ, and tends to infinity ΔT_{2gar} when approaching k_2 to a certain extent which is greater at larger values of k_1.

Behaviour of error indicated that there are some limits to the values of k_1 and k_2. Based on the nature of relationships and graphic material received is below these values k_1 and k_2 in which fractile α_2 becomes equal to a constant:

$$\alpha_2(t) = m_0 - m_0 k_1 t + u\sigma_0 + uk_2 t = c\,. \tag{12}$$

This constant is easy to find it is the initial fractile value :

$$c = \alpha_2(0) = m_0 + u\sigma_0\ . \tag{13}$$

Where is the following condition: $-m_0k_1t$ must compensate uk_2t. The result is the equation:

$$-m_0 k_1 t = uk_2 t\,.$$

To get the limit equation will reduce t:

$$\frac{k_1}{k_2} = \frac{-u}{m_0}\,. \tag{14}$$

For the growing dependence of all remains the same and the results are similar:

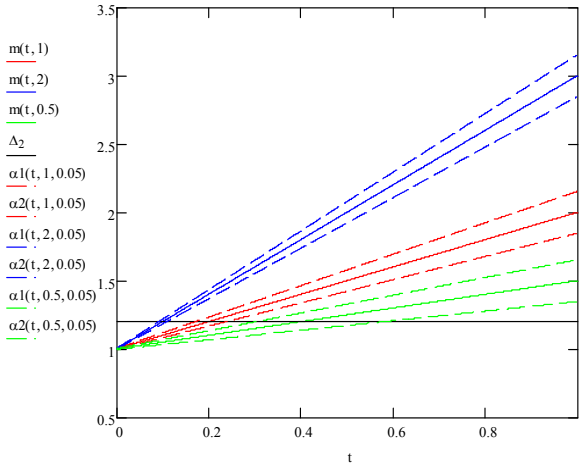

Fig. 5. Graph of the mathematical expectation and fractile for 3 different values of k_1 for fixed value of k_2.

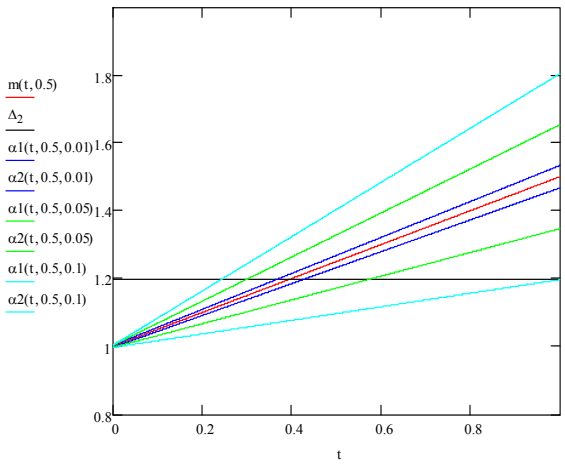

Fig. 6. Graph of the mathematical expectation and fractile for 3 different values of k_2 for fixed value of k_1.

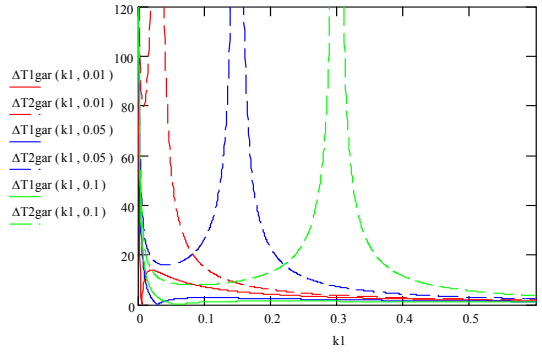

Fig. 7. Graph of guaranteed time error equation on k_1 factor.

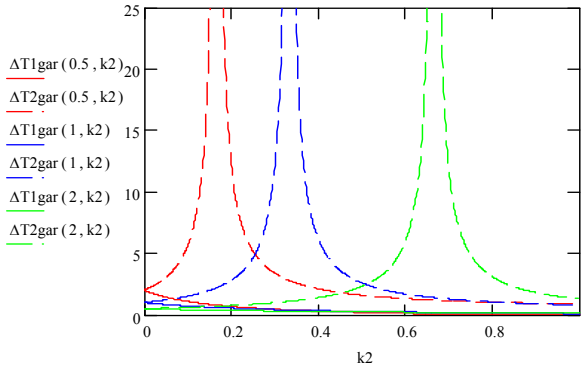

Fig. 4. Graph of guaranteed time error equation on k_2 factor.

The limit for the case of the growing nature of drift takes the form:

$$\frac{k_1}{k_2} = \frac{u}{m_0}. \tag{15}$$

For the exponential parameter drift processes

Consider the descending process. In the linear approximation moments T_{gar}, t_1, t_2 are determined from the equations:

$$m(T_{gar}) = m_0 \exp(-k_1 T_{gar}) = \Delta_1; \tag{16}$$

$$\begin{aligned} \alpha_1(t) &= m_0 \exp(-k_1 t_1) - u\sigma_0 - uk_2 t_1 = \Delta_1; \\ \alpha_2(t) &= m_0 \exp(-k_1 t_2) + u\sigma_0 + uk_2 t_2 = \Delta_1. \end{aligned} \tag{17}$$

Solving the first equation we get:

$$T_{gar} = \ln\left(\frac{m_0}{\Delta_1}\right)^{1/k_1}. \tag{18}$$

The second and third equation is transcendental relative to t1, t2precise methods of their solutions do not exist. Therefore, schedule exponent $e^{-k_1 t_2}$ in series:

$$\exp(-k_1 t) = 1 - k_1 t + \frac{(-k_1 t)^2}{2!} + \frac{(-k_1 t)^3}{3!} + \ldots \tag{19}$$

This alternating series as known is converge for any $k_1 t_1$. Where as $k_1 t_1$ may be small, can be neglected components with the powers number begin from second. That is consider that [Korn, 1984]:

$$\exp(-k_1 t) = 1 - k_1 t.$$

And:

$$\varepsilon = \sum_{n=2}^{\infty} \frac{(-k_1 t)^n}{n!}. \tag{20}$$

Then equation (17) can be rewritten as:

$$m_0\left(1-k_1T_{gar}\right)-u\sigma_0-uk_2T_{gar}\approx\Delta_1\,. \tag{21}$$

And:

$$t_1\approx\frac{m_0-\Delta_1-u\sigma_0}{m_0k_1+uk_2},$$

similarly:

$$t_2\approx\frac{-m_0+\Delta_1-u\sigma_0}{-m_0k_1+uk_2}.$$

So:

$$\begin{aligned}\Delta T_{1gar}&=T_{gar}-t_1\approx\ln\left(\frac{m_0}{\Delta_1}\right)^{1/k_1}-\frac{m_0-\Delta_1-u\sigma_0}{m_0k_1+uk_2};\\ \Delta T_{2gar}&=t_2-T_{gar}\approx\ln\left(\frac{m_0}{\Delta_1}\right)^{1/k_1}-\frac{-m_0+\Delta_1-u\sigma_0}{-m_0k_1+uk_2}.\end{aligned} \tag{22}$$

And ΔT is determined by the sum:

$$\Delta T=\Delta T_{1gar}+\Delta T_{2gar}\,.$$

In the case of the growing exponential and linear approximation we obtain the relation:

$$m(t)=m_0\left[1-\exp(-k_1T_{gar})\right]=\Delta_2; \tag{23}$$

$$\begin{aligned}\alpha_1(t)&=m_0\left[1-\exp(-k_1t_2)\right]-u\sigma_0-uk_2t_2=\Delta_2;\\ \alpha_2(t)&=m_0\left[1-\exp(-k_1t_1)\right]+u\sigma_0+uk_2t_1=\Delta_2\,.\end{aligned} \tag{24}$$

Guaranteed time errors is calculated by the equations:

$$\Delta T_{1gar}=T_{gar}-t_1\approx\ln\left(\frac{m_0}{m_0-\Delta_2}\right)^{1/k_1}-\frac{\Delta_2-u\sigma_0}{-m_0k_1+uk_2}; \tag{25}$$

$$\Delta T_{2gar}=t_2-T_{gar}\approx\ln\left(\frac{m_0}{\Delta_1}\right)^{1/k_1}-\frac{\Delta_2+u\sigma_0}{m_0k_1+uk_2}\,. \tag{26}$$

Losing parametric reliability time dispersion, as in the previous case, determined by the sum:

$$\Delta T=\Delta T_{1gar}+\Delta T_{2gar}\,.$$

Now consider the case of quadratic approximation of decreasing and increasing exponentials, according to preliminary considerations will describe the exponential quadratic equation. Then:

$$\exp\left(-k_1t\right)=1-k_1t+\frac{(-k_1t)^2}{2!}\,. \tag{27}$$

The equations of mathematical expectation m(t) and fractiles $\alpha_1(t)$ and $\alpha_2(t)$ when descending exponentially take the form:

$$m(t) = m_0 \exp(-k_1 T_{gar}) = \Delta_1; \tag{28}$$

$$\alpha_1(t) = m_0\left[1 - k_1 t_1 + \frac{(-k_1 t_1)^2}{2!}\right] - u\sigma_0 - uk_2 t_1 = \Delta_1;$$

$$\alpha_2(t) = m_0\left[1 - k_1 t_2 + \frac{(-k_1 t_2)^2}{2!}\right] + u\sigma_0 + uk_2 t_2 = \Delta_1. \tag{29}$$

The solution of these equations T_{gar}, t_1, t_2 are :

$$T_{gar} = \ln\left(\frac{m_0}{\Delta_1}\right)^{1/k_1}; \tag{30}$$

$$t_1 \approx \frac{(m_0 k_1 + uk_2) \pm \sqrt{(m_0 k_1 + uk_2)^2 - 2(m_0 - u\sigma_0 - \Delta_1) m_0 k_1^2}}{m_0 k_1^2};$$

$$t_2 \approx \frac{(m_0 k_1 + uk_2) \pm \sqrt{(m_0 k_1 - uk_2)^2 - 2(m_0 + u\sigma_0 - \Delta_1) m_0 k_1^2}}{m_0 k_1^2}. \tag{31}$$

Changing the output setting for the growing exponential law describes by the dependencies:

$$m(t) = m_0\left[1 - \exp(-k_1 T_{gar})\right] = \Delta_2; \tag{32}$$

$$\alpha_1(t) = m_0\left[1 - \left(1 - k_1 t_2 + \frac{(-k_1 t_2)^2}{2!}\right)\right] - u\sigma_0 - uk_2 t_2 = \Delta_2;$$

$$\alpha_2(t) = m_0\left[1 - \left(1 - k_1 t_1 + \frac{(-k_1 t_1)^2}{2!}\right)\right] + u\sigma_0 + uk_2 t_1 = \Delta_2, \tag{33}$$

$$t_1 \approx \frac{(m_0 k_1 + uk_2) \pm \sqrt{(m_0 k_1 + uk_2)^2 - 2(\Delta_2 - u\sigma_0) m_0 k_1^2}}{m_0 k_1^2}; \tag{34}$$

$$t_2 \approx \frac{(m_0 k_1 + uk_2) \pm \sqrt{(m_0 k_1 - uk_2)^2 - 2(\Delta_2 + u\sigma_0) m_0 k_1^2}}{m_0 k_1^2}. \tag{34}$$

The choice of linear or quadratic approximation of the average change in alue during the operation carried out by comparing the approximation error with the requirements for the accuracy of prediction reliability. These dependences reflect the relationship between the reliability of the devices, the initial values of parameters and patterns of change in service. It is clear that among the characteristics most subject to management during the initial values of parameters that can be set rationally considering reasonable manufacturing tolerances. Based on the above equations are built dependency graphs of mathematical expectation and fractiles for different values of slope k_1 and k_2 (Fig. 9, 10).

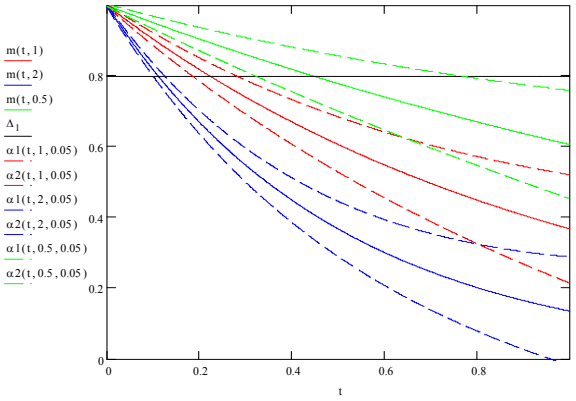

Fig. 9. Graph of the mathematical expectation and fractiles for different values of k_1 for fixed values of k_2.

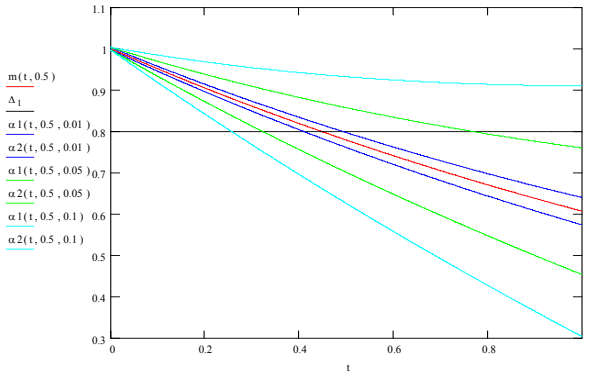

Fig. 10. Graph of the mathematical expectation and fractiles for different values of k_2 for fixed values of k_1.

On fig. 9 and 10 shown that there are times when fractile not cross tolerance level changing its direction to reversed. It is similar situation as with linear drift. To determine the moment of time in which fractile change their direction build derivatives of each fractile. From mathematics we know that the derivative shows tangent angle function, so when derivative crossed with zero level the fractile is a change direction (Fig. 11).

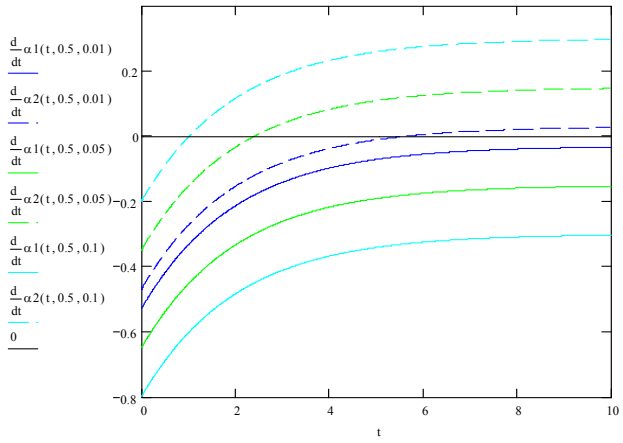

Fig. 11. Family of derivatives on fractiles α_1, α_2.

On fig. 11 shown time points when fractile α_2 begin to increase ($t \approx 1, 1.5, 5.5$), but if the fractile not crossed the tolerance level to it time it will not cross never.

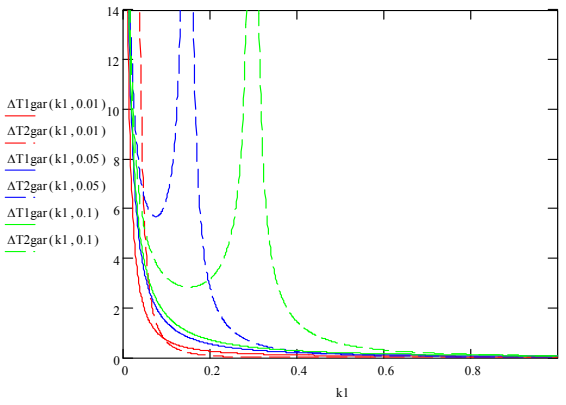

Fig. 12. Graph of guaranteed time error equation on k_1 factor.

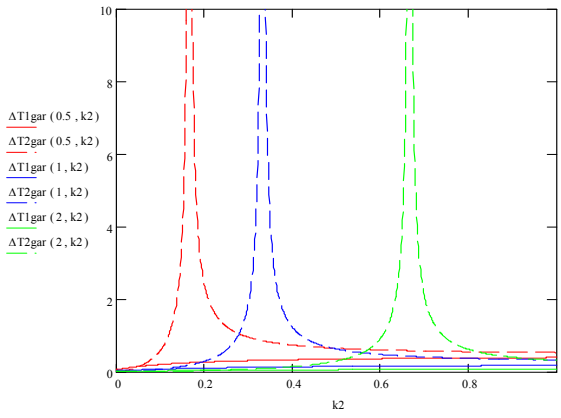

Fig. 13. Graph of guaranteed time error equation on k_2 factor.

For exponential character of drift error behaves similarly to linear drift. We can identify the limit equation from the following equation systems:

$$\begin{cases} \alpha_2(t)' = 0 \\ \alpha_2(t) = \Delta_1 \end{cases}. \tag{35}$$

But formed equation is transcendent.

Similar properties have a growing process. Schedules for the growing process are shown in fig. 14, 15, 16, 17.

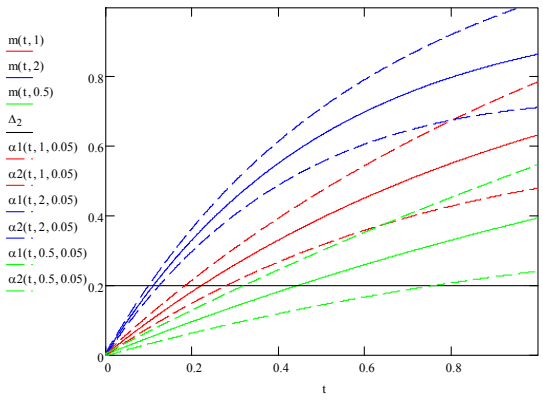

Fig.14. Graph of the mathematical expectation and fractile for different values of k_1 at fixed values of k_2.

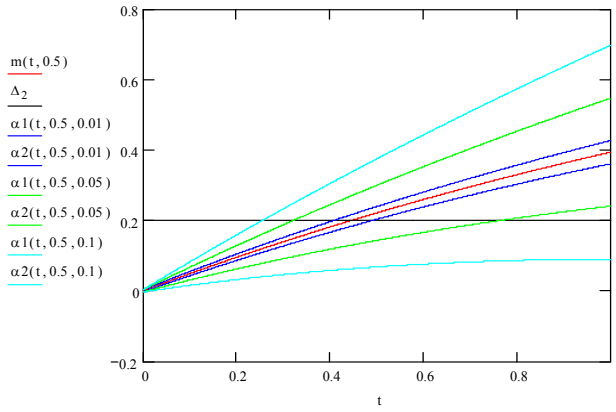

Fig. 15. Graph of the mathematical expectation and fractile for different values of k_2 for fixed values f k_1.

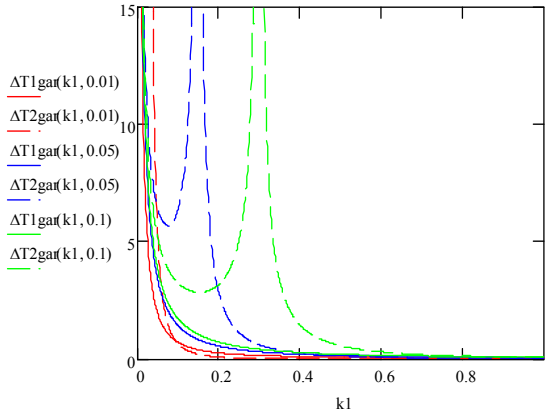

Fig. 16. Graph of guaranteed time error equation on k_1 factor.

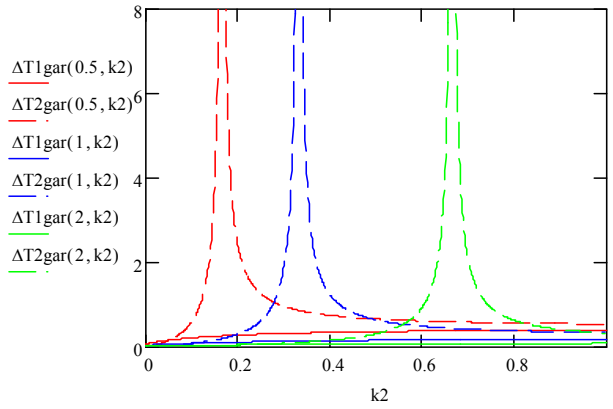

Fig. 17. Graph of guaranteed time error equation on k_2 factor.

Conclusion

As a result of the research is presented the some boundary conditions ("limit") to which method is suitable and effectiveness. For linear drift parameter limit is determined and clearly established (14, 15), and in the case of exponential nature of the drift parameter limit becomes transcendental form and therefore requires the solution of the transcendent equation for each case is derived from (35). Also found that reducing the error of guaranteed time desired is the increase in steepness parameter drift and drift reducing the slope standard deviation, but in terms of reliability necessary to reduce both the coefficients of steepness becouse is advisable to reduce the slope coefficient of standard deviation drift .

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Authors' Information

prof. Leonid Nedostup *- Lviv National University "Lviv Polytechnic", Institute of Telecommunications Radio and Electronic Engineering, Stepan Bandera str. 12, 79013, Lviv, Ukraine.*

sci. Miroslav Kyselychnyk *- Lviv National University "Lviv Polytechnic", Institute of Telecommunications Radio and Electronic Engineering, Stepan Bandera str. 12, 79013, Lviv, Ukraine, e-mail: mkiselychnyk@polynet.lviv.ua*

postgraduate Pavlo Zayarnyuk *- Lviv National University "Lviv Polytechnic", Institute of Telecommunications Radio and Electronic Engineering, Stepan Bandera str. 12, 79013, Lviv, Ukraine, e-mail: ZayarnyukPM@gmail.com*

ENERGY-EFFICIENT PROTOCOL IN OMNET++ SIMULATION ENVIRONMENT

Krzysztof Daniluk

***Abstract**: New idea for energy-efficient extension for OSPF protocol is presented. New concept is based on Dijkstra's algorithm, which recalculates shortest path each time, when metric is updated. There is introduced in OSPF new metric's value based on traffic load on routers' interfaces.*

***Keywords**: energy-efficiency, OMNeT++ simulation environment, OSPF routing protocol*

***ACM Classification Keywords**: I.6 Simulation and Modeling*

Introduction

Green networking is becoming more and more popular trend. Bigger power usage of information communication technologies limit the wireless networks performance. This problem touches also wired networks, because energy costs are big part of overhead costs for network devices. Also carbon dioxide emissions reduction is becoming a significant problem. Many public organizations and internet service providers report statistics of growing trend for network energy requirements [Bianco, 2007], [Qureshi, 2009], as well as for carbon footprint.

One of the interesting examples is energy consumption of Telecom Italia network, which reached more than 2TWh in 2006, i.e. 1% of the total energy demand in Italy. British Telecom 2.6TWh in 2008, Deutsche Telekom more than 3.5TWh.

To support further development of telecom operators there is a need to run more sophisticated architectures, more complex operations in a scalable way [Chabarek, 2008]. Also from the Future Internet point of view, it can be said, that energy awareness is becoming an important part of the network design. Interesting challenge is creating mechanisms for network equipment enabling energy savings. An idea how it can be done is following: adapting network capacities and resources to current traffic loads, in the same time not forgetting about Quality of Service (QoS).

There is done broad spectrum of research focusing on energy aware infrastructures, applications, transmission and adaptive control of device activity, that form a network.

Open-Shortest Path First Protocol

Open Shortest Path First is an adaptive routing protocol for Internet Protocol networks [Azzedine, 2003]. Uses a link state routing algorithm, belongs to the group of interior routing protocols, operating in a single autonomous system. For IPv4 is defined as OSPF Version 2, for IPv6 – OSPF Version 3.

OSPF is one of the most widely-used interior gateway protocols [Haider, 2011] [Daniluk, 2012] in large networks. OSPF as an interior gateway protocol routes IP packets inside a single routing domain, i.e. autonomous system.

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A topology map of the network is built based on link state information from routers. OSPF is able to detect changes in the topology, like link failures. There is computed the shortest path tree for each route using a Dijkstra's algorithm. On each router is kept link-state information, called link-state database (LSDB), which is a tree image of the entire network topology.

Copies of LSDB are periodically flooded in the network on all OSPF routers. There are used cost factors in OSPF routing policies in constructing a route table. Cost factors can be following: distance (round-trip time) in the network.

OSPF does not use a TCP/IP transport protocol (UDP, TCP), but is encapsulated in IP datagrams.

Link State Advertisement (LSA) is used to inform all other local routers in the same OSPF area about the router's local routing topology. LSAs are not flooded out on all interfaces, but only on those that belong to the appropriate area. Thanks this detailed information can be kept localized.

There are different types of LSA.

Some of them announce presence of the router and lists of the links (also metrics) to other routers or networks in the same area. These LSAs are flooded across their own area only, it is type 1: Router LSA.

On the other hand we can see Area Border Router (ABR), which learned on one of its attached areas, summarizes and sends it out on other areas it is connected to. The summarization provides scalability by removing detailed topology information for other areas. Routing information is summarized into just an address prefix and metric.

Power management mechanisms

Modern power management mechanisms must deal with optimization at all levels of network structure. To do this there are used power scaling and standby capabilities, to decrease energy demands [Bolla, 2010] [Zhang, 2010].

The smart standby puts a device in a very low energy mode, in which only some vital functionalities are provided. It means, that standby capability can be applied in devices, that will be not used for a longer period of time.

The dynamic power scaling reduces the energy requirement of a network [Cuomo, 2011] by scaling its performance. There are two main families of power scaling approaches:

Adaptive rate techniques (AR): scaling the device's processing capacity, transmission, reception speed of the network interface.

Low power idle techniques (LPI): using short inactivity periods by putting a device into low power state. They are presented in fig. 1.

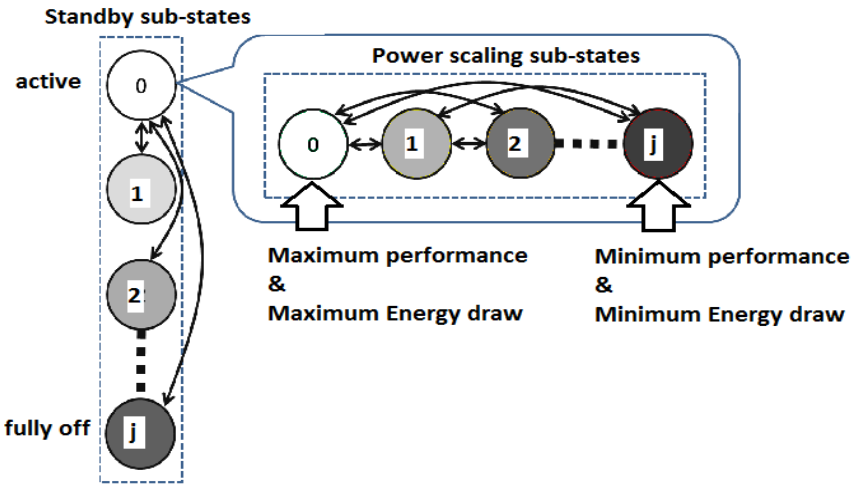

Fig. 1 Power scaling and standby power states

It is good to underline, that most personal computers follow ACPI (Advanced Configuration and Power Interface) specification defining a number of power-aware states, where is used scaling down processor voltage and clock frequency in case, when processor is in stand-by mode.

Different situation is for typical network devices, where is not implemented any energy saving mechanism.

An interesting idea would be using Green Abstraction Layer (GAL) [Bolla, 2010], interface between monitoring, control and hardware for exchanging data informing about power status of the device. It is built in order to hide the implementation details of energy saving approaches.

The Green Standard Interface is a simple internal interface of the „Green Abstraction Layer" (GAL) for exchanging power management data among data-plane elements and processes realizing control plane strategies. Important fact is creating power domains, building power management Quality of Service (QoS) by defining higher and lower level power states differentiated with frequency and voltage.

GRIDA algorithm

In one of the papers [Bianzino, 2012] is presented a new algorithm, called GRIDA, which is based on OSPF and extends its functionality. This algorithm may be used in networks, where a Link-State routing algorithm like OSPF is running.

The key idea of GRIDA is taking independent decisions, optimizing a selfish utility function at random time intervals.

What's more, there is no centralized knowledge, like Traffic Matrix, routing paths, but only LOAD and ENERGY COST of incident links and PERIODIC LSA reporting the network state.

If the network is congested or disconnected, then the node is forced to turn on all its interfaces (all-on configuration).

New possibilities for functionality of OSPF simulator in OMNeT++ environment – new author's approach

The main idea is introducing new elements to OSPF protocol's structure. The key feature is extending LSA Update messages, where routers get energy values of adjacency links. Thanks this they can, in a distributed way, control the energy states of their interfaces.

Nodes share information about the incident link load or power consumption through the link-state protocol.

There is also no centralized knowledge, LSAs (sent when change of the network topology, increasing traffic load) are reporting the network state and can suggest new energy states for other router's interfaces.

New: LSAUpdate packets are introducing updates based on following criteria: energy-efficiency.

In already done experiments a simulation environment for computer networks, called OMNeT++, is used. An example of network's scheme in OMNeT++ simulation environment is presented in fig. 2, nowadays there are done tests improving OSPF simulator in OMNeT++ environment.

The aim of this work will be further improving OSPF simulator in OMNeT++ environment, where unused links of routers, can be turned off or switched to different energy states, thanks this the energy can be saved and the computer network can work more efficiently.

In fig. 2 is presented an example network scheme, where routers R1 and R2 are exchanging with "energy information" like traffic load, current energy state of their adjacency links. Thanks this their routing table can be built also based on energy criteria of the links.

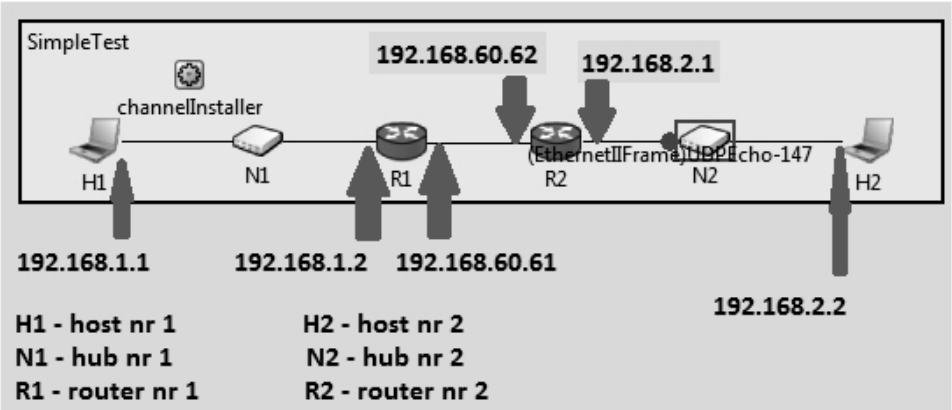

Fig. 2 OMNeT++ simulation environment, simple network presented

Nowadays is finished implementation part for following extension for OSPF protocol in OMNeT++ simulation environment - on each interface of the router is analyzed traffic load, like bits/second on each interface.

If this limit is exceeded, then link state cost is increased. This means, that there is changed metric of particular link. When link state cost is changed, then there is run function to recalculate the routing table of the router. When this is finished, Link State Advertisement (LSA) packets send new Link State topology to other routers, i.e. there is new version of Link-State Database (LSDB) on each router. This is done to balance the traffic load on the routers' interfaces. This is first step to optimize energy usage by routers.

Having possibility to balance the traffic load on the interfaces and combining this with Dijkstra algorithm used in OSPF, can be next introduced "power levels" of router's interfaces based on the traffic load on them.

Conclusion

There was extended OSPF simulator in OMNeT++ environment. The work is still in progress.

Currently – Dijkstra's algorithm is run each time, when metric of router's link is changed. Router's link metric is changed, when traffic load exceeds set limit for the interface in order to keep load balancing. The aim of this solution will be to control energy states of router's links.

Energy-efficiency can be understood currently as keeping load balancing for router's links. Thanks new functionality the routers will be able to exchange also with energy usage information of their links, thanks this there will be possibility to control usage of routers' interfaces, used and unused connections, can be controlled activity on the links. If necessary the links can be turned off, or can be switched to the different energy states, which aim is to save the energy and cut the costs in big computer networks.

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Authors' Information

Krzysztof Daniluk – *PhD student, Warsaw University of Technology, Warsaw, Poland, Faculty of Electronics and Information Technology, Institute of Control and Computation Engineering, K.Daniluk@stud.elka.pw.edu.pl*

METHODS OF RECONSTRUCTION OF SURFACE PROFILES MEASURED BY STYLUS METHOD

Sławomir Górka, Paweł Pawlus

Abstract: *The paper shows information of distortion of measurement results by stylus method. The review of surface topography reconstruction method is presented. These methods were used by the present authors to reconstruct one-process and two-process modeled and measured profiles. In the final part of the paper, example results of surface profile reconstruction are given.*

Keywords: *Surface topography, stylus method, surface reconstruction, simulation*

ACM Classification Keywords: J.2 *Physical Sciences And Engineering;* ***G.1.2*** *Approximation;* ***G.1.3*** *Numerical Linear Algebra;*

Introduction

Profile measurement using stylus technique still plays an important role in the assessment of surface topography. There are the following advantages of this method: short measurement time, the ability to provide information about surface topography and low cost of instrument.

As the stylus scans the surface, the pick-up converts the mechanical movement of the stylus to an electrical signal (via transducer) which is transmitted to computer (see Figure 1).

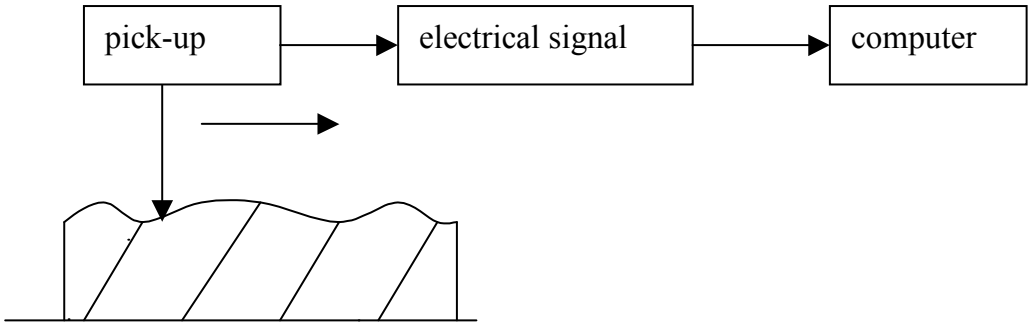

Fig. 1. Schematic diagram of stylus instrument

The pick-up is made from the following elements: the stylus, the transducer and/or the skid. The skidless pick-up is fixed rigidly to a reference plane, which is usually the datum bar inside the traverse unit.

The stylus is not mathematical point, it has finite dimension. According to ISO standards a stylus may have an included angle of 60 or 90 degrees and a tip radius of curvature of 2, 5 or 10 micrometers. But sometimes flat styli are used.

The stylus tip radius is very important in measuring of surface topography. The so-called mechanical filtration is done during the stylus tip movement. The effect of tip radius is larger than the influence of flank angle. This mechanical filtration effect is similar to low-pass digital filtration. As the result of it, the measured surface height decreased, but main wavelength increased. The distortion of surface topography depends on its shape and on dimension of stylus tip. The lower sizes of the stylus tip causes smaller distortions of the results of measurement,

but tips of small dimensions are expensive, they are also subjected to wear. Figure 2 presents shapes of new and worn stylus tip.

a b

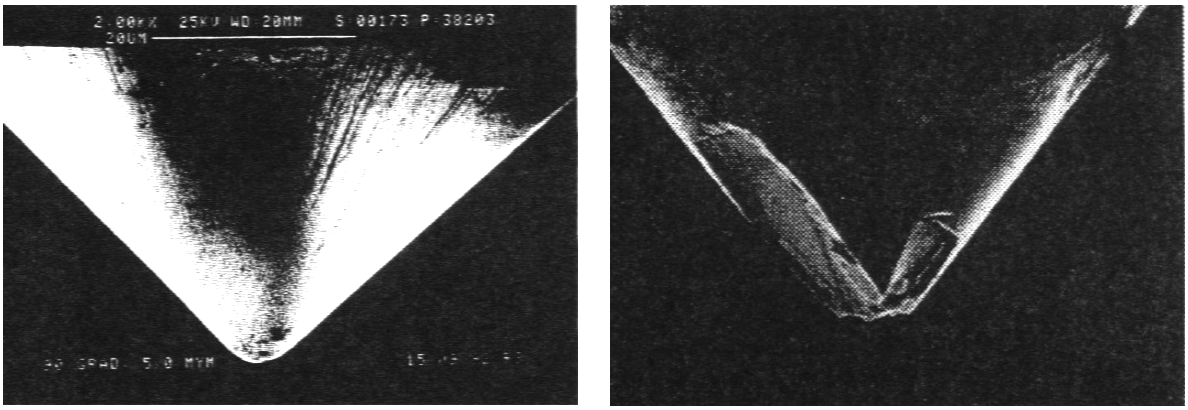

Fig. 2. New (a) and damaged stylus tip (b)

Stylus tip does not penetrate narrow valleys or wavelengths smaller than tip radius. Shunmugam and Radhakrishnan found that mechanical filtration caused distortion of features 10 times larger than stylus tip size [Shunmugam, 1976]. Distortion of surfaces after typical manufacturing processes owing to surface measurement by stylus tip with probe radius of 2 μm is low, but application of 10 μm radius causes decrease of the Ra parameter of 10-15% [Whitehouse, 1974]. However due to use of tip of smaller dimension distortion of very fine (smooth) surfaces can be large, because these surfaces contain very small wavelengths [Hillman, 1984]. Usually for surfaces created in one machining process bigger height corresponds to larger wavelengths, however this problem of two-process textures (plateau-honed cylinder surface is the typical example) is more complicated and therefore distortion of the measurement results of such surfaces can be sometimes substantial [Pawlus, 2004; Pawlus, 2002]. The problem is not only stylus tip curvature, but also its local changes [Vorburger, 1979]. The authors of the papers [Elewa, 1986; Trumpold, 2000; O'Donnell, 1993; Poon, 1995; Chetwynd, 1979; Mendeleyev, 1997; Wu, 1999; Shunmugam, 1974; Radhakrishnan, 1970; Vorburger, 1998; de Vries, 1985] also analysed measurement errors caused by mechanical filtration, most of them simulated co-action between the stylus tip and surface.

Because the problem of surface measurement results distortion by stylus tip of finite sizes is of great practical importance, scientists tried to solve the task of surface reconstruction. Since the mentioned problem is very substantial for very smooth surfaces, the scientists analysed mainly the results of measurement by Scanning Probe Microscopes (SPM). However reconstruction of surfaces measured by stylus method was also studied [Villarubia, 1994]. Some stylus instruments contain software for measured surface topography reconstruction.

Methods of surface topography reconstruction

Methods of surface texture reconstruction can be divided into 2 groups:

- when the shape of tip in unknown,
- when the shape of tip is known.

In the first group it is first necessary to obtain the shape of the stylus tip (blind reconstruction methods). Two approaches are commonly used. In the first of them the shape of tip can be obtained using similar technique to razor-blade method. The razor-blade profiles are clearly the best for showing the actual shape of the stylus tip (see Figure 3).

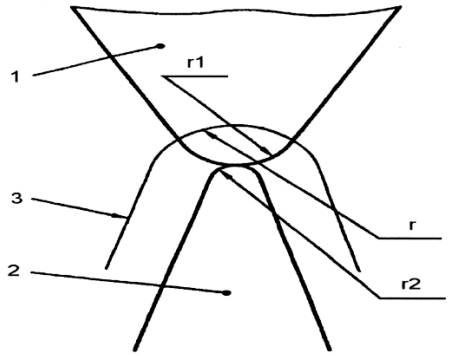

Fig. 3. The idea of razor-blade method [Wieczorowski, 1996]

Figure 4 presents idea of blind reconstruction method. It was described in papers [Villarubia, 1994, 1996, 1997; Dongmo, 1996, 2000]**.** In Figure 4a the shape of tip is presented as well as the fragment of original (simulated) profile. The idea of this method consists on the overlapping of the maxima 1 and 2, searching for their joint parts (shaded in the Figure 4b) being the new peak. Its peak is superimposed on the third maximum 3 (see figure 4c). Then the upper envelope of its new peak is found similarly to razor-blade technique. The reconstructed stylus tip is shown in Figure 4d.

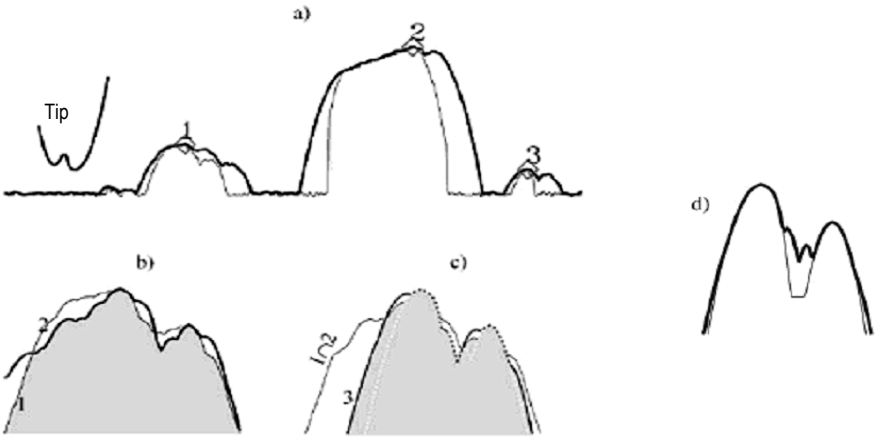

Fig. 4. The idea of method of blind tip reconstruction (description in text)

Usefulness of this method was checked [Górka, 2011]. The authors of paper [Dongmo, 1996] presented the method of the radius of tip estimation. It consists of erosion (lower envelope) following by dilation (upper envelope) of image when radius of envelope "r" increased. Erosion followed by dilation is called opening procedure. The difference between the experimental image and the open image can be quantified repeating several tomes the opening procedure, for r smaller and larger than the real tip radius and evaluating the differences allows us to fix the upper limit for the effective tip radius (see Figure 5). This method was detailed described in Reference [Górka, 2009].

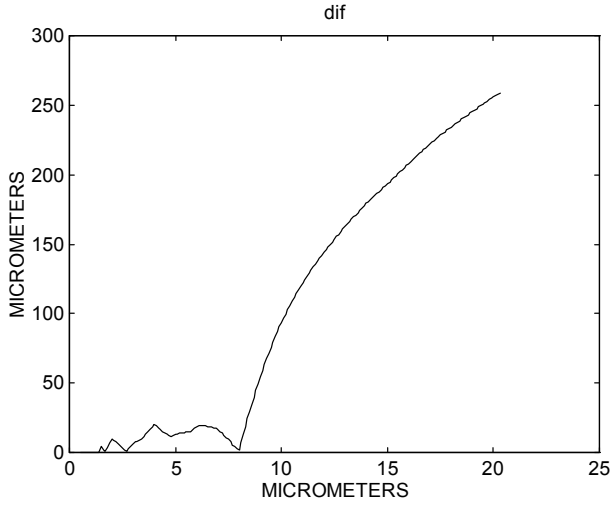

Fig. 5. Plot of the difference between open images and original images – the radius of peak was 8 μm

When the shape of tip is known the reconstruction relies on using the upper envelope of measured profile.

There are several methods of reconstruction of measured surface topography. The first of them depends on the analysis of initial profile parameters on these distortion. The aim of this approach is to find what tips cannot be used for surface topography after selected machining Dongmo et al. [Dongmo, 1998] used this method with regard to measured surfaces if known shape.

Reconstruction of surface topography on the basis of known shape of stylus tip is another possibility. The initial approaches used geometrical dependences [Chicon, 1987;Keller, 1991;Odin, 1994; Pingali, 1994; Reiss, 1990; Watts, 1997]. Figure 6 presents an idea of method used in work [Watts, 1997].

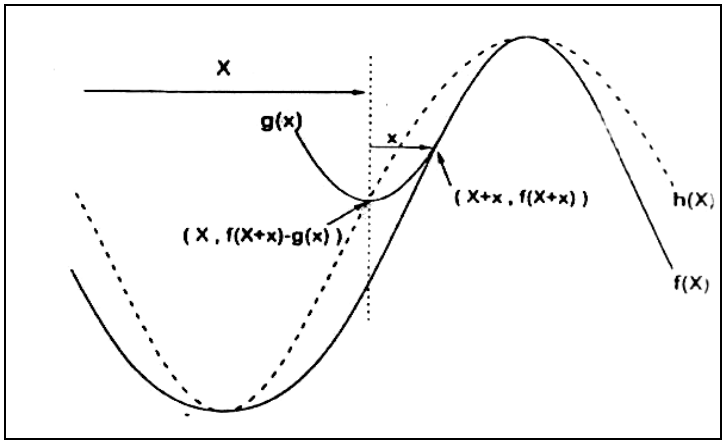

Figure 6. Scheme of method of surface profile reconstruction by geometric method - f(X) is original surface, h(X) – distorted surface, g(x) – shape of stylus tip. Point (X+x, f(X+x)) is contact point of stylus tip with measured surface. Point (X, f(X+x)-g(x)) is obtained position of stylus tip as the result of measurement.

Profile (shape) of stylus tip is determined by the following equation:

$$g(x) = f(X+x) - h(X) \tag{1}$$

x is lateral distance between position of peak of stylus tip and its contact point with surface. One can find:

$$g'(x) = f'(X+x) \tag{2}$$

It means that in contact point slopes (derivatives) of tip and surface are the same. Therefore:

$$g'(x) = \frac{d}{dx} f(X + x) - \frac{d}{dx} h(X)$$
$$g'(x) = f'(X + x)\left(1 + \frac{dX}{dx}\right) - h'(X)\frac{dX}{dx} \quad (3)$$

After inserting for left side of equation (3) value from equation (2) one can obtain:

$$\frac{dX}{dx} f'(X + x) - h'(X) = 0 \quad (4)$$

so:

$$f'(X + x) = h'(X) \quad (5)$$

It means that slope in contact point of the tip with surface (equal to slope of stylus tip) and slope of distorted profile is the same. Therefore it is possible to obtain coordinates of the original surface on the basis of measured profile and the shape of stylus tip. The application of this method to areal (3D) surface topography measurement is possible, however its idea was presented in relation to 2D profile.

However in majority of methods presently used the lower envelope of distorted surface profile is applied **[**Villarubia, 1997; Dietzsch, 2004, 2005; Keller, 1993; Krystek, 2004**].** It is not necessary to use derivative, therefore this method this method is not sensitive on presence of individual peaks. However not all the surface points can be correctly reconstructed. Figure 7 presents an idea of this method on the basis of paper [Dietzsch, 2004].

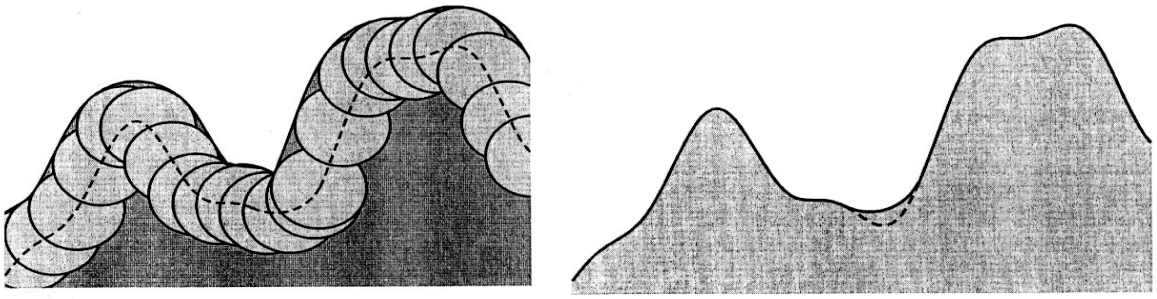

Fig. 7. Scheme of surface profile reconstruction by lower envelope method. Solid line – reconstructed profile, dashed line – original profile

Scope of research

In order to proper asses the quality of surface profile reconstruction the shapes of the original profiles should be known. Therefore the mechanical filtration was simulated. The method elaborated by Wu [Wu, 1999] was used (see Figure 8)

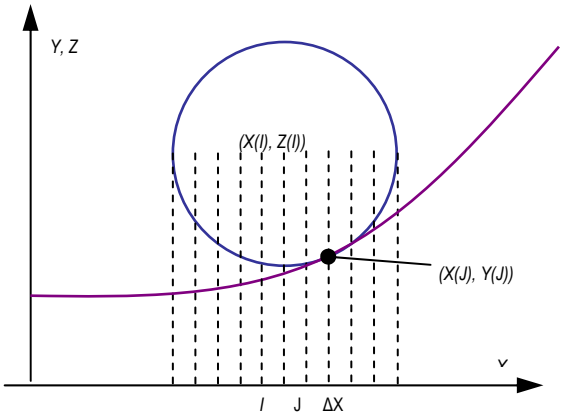

Fig. 8. Method of mechanical filtration simulation

It was assumed in model that the radius of stylus tip is equal to r and that elastic and plastic deformation didn't occur.

Point of contact has coordinates X(J), Y(J), but center of stylus tip: X(I), Z(I). Index J of contact point was found as the result of searching of discrete points in order to obtain maximum of the function:

$$H(J)+Z(J)=Z(I)=\max_{k}(H(k)+Y(k))$$

where:

$$H(k)=\sqrt{r^2-(k-I)^2(\Delta x)^2}$$

There was the following range of k index: from: I – (r/Δx) to I + (r/Δx).

The so-called edge problem on outer profile details exists. It was solved by the assumption that profile close to end points was flat. The special software was developed. Its correctness was verified by comparing the results of the calculation with those obtained with application of software elaborated by Villarbia [ftp.nist.gov/pub/spm_morph]. The mechanical filtration by probe tips with radii of 2 μm, 5 μm and 10 μm was done.

The sensitivity of the profile type on surface profile distortion due to mechanical filtration and then reconstruction may be better assessed when surface profiles of desired shape can be simulated. One-process random profiles of Gaussian ordinate distribution was modeled using the procedure developed by Wu [Wu, 2000]. Each profile of exponential shape of the autocorrelation function is characterized by the following parameters: standard deviation of height Pq and correlation length (horizontal parameter) – the distance at which autocorrelation function slowly decayed to the desired value (0.1) [Whitehouse, 1970].

Reconstruction results of 2-process profiles is more complicated. The parameters describing surface after 2 processes can be calculated from the probability plot of material ratio curve (ISO 13565-3). The intersection point on normal probability graph of abscissa Pmq defines the separation of plateau and base textures and is an important feature of the model. The proposed plateau roughness Ppq, valley roughness Pvq and Pmq are three parameters characterising two-process surface. The slope of each presented straight lines gives the Pq roughness of the corresponding process. Also the transition characteristic (plateau depth Pd) can be estimated [Pawlus, 2008].

The following procedure should be done in order to simulate two-process profile:

1. Creation two Gaussian profiles PP (plateau) and PV (valley) with correlation lengths and standard deviations as parameters characterizing them.
2. The choice of the distance (Pd) between the mean lines of the profiles (the centres of the distributions).

3. For all the points "i" of two distributions (profiles): If PP(i) > PV(i) then RP (i) (resulting profile after two processes) = PV(i), else RP (i) = PP(i) [40].

Figure 9 presents example of creation of 2-process profile.

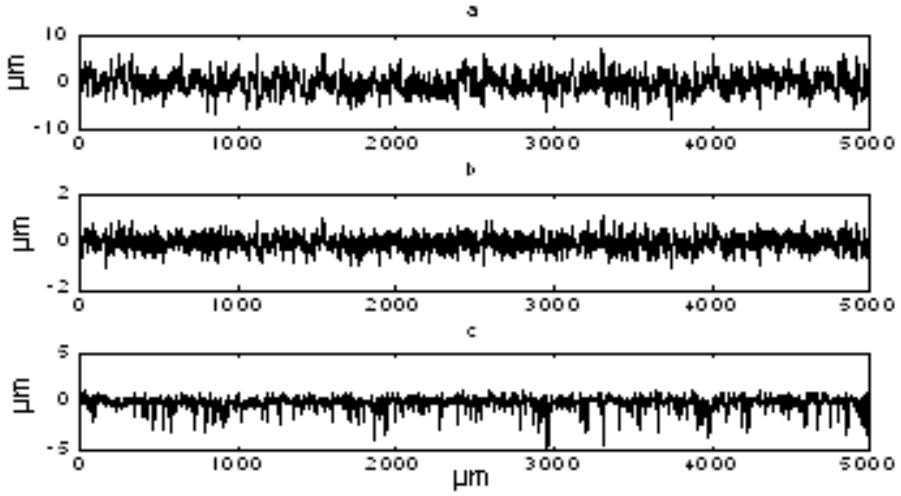

Fig. 9. Computer creation of two-process profile: valley profile (a), plateau profile (b), resulting two-process profile (c)

- Profiles measured by stylus tip of 2 µm radius were also subjected to mechanical filtration.
- In order to analyse the possibilities of reconstruction of simulated profile the special software was elaborated. First, geometrical method presented above was used. It is possible to reconstruct only some points of the profiles. Three methods were used to determine coordinates of the other points:
  - these points were connected by straight line (GS),
  - points of distorted profile were left (GD).
  - these points were connected by curve resulting from enveloped method (GE).

The envelope method (E) was also used.

The geometric methods (GS, GD and GE) depend on calculation of the radius of distorted profile and then checking slope of stylus tip. It is possible to find in what point tip slope is equal to measured profile slope and using mathematical (trigonometric) dependences obtain point of reconstructed profile. Since slopes of surface image and profile are not the same, the absolute values of slope differences were calculated on the basis of it, the smallest value was selected.

Envelope method (O) relies on application of lower envelope of the distorted profile. Envelope means position of the centre of the wheel. The especially elaborated software was used for stylus tip of wheel shape. For other tip shapes, the software developed by Villarubia [Chicon, 1987] can be applied. The correctness of reconstruction was assessed using coefficient of linear correlation.

Results and discussion

First, the reconstruction of one-process profiles will be analysed.

It was found that after reconstruction information about profile was not substantially improved when profile distortion be mechanical filtration was high. Due to reconstruction, the statistical parameters characterizing amplitude such as Pa and Pq usually decreased. However changes in parameter describing maximum height like Pz was small. Better values of profile slope, peak curvature and usually peak density and horizontal parameters were obtained as a result of reconstruction. Application of reconstruction caused also improvement of estimation

of peak height above mean line. After reconstruction the parameters characterizing valleys like density, curvature and height had worse values in comparison to measured profiles.

However the coefficient of linear correlation between reconstructed and original profiles was usually higher than that between measured and original profiles. Only application of GE method assured sometimes smaller values of linear correlation coefficient. Information about ratio of Pda/Pdq (ratios of average slope to rms. slope) was more distorted after this method usage. However some other parameters were improved after this method usage. In all the cases applications of GS and GD methods caused increase in the linear correlation coefficient. After GD method application the resulted standard deviation of height was comparatively high. Application of GS method caused similar results to those after use of the envelope method (E), although standard deviation of profile amplitude was a little smaller after the GS method application.

Reconstruction of profile by envelope method (E) caused the biggest increase of linear correlation coefficient of reconstructed profile with original profile from the use of all the tested methods, for example from 0.24 to 0.35 or from 0.39 to 0.52.

Generally profile reconstruction using all the analysed methods caused similar results. The proper effect of profile reconstruction was larger when the distortion of profile by mechanical filtration was smaller. Better results were obtained when sampling interval was smaller than the radius of tip. For larger sampling interval errors of parameters depending on it (like slope) can be larger.

Figure 10 presents original profile, distorted profile and profile reconstructed using GS and E methods. The linear coefficient of correlation increased from 0.39 to 0.49 after using GS method, but from 0.39 to 0.51 after E method application.

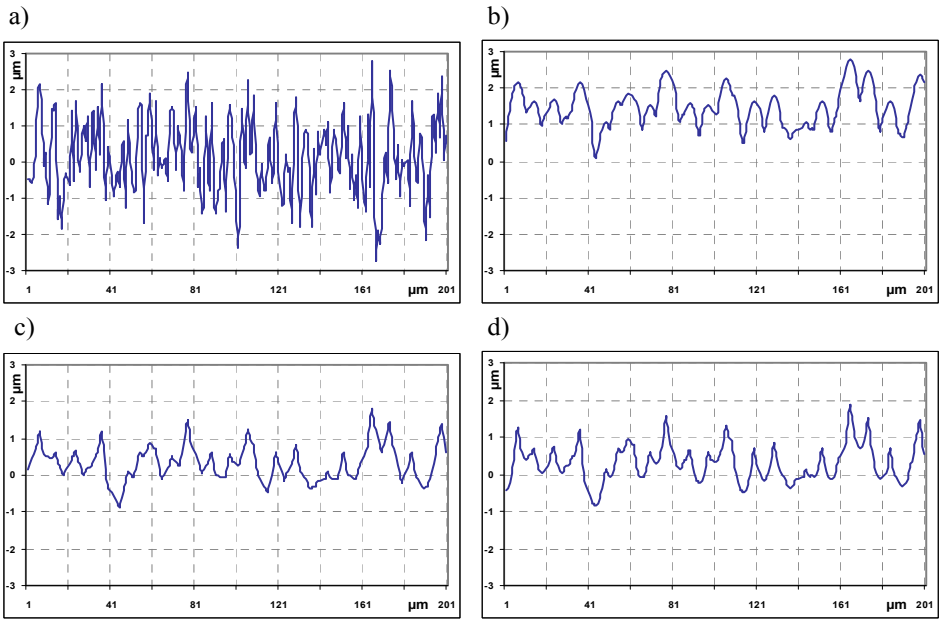

Fig. 10. Details of original (a), distorted profile (b), reconstructed profile using GS method (c) and E method (d)

Figure 11 presents modeled profile after mechanical filtration by spherical tip of radii r = 2 µm, 5 µm, 10 µm (upper envelopes) and lower envelopes of distorted profiles (reconstructed profile) using the same tips. As seen, only the envelope method as the best from al the tested methods was used here.

The radius of stylus tip was 2 µm (left), 5 µm (middle) and 10 µm (right).

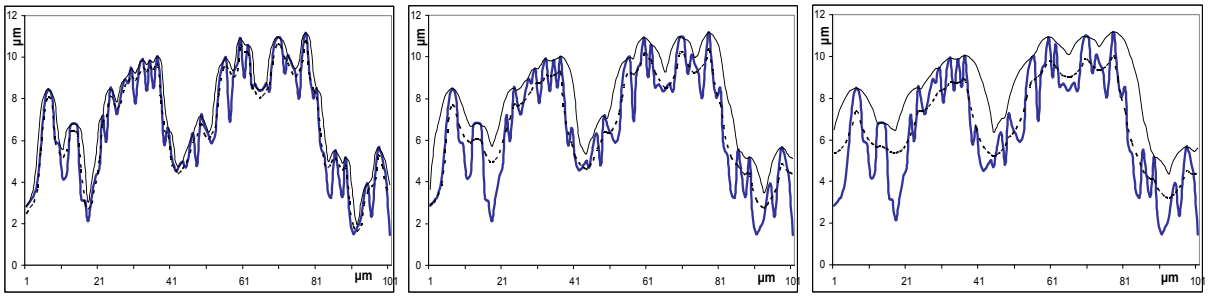

Fig. 11. Fragment of irregularity profile (Rq = 5 µm – thick line), profile detail after mechanical filtration by spherical tip (thin line) and detail of lower envelope of distorted profile (dashed line)

In addition measured profiles after grinding by stylus tip of 2 µm radius were analysed. These profiles were not seriously distorted by mechanical filtration therefore after reconstruction their parameters were improved. It concerns horizontal parameters like PSm and correlation length which decreased after reconstruction, average height parameters like Pa and Pq, slope and peak height and density (these parameters increased after reconstruction). In the majority of cases profile reconstruction led to increase of linear correlation coefficient between measured (reconstructed) and original profiles.

Next, the reconstruction of 2-process profiles will be analysed. It was found that after reconstruction, parameters characterizing the maximum height decreased or increased. When lower envelope was used (E method) the parameters characterizing the average height increased, so reconstruction improved these values. After using geometrical method, this parameter increased or decreased, however the errors were the lowest after using the GS method, larger after GD and the largest after GE method application. Similarly to profiles of Gaussian ordinate distribution GE method usage caused the biggest errors of the ratio of slopes Pda/Pdq estimation, although some other parameters were reconstructed properly. The asymmetry of the ordinate distribution is very important feature of two-process surface. It can be characterized by the emptiness coefficient Pp/Pt or the skewness Psk. It is difficult to say what method is the best in the emptiness coefficient estimation. However in most cases the values of skewness Psk (and of kurtosis Pku) was the closest to that of initial profile when reconstruction was done by envelope method (E). Application of envelope method did not cause peak and valley density changes comparing to distorted profile. Similar observation was done with regard to profiles of Gaussian ordinate distribution.

Generally reconstruction led to better values of profile slope, peak curvatures and usually peak density as well as horizontal parameters. Reconstruction method allowed to better estimation of standard deviation of peak height and peak height above the mean line.

In general, the reconstruction caused increase of the linear correlation coefficient in comparison to pair: measured profile-distorted profile. Only in some cases after GE method application this coefficient decreased, in other cases – increased. The worst results were achieved after GE method application, but better after GD and then GS method usage. But generally envelope method (E) assured the best results of profile reconstruction. The highest values of linear correlation coefficient were achieved for not distorted profiles (about 0.99) – it corresponds to the case of larger correlation length of valley part in comparison to that of plateau part (plateau honed cylinder is typical example of such profile).

The increase of sampling interval caused some changes of errors of parameters depending of sampling interval like slope and peak curvature of reconstructed surface.

Similar research were done with regard to plateau-honed cylinder profiles measured by stylus tip of 2 µm radius. The mechanical filtration by probe tip of 10 µm radius was done with subsequent reconstruction by envelope method (E). Generally the results were similar above (of simulated profiles).

Figure 12 presents detail of modeled 2-process profiles distorted by simulated mechanical filtration of 10 μm radius and the same details of reconstructed profile using GS and E method. The correlation coefficient between modeled and distorted profiles was 0.81, the profile reconstruction by GS method led us to increase this coefficient to 0.87, by E method to 0.89. The values of selected profile parameters are also presented.

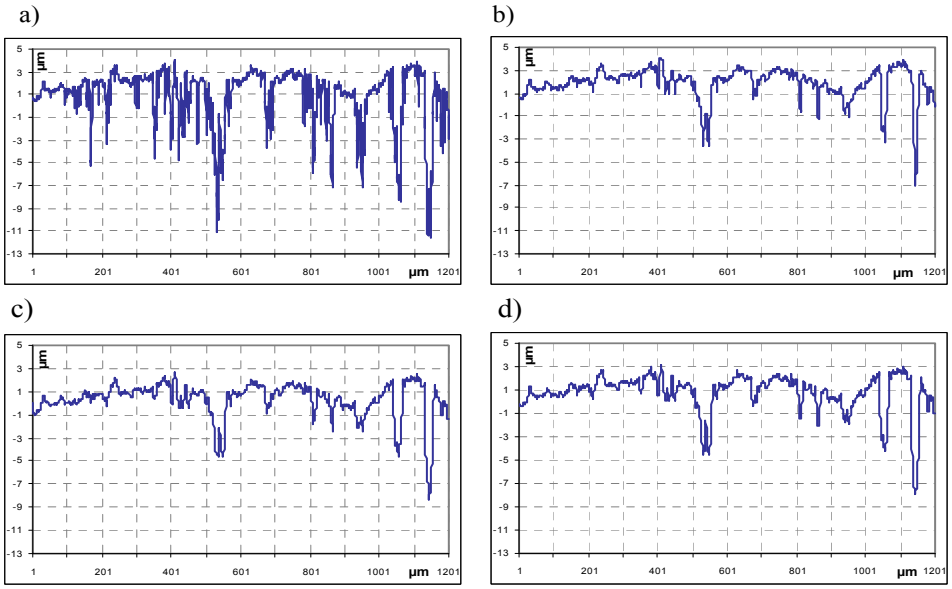

Fig. 12. a) Detail of modeled profile – Pq = 2.74μm, PΔq = 1.12, PSk = -1.34, b) its profile after simulated mechanical filtration by stylus tip of 10 μm radius – Pq = 1.52 μm, PΔq = 0.26, PSk = -1.3, c) reconstructed profile by GS method – Pq = 1.68 μm, PΔq = 0.24, PSk = -1.27, d) reconstructed profile by E method - Pq = 1.77 μm, PΔq =0.26, PSk = -1.29

Conclusions

Geometrical and envelope methods of surface profile reconstruction were studied and compared. From among these methods the lower envelope method and geometrical method depending on not-reconstructed point connection by straight line are the best for one-process profiles. However the envelope method was recommended by the present authors. It is especially useful for surface profile not seriously distorted by mechanical filtration.

Envelope method was also found as the best for two-process (stratified) profiles reconstruction. After this method application the values of amplitude parameters Pa and Pq were usually improved.

Generally, the profile reconstruction caused increase of linear correlation coefficient in comparison to pair: measured profile – original profile.

Computer simulations of one-process and two-process profiles as well as of co-action between stylus tip and surface topography (mechanical filtration) are useful tools during analysis of surface reconstruction.

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Authors' Information

Sławomir Górka *– PhD, Rzeszów University of Technology, Department of Computer Science; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: sgorka@prz.edu.pl*

Major fields of scientific research: management information systems, technical measurement, aviation. Author or coauthor of 16 publications and 6 scientific reports for industry.

Paweł Pawlus *– professor, DSc, Rzeszów University of Technology, Department of Manufacturing Technology and Production Organisation; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: ppawlus@prz.rzeszow.pl*

Major fields of scientific research: tribology, technical measurement. Author or coauthor of about 200 papers mainly in the field of surface topography analysis and influence.

COMPUTER PROGRAM FOR SYMULATION OF PRESSURE DISTRIBUTION IN THE HYDRODYNAMIC RADIAL BEARING

Wiesław Graboń, Jan Smykla

Abstract: *The article presents selected numerical methods that are used to solve equations representing the mathematical formulation of engineering problems. The examples of the use of numerical methods in tribology are shown in this paper as well. The way of creating a computer program based on the theory of hydrodynamic lubrication announced by Reynolds is discussed. This program uses the finite difference method to calculate the distribution of hydrodynamic pressure in the radial bearing.*

Keywords: *Tribology, Computer program, Numerical methods.*

ACM Classification Keywords: *Numerical Analysis, Software engineering.*

Introduction

During tribological studies physical values are often presented as differential equations that describe the laws of physics. These equations can be solved analytically but due to the fact that there may be many of them; they can be complicated and difficult to solve (nonlinear partial differential equation), numerical methods which give approximate required solution are used. Appropriate software allows to obtain numerical solutions of equations representing mathematically formulated engineering problems. The basic methods of calculation used in computer programs are:

- Finite Difference Method (FDM),
- Finite Element Method (FEM),
- Finite Volume Method (FVM).

In brief, these methods rely on the division of the considered continuous area into a finite number of subdivisions (meshing), and then searching and finding approximate solutions in these subdivisions. The solution at any point of space is achieved by interpolation of obtained results. The main differences between these methods are way of finding a solution, defining boundary conditions and method of analysis [Gryboś, 1998].

To calculate the distribution of hydrodynamic pressure in the radial bearing, the finite difference method was used. This method involves approximations that replace the derivatives procured from the differential equations into the finite difference equation, that is approximation of differential equations into difference quotients. These approximations, in algebraic form are associated with each value of the dependent variable in the point of the solution area with values in a number of neighbouring points. These points are selected so as to form a regular grid [Kmiotek, 2008]. A type of grid is usually dependent on the type of coordinate system, suitable for the investigated issue. The most commonly used grid models for two-dimensional problems are presented in Figure 1.

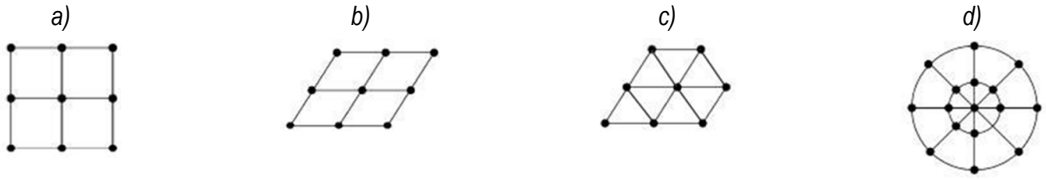

Fig. 1. The most commonly used grid models for two-dimensional problems: a) rectangular, b) – diagonal, c)-triangular, d) – circular [Kotyński, 2009]

The most important advantages of FDM:

- theoretically it is suitable to solve any type of differential equation (ordinary, partial, linear, nonlinear),
- it allows taking into account the heterogeneity of material,
- it is conceptually simple and uncomplicated to implement on a computer,
- it generates a set of equations which is characterized by the unique matrix that allows using of fast iterative methods for solving this set of equations.

The main disadvantages are:

- difficulties in taking into account the geometry in the case of irregular shapes,
- it can lead to large errors for too coarse grid and to a huge number of nodes and unknowns for too fine mesh leads,
- although there is a possibility of the local density of mesh nodes, it greatly complicates the installation of the equations themselves,
- it is probably not suitable for solving the field equations in unlimited areas because it requires the imposition of a finite number of nodes to a grid area [MRS].

The range of use is quite wide: issues in electromagnetic fields, temperature fields, mechanics, hydromechanics. By using FDM as well as other methods, engineering problems can be modeled in the computer memory without the need of building a prototype which greatly simplifies and accelerates the design process.

Discretization of the area on a large number of elements used in each of the methods usually gives more accurate calculation results. However, it requires more FLOPS. In case of very complex systems, solving a problem might be time consuming.

The use of numerical methods in tribological research

The theory of hydrodynamic lubrication announced by Reynolds based on the modification of the physical model of Petrov takes into considerations insights from the experience of Tower. Reynolds took into consideration the eccentric journal position in the bearing which is a prerequisite for the formation of hydrodynamic lift. Mathematical writing of Reynolds theory is based on principles: the conservation of mass (continuity equation) and momentum (Navier-Stokes equation). Reynolds equation is a partial differential equation of second order, inhomogeneous, linear. It's impossible to solve this equation by analytical determination. Reynolds' analyses and his mathematical record of pressure distribution in oil film became the foundation for further development of the theory of hydrodynamic lubrication.

Further work on the development of the theory of hydrodynamic lubrication focused on as exact solutions as possible of the Reynolds' equations for various geometric and dynamic characteristics of the lubricating film and took into account the actual conditions in the lubricating film [Lawrowski, 2008]. The authors [Korzyński, 2007] have analyzed the use of numerical techniques in tribological studies in Poland which shows that the precursor of the numerical calculations of Reynolds' full equation for isothermal laminar flow in slide journal bearing of finite

length was J. Burcan who described the results in the article [Burcan, 1971]. The same author in [Burcan, 1973] presented a numerical calculation of the bearing with hyperboloid bearing liner, while the solution for the non-isothermallubricating film was presented in [Burcan, 1975]. It is worth to mention another article [Krzeminski-Freda, 1972] from that period, in which the elasto-hydrodynamic lubrication problem has been solved numerically as well. An interesting study on the issue of flat oil flow in slide radial- bearing is shown in [Wierzcholski, 1974]. The complete solution of Reynolds' equation for the pseudoplastic Reinara-Rivlina power model, was presented in [Wierzcholski, 1980] [Wierzcholski, 1978] who used the numerical calculation technique. Numerical solution of the problem of hydrodynamic lubrication when the oil film is cavitated shown in [Kicinski, 1985] who modifies and improves the classical Reynolds' equation. In those years presented works were pioneering because the technique of numerical calculation was not developed that much and so easy to use as today. Currently, it is possible to make intensively developed research in the field of friction, lubrication and wear among them thanks to tremendously advanced computer technology and methods of calculation.

An example of work that uses advanced computer software is the work of [Sęp, 2006] in which the three-dimensional adiabatic flow of oil in the radial hydrodynamic bearing was modeled. This model assumes that in the tested bearing fluid friction occurs and oil completely separates cooperating elements. The oil flow system is described by Navier-Stokes equations together with the energy equation. Oil characteristics and boundary conditions for the test model were determined, and then were the flow equations solved using the finite element software package ADINA 8.1. The results of computer simulation enabled the determination of hydrodynamic pressure distribution, temperature and flow velocity in the oil film. In order to verify the computer simulation the author conducted experimental study. He constructed a test stand to measure the relative displacement of journal and bush; the pressure and temperature in the oil film.

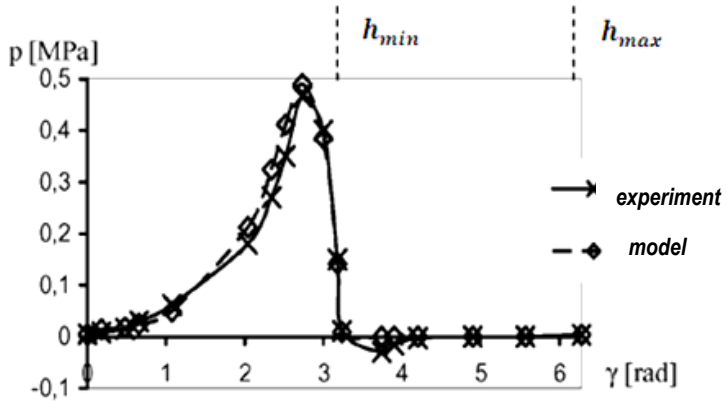

Fig. 2. Comparison between experimental and calculated circumferential pressure distribution [Sęp, 2006]

Figure 2 shows the comparison of pressure distribution obtained through computer simulations and in the experiment. Comparison of experimental results and numerical calculations showed that the results are not identical but they have very high level of compatibility. The differences among results exist due to both shortcomings in the methods of measurement and computer modeling imperfections (approximations in the mathematical description of phenomena, errors of the calculation method) [Sep 2006].

The authors [Ronen, 2001] have studied the effect of surface microstructure, (made as a form of micro pores on the element simulating the piston ring) on the tribological properties of a simplified model of friction pair ring-cylinder. By means of numerical methods they have solved the system of equations consisting of the Reynolds equation and the equation of motion for the simplified model of a ring-cylinder in which the surface of the element of a model imitating ring was textured. They showed that surface texturing can effectively influence the

maintenance of the hydrodynamic effect, even in the parallel surfaces and also that optimally chosen surface texture can significantly reduce the frictional losses in the reciprocating automotive components.

The authors of the publication [Kligerman, 2005] performed an analytical model as well, in order to study the possibility of reducing friction between the piston ring and cylinder liner. In their research they took into account the piston rings with specially prepared laser surface structure. In this model the distribution of hydrodynamic pressure and time-dependent clearance between the piston ring and cylinder liner are received from the simultaneous solution using numerical methods of Reynolds equation and equations of motion of the ring in the radial direction. Using a created model, they analyzed the influence of texturing parameters such as dimples depth, texture density area, and textured portion of the nominal contact surface on the average friction force between a piston ring and cylinder liner at different ring widths and operating conditions.

In [Raeymaekers, 2007] there were made attempts to show that the coefficient of friction between magnetic tape and the guide at which the tape moves can be reduced through the implementation of micro dimples on the guide. Micro dimples were made by laser texturing. The microstructure in the form of micro dimples conduces the formation of the air cushion between the tape and the guide, which helps to decrease the friction coefficient between the cooperating elements. Model was created in order to find optimal parameters for the geometry of texture made on the surface of the guide, by which it is possible to reach a maximum pressure of the air cushion and thus it will decrease the friction coefficient between the two cooperating elements. Presuming additional simplifying assumptions concerning, among others, lack of flexibility of the tape and the assumption that the full lubrication fluid is formed in the model, Reynolds equation was used to describe the pressure distribution, reigning in the space between the tape and roll. Also the authors of [Arregui, 2008] conducted the simulation of head - magnetic tape storage device. In this work to describe the distribution of pressure in the forming air cushion between the tape and head Reynolds equation was used as well. To reflect the specificity of the system accurately, additional mathematical model describing the movement of the tape was introduced. To solve the mathematical equations they introduced a new numerical method which is based on the finite element method.

An example of use of numerical methods in tribological studies of human hip joint is the work of [Wierzcholski, 2002]. In this work the authors carried out the numerical analysis of the friction coefficient for asymmetric isothermal steady flow of non-Newtonian synovial fluid in human hip joint including variable viscosity dependent on changes in speed deformation during the lubrication. This work presents the results of numerical values representing the coefficients of friction in the human hip joint obtained for the real working conditions, taking into consideration non-conventional lubrication conditions. Numerical calculations were performed using the finite differences method in the integration of partial differential equations in the areas of joint that were lubricated by synovial fluid. A very important aspect of this work is the fact that the numerically obtained values of the friction coefficients occurring in the gap of human hip joint are used in orthopedic therapy. The follow-up of the same author's research on the tribological issues taking place in the human hip joint is the work of [Wierzcholski, 2007] in which the numerical values of variables like pressure, compressive stress and load occurring on cartilage that is situated on the spherical head bone of the hip joint of the man were assigned. In these studies the case of hydrodynamic lubrication of the hip joint carried out during the rotation of the head bone of the joint was taken into account. Synovial fluid layer completely separates the cartilage on the surface of the head bone and the acetabulum. For the purposes of research non-Newtonian properties of synovial fluid for which viscosity decreases with increasing of the speed of deformation were included. Constant density of the synovial fluid was adopted. The model takes into account that during the operation the height of the gap of the hip joint which is restricted by the area of the joint cartilage changes its value. In numerical calculations the method of finite differences was used.

Modeling pressure distribution in the hydrodynamic radial bearing

The theory of hydrodynamic lubrication is based on the following assumptions adopted by Reynolds:

- The lubricant is a Newtonian liquid - this assumption is fulfilled by lubricating oils and most of other liquids used as lubricants,
- There is a laminar flow of fluids - most of the hydrodynamically lubricated units fulfill this assumption,
- The inertia forces caused by acceleration of the flow are excluded. The forces of inertia are small in comparison with tangential forces working on the liquid,
- It is assumed that the liquid is incompressible - meaning that the volume of liquid passing through each cross-section the oil gap per unit time is constant.

For many practical engineering applications it is assumed that the viscosity throughout the gap lubricant is constant i.e., η = const. This approach is known in the literature as "isoviscous" model, where thermal effects in hydrodynamic film are omitted. Under this assumption, and many others described in details in [Kicinski, 1994] [Hebda, 1980] the pressure distribution $p\ (x, z)$ in the oil film of statically loaded, lubricated by incompressible liquid radial bearing is described by the equation of Reynolds [Hebda, 1980] :

$$\frac{\partial}{\partial x}\left(h^3 \cdot \frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial z}\left(h^3 \cdot \frac{\partial p}{\partial z}\right) = 6 \cdot U\eta \frac{\partial h}{\partial x} \tag{1}$$

where:

p - is the pressure [Pa],

h - is the hydrodynamic film thickness [m],

U - the peripheral velocity of journal on bearing [m/s],

η - is the dynamic viscosity of the bearing [Pas],

x, z - are hydrodynamic film co-ordinates [m].

In order to obtain the numerical solution of a model of radial bearing, according to the theory of hydrodynamic lubrication it is necessary to determine the geometry of the oil gap. The schematic drawing N° 3 shows the basic geometrical correlations occurring in the radial bearing. For easier readability a big difference between the radius of the journal and bearing was adopted. In fact, this difference is not so big. In comparison to the dimensions of the bearing, thickness of formed oil film is very small. The angle β is equal to 2π for a full bearing, if β is less than 2π it is known as partial bearing. We will only be considering the case where β is equal to π.

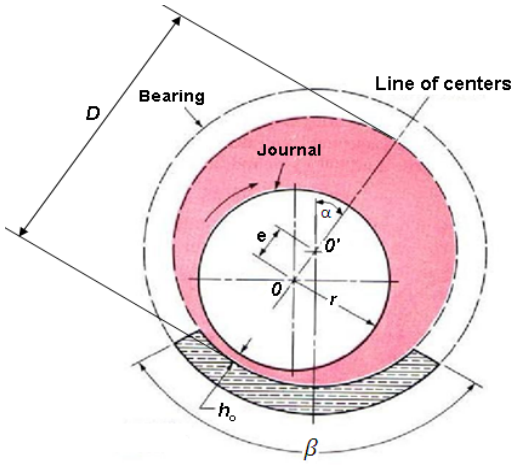

*Fig. 3. The basic geometrical correlations in the radial bearing: D - diameter of the bearing, d = 2 * r-diameter of the journal, r - radius of the journal, c - radial clearance, e - absolute eccentricity, h0 - the minimum oil film thickness, [HBT]*

Numerical implementation

For the purposes of getting numerical solution of Reynolds equation, it was brought to dimensionless form by adopting the following substitution (based on the work [Hebda, 1980]):

$$\bar{x} = \frac{x}{d} \qquad \bar{z} = \frac{z}{L} \qquad \bar{h} = \frac{h}{2c} \qquad \bar{p} = \frac{p}{\omega\eta}\left(\frac{c}{r}\right)^2 \tag{2}$$

where:

$\bar{x}$, $\bar{z}$- are non-dimensional hydrodynamic film co-ordinates [m],

L - is the bearing axial length [m],

d - diameter of the journal [m],

$\bar{p}$ - is the non-dimensional pressure,

$\bar{h}$ - is the non-dimensional hydrodynamic film thickness,

c - is the bearing radial clearance [m],

η - is the dynamic viscosity of the bearing [Pas],

ω – angular velocity [rad/s],

and taken as: *U* = *ω* * *d* / *2* and appropriate transformation was made so that it took the form of the equation:

$$\frac{\partial}{\partial\bar{x}}\left(\bar{h}^3\frac{\partial\bar{p}}{\partial\bar{x}}\right) + \left(\frac{d}{L}\right)^2 \cdot \frac{\partial}{\partial\bar{z}}\left(\bar{h}^3\frac{\partial\bar{p}}{\partial\bar{z}}\right) = 3\frac{\partial\bar{h}}{\partial\bar{x}} \tag{3}$$

Following the numerical solution of equation (3), i.e. after specifying the dependence of dimensionless pressure distribution upon dimensionless coordinates, obtained quantity was expressed back in the standard pressure forms. In order to facilitate the numerical implementation the surface of bearing has been spread and nodal points have been set aside in the surface area *(m +1) * (n +1).*

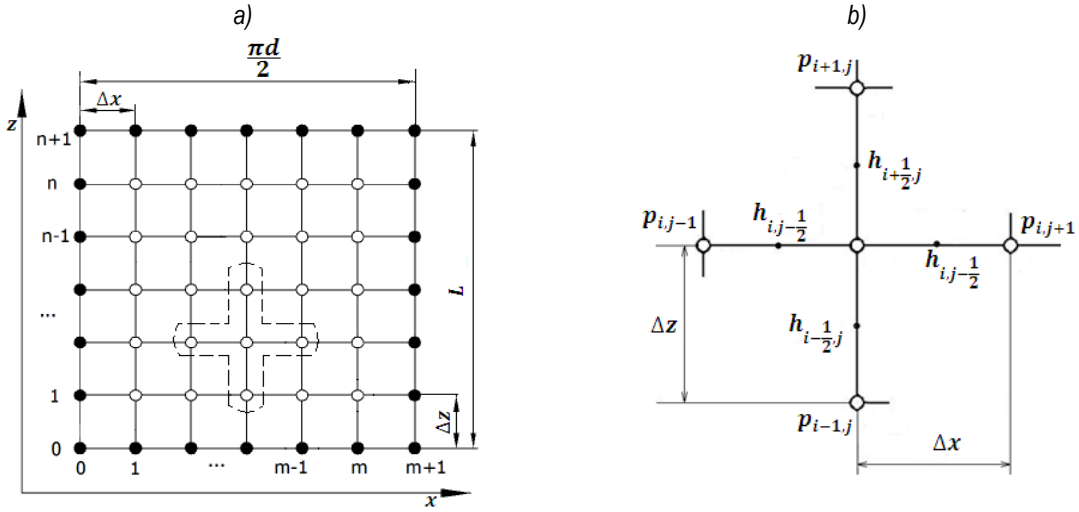

Fig. 4 Separation of the set of nodal points for the finite difference method from the surface of the bearing a) schematic drawing showing the grid points used, b) view of a single set of five adjacent points

In the point with the indexs *i, j* (Fig. 4) individual units of the Reynolds equation are brought closer, replacing the derivatives into differential quotients:

$$\frac{\partial}{\partial \bar{x}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{x}}\right)=\frac{\bar{h}^3_{i,j+\frac{1}{2}}\left(\frac{\bar{p}_{i,j+1}-\bar{p}_{i,j}}{\Delta \bar{x}}\right)-\bar{h}^3_{i,j-\frac{1}{2}}\left(\frac{\bar{p}_{i,j}-\bar{p}_{i,j-1}}{\Delta \bar{x}}\right)}{\Delta \bar{x}}$$

$$\frac{\partial}{\partial \bar{z}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{z}}\right)=\frac{\bar{h}^3_{i+\frac{1}{2},j}\left(\frac{\bar{p}_{i+1,j}-\bar{p}_{i,j}}{\Delta \bar{z}}\right)-\bar{h}^3_{i-\frac{1}{2},j}\left(\frac{\bar{p}_{i,j}-\bar{p}_{i-1,j}}{\Delta \bar{z}}\right)}{\Delta \bar{z}} \qquad (4)$$

$$\frac{\partial \bar{h}}{\partial \bar{x}}=\frac{\bar{h}_{i,j+\frac{1}{2}}-\bar{h}_{i,j-\frac{1}{2}}}{\Delta \bar{x}}$$

After the substitution into (3) the difference quotients (4) and organizing them, the following expression about $\bar{p}_{i,j}$ is obtained:

$$\bar{p}_{i,j}=\frac{\frac{3(\bar{h}_{i,j-\frac{1}{2}}-\bar{h}_{i,j+\frac{1}{2}})}{\Delta \bar{x}}+\left(\frac{d}{L}\right)^2\left(\frac{\bar{h}^3_{i-\frac{1}{2},j}\cdot \bar{p}_{i-1,j}+\bar{h}^3_{i+\frac{1}{2},j}\cdot \bar{p}_{i+1,j}}{\Delta \bar{z}^2}\right)+\left(\frac{\bar{h}^3_{i,j-\frac{1}{2}}\cdot \bar{p}_{i,j-1}+\bar{h}^3_{i,j+\frac{1}{2}}\cdot \bar{p}_{i,j+1}}{\Delta \bar{x}^2}\right)}{\left(\frac{\bar{h}^3_{i,j+\frac{1}{2}}+\bar{h}^3_{i,j-\frac{1}{2}}}{\Delta \bar{x}^2}+\left(\frac{d}{L}\right)^2\frac{\bar{h}^3_{i+\frac{1}{2}j}+\bar{h}^3_{i-\frac{1}{2}j}}{\Delta \bar{z}^2}\right)} \qquad (5)$$

Equation 5 can be presented in general form:

$$\bar{p}_{i,j}=a_0+a_1\cdot \bar{p}_{i+1,j}+a_2\cdot \bar{p}_{i-1,j}+a_3\cdot \bar{p}_{i,j+1}+a_4\cdot \bar{p}_{i,j-1} \qquad (6)$$

where a_0, a_1, a_2, a_3, a_4 - constant data for each grid point.

Pressure $\bar{p}_{i,j}$ is a function of these constants and a function of the four nearby pressure data (in the grid). For *n*m* grid points (Fig. 4) *n*m* equations were obtained and further fixed in a program written in Matlab environment. Finally, the way of pressure distribution *p = p (x, z)* was obtained. For points lying on the edge of the acetabulum (black ones in Figure 3) there is no need to write the equation, since the pressure at these points is known.

If the pivot axis and the acetabulum are parallel, the thickness of the oil gap *h* is only a function of one variable angle *φ*:

$$h(\varphi)=\sqrt{\left(\frac{D}{2}\right)^2+eD\sin(\alpha+\varphi)+e^2}-r \qquad (7)$$

The variable *x* is a linear function of radius *D / 2* of the form:

$$x=\varphi\cdot\frac{D}{2} \qquad (8)$$

Following transformation of derivative of *h* with respect to *x* is given by:

$$\frac{dh}{dx}=\frac{eD\cos(\alpha+\varphi)}{2\sqrt{\left(\frac{D}{2}\right)^2+eD\sin(\alpha+\varphi)+e^2}} \qquad (9)$$

As before, at the point with the indexes *i, j* (Fig. 3), with respect of the above formulas each word of the Reylnods equation (3) are brought closer by replacing pressure derivatives into differential quotients:

$$\frac{\partial}{\partial \bar{x}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{x}}\right)=3\bar{h}^2\frac{d\bar{h}}{d\bar{x}}\cdot\frac{\partial \bar{p}}{\partial \bar{x}}+\bar{h}^3\frac{\partial^2 \bar{p}}{\partial \bar{x}^2}=3\bar{h}_j^2\frac{d\bar{h}}{d\bar{x}}(j)\left(\frac{\bar{p}_{i,j+1}-\bar{p}_{i,j-1}}{2\Delta\bar{x}}\right)+\bar{h}_j^3\left(\frac{\bar{p}_{i,j-1}-2\bar{p}_{i,j}+\bar{p}_{j,j+1}}{\Delta\bar{x}^2}\right)$$
$$\frac{\partial}{\partial \bar{z}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{z}}\right)=\bar{h}_j^3\frac{\partial^2 \bar{p}}{\partial \bar{z}^2}=\bar{h}_j^3\left(\frac{\bar{p}_{i-1,j}-2\bar{p}_{i,j}+\bar{p}_{i+1,j}}{\Delta\bar{z}^2}\right) \quad (10)$$

After the substitution of members (10) to (3) and organizing them, the equation was obtained:

$$\frac{\partial}{\partial \bar{x}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{x}}\right)=3\bar{h}^2\frac{d\bar{h}}{d\bar{x}}\cdot\frac{\partial \bar{p}}{\partial \bar{x}}+\bar{h}^3\frac{\partial^2 \bar{p}}{\partial \bar{x}^2}=3\bar{h}_j^2\frac{d\bar{h}}{d\bar{x}}(j)\left(\frac{\bar{p}_{i,j+1}-\bar{p}_{i,j-1}}{2\Delta\bar{x}}\right)+\bar{h}_j^3\left(\frac{\bar{p}_{i,j-1}-2\bar{p}_{i,j}+\bar{p}_{j,j+1}}{\Delta\bar{x}^2}\right)$$
$$\frac{\partial}{\partial \bar{z}}\left(\bar{h}^3\frac{\partial \bar{p}}{\partial \bar{z}}\right)=\bar{h}_j^3\frac{\partial^2 \bar{p}}{\partial \bar{z}^2}=\bar{h}_j^3\left(\frac{\bar{p}_{i-1,j}-2\bar{p}_{i,j}+\bar{p}_{i+1,j}}{\Delta\bar{z}^2}\right) \quad (11)$$

Replacing the matrix of unknowns at elements of $\bar{p}_{i,j}$ (*i = 1: n, j = 1: m*) on a single column vector $\bar{p}$ of $\bar{p}_k$ elements given by:

$$k=(i-1)m+j \quad (12)$$

equation (11) can be written as:

$$a_{k,k-1}\bar{p}_{k-1}+a_{k,k}\bar{p}_k+a_{k,k+1}\bar{p}_{k+1}+a_{k,k-m}\bar{p}_{k-m}+a_{k,k+m}\bar{p}_{k+m}=b_k \quad (13)$$

where:

$$a_{k,k-1}=\frac{\bar{h}_j^3}{\Delta\bar{x}^2}-\frac{3\bar{h}_j^2}{2\Delta\bar{x}}\frac{d\bar{h}}{d\bar{x}}(j)\ ,\ a_{k,k}=-\left(\frac{2\bar{h}_j^3}{\Delta\bar{x}^2}+2\left(\frac{d}{L}\right)^2\frac{\bar{h}_j^3}{\Delta\bar{z}^2}\right)\ ,\ a_{k,k+1}=\frac{\bar{h}_j^3}{\Delta\bar{x}^2}+\frac{3\bar{h}_j^2}{2\Delta\bar{x}}\frac{d\bar{h}}{d\bar{x}}(j)$$
$$a_{k,k-m}=\left(\frac{d}{L}\right)^2\frac{\bar{h}_j^3}{\Delta\bar{z}^2}\ ,\quad a_{k,k+m}=\left(\frac{d}{L}\right)^2\frac{\bar{h}_j^3}{\Delta\bar{z}^2}\ ,\quad b_k=3\frac{d\bar{h}}{d\bar{x}} \quad (14)$$

The coefficients $a_{k,k-1}, a_{k,k}, a_{k,k+1}, a_{k,k-m}, a_{k,k+m}$ are elements different from zero in the matrix A, the b_k coefficient is the element of one-column vector B. As a result a system of linear equations are given in a form of:

$$A\bar{p}=b \quad (15)$$

with the unknowns $\bar{p}$.

By solving numerically set of equations (15) according to the formula: $\bar{p}=A^{-1}b$ pressure values were obtained.

The visualization of results

Calculations were carried out in a rectangular system *x, y, z* (Fig. 5), where the x-axis was the length of the arc on the surface of the bearing, and the z-axis was the length of the bearing itself. Dimensionless pressure distribution on the surface of the bearing in a spatial configuration *X, Y, Z* is presented in Figure 6. Calculations are performed for *n = 20*, *m = 60*. Figure 7 shows the differences between dimensionless pressure $\bar{p}1$ (calculated

according to formula 11) and $\bar{p}$ (calculated according to formula 5). Figure 8 shows the distribution of dimensionless pressure $\bar{p}1$ and p for one section z = 23.8095 and the difference $\bar{p}1$-$\bar{p}$ along the x axis.

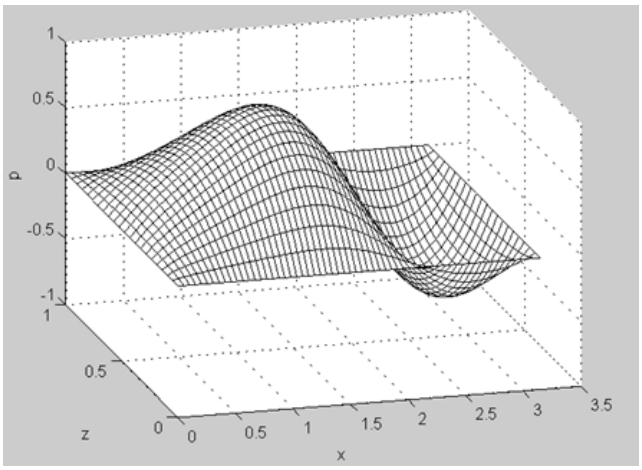

Fig. 5. The dimensionless pressure distribution in the oil film of a bearing in the rectangular system x,y,z

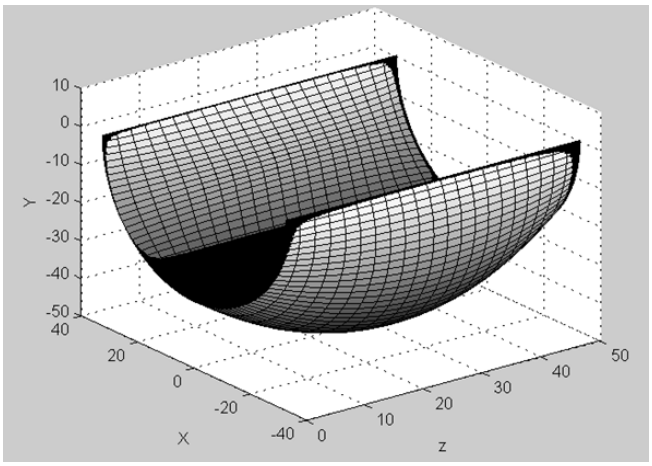

Fig. 6. The distribution of dimensionless pressure in the oil film of a bearing in spatial layout X,Y,Z

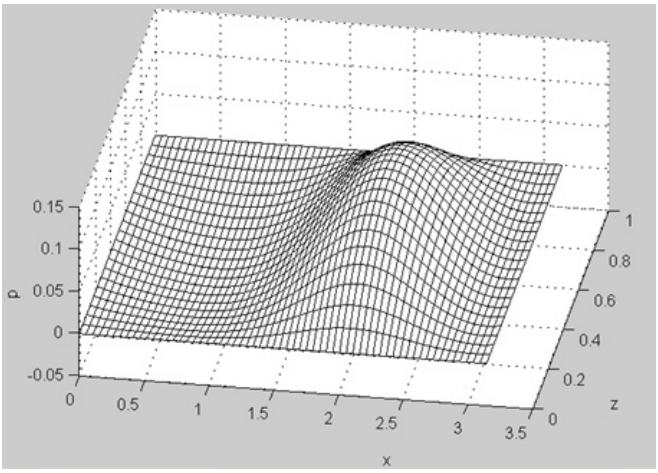

Fig. 7. The difference between dimensionless pressure $\bar{p}1$ and $\bar{p}$ in the rectangular system x, y, z

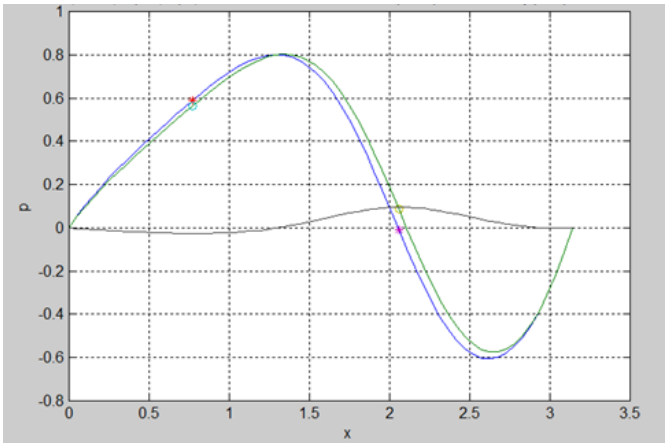

Fig. 8. The distribution of dimensionless pressure $\bar{p}1$ (denoted by "o") and $\bar{p}$ (denoted by "") and the difference ($\bar{p}1$-$\bar{p}$ – denoted by solid line) along the x axis for the cross section z = 23.8095*

Conclusions

The complexity of tribological phenomena is so large that without the use of computer technology it is difficult to make any research in this area. Computer technology that uses advanced numerical methods is a supportive tool, in many cases it allows to carry out modelling and simulation of complex tribological occurrence which take place in different nodes and different working conditions. This paper presents only a few examples which, to some extent, reflect the use of numerical methods in tribological studies. The finite difference method used in this work makes it possible to solve the Reynolds equation for arbitrary input parameters. It cannot be forgotten that in order to determine the real condition of the bearing, there is a need for specifying the parameters under which hydrodynamic oil film that is able to move the load inflicted (not considered by the Reynolds equation) will be generated. Program prepared by the authors and presented in this paper allows to understand both the way of the implementation of numerical calculations and the very essence of the theory of hydrodynamic lubrication.

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Authors' Information

Wiesław Graboń *– Department of Computer Science, Rzeszow University of Technology; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: wgrabon@prz.edu.pl*

Major Fields of Scientific Research: Software engineering information systems, Modeling of manufacturing processes.

Jan Smykla - former employee of Department of Computer Science, Rzeszow University of Technology; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: *jsmykla@dami-rz.pl*