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DEVELOPMENT OF THE APPROACH TO FORMALIZATION OF VECTOR'S INDICATORS OF SUSTAINABLE DEVELOPMENT

Vladimir Pankratov

Abstract*: A synthesis of methodologies of foresight and sustainable development is offered for problem solution on the development of the formalization of vector's indicators of sustainable development in different directions. The approach to the building of indicators of the environmental component of sustainable development vector at the stage of the data compilation to a single indicator is proposed. The procedure for the formation of the indicator using common hierarchical structure was proposed. It allows considering, evaluating, and forecasting each indicator, which is built. This result is achieved by the recovery of the main functional dependencies on the basis of the characteristics of the groups defined by discrete samples. In the result the functional dependencies of these indicators from a number of parameters that affect them are obtained. The practical implementation of the approach based on the use of the proposed algorithm was realized. The indicators were taken on data of state statistics and the statistics that are offered directly on the website of statistics of the Crimean region.*

Keywords: *synthesis, sustainable development, foresight methodology, recovery of the functional dependencies, indicators.*

ACM Classification Keywords: *H.4.2. Information System Application: type of system strategy*

Introduction

At this time, not only the researchers, but also the ordinary citizens deal with the question of building and following the strategy of sustainable development. Most international corporations have already created their strategies of the sustainable development principles implementation in production and corporate culture of their companies. In addition, a number of enterprises, companies, cities of Ukraine have developed or are developing their own strategies for sustainable development until 2020, although this strategy is considered more in the context of the economic and social aspects.

For the solution of problems of sustainable development there must be the values of some parameters to characterize the factors that are measured, analyzed and forecasted. In General, sustainable development is a harmony of three areas, namely: environmental, social and economic [Zgurovsky, 2007].

The solution of the problem of sustainable development comes down to the building a set of variables, indicators and indexes that represent an important basis for decision making, promote the transfer of knowledge from the physical and social sciences to the control information blocks. In a number of techniques that are being developed at the moment, considerable attention is paid to formalization of the measures and indicators combination into a single vector of sustainable development, which includes three components [Zgurovsky and Boldak, 2011]. Regardless of the methodology, which is used and the total group of factors by categories, the main objective is that at the stage of the data compilation to a single indicator some weight coefficients are entered to obtain the final result. However, such approach allows using the indicators only for comparison of countries/regions and so on, among themselves or with artificially created pattern - the ideal country, or the maximum possible amount of data received (depending on interpretation).

The necessity of building a desirable future in the framework of sustainable development requires the development of a comprehensive approach to solving the problem: on the one hand, the involvement of foresight methodologies for building the alternative scenarios and cognitive modeling for preparation of a decision-making on the implementation of one of the alternative scenarios, and, on the other hand, the methodology of sustainable development for the formation of appropriate indicators, indexes, and other quantity measures.

In this work for problem solution on the development of the formalization of vector's indicators of sustainable development and during decision making by the DM in different directions, a synthesis of methodologies of foresight and sustainable development is offered. The approach to the building of indicators of the environmental component of sustainable development vector at the stage of the data compilation to a single indicator will provide an opportunity to consider, evaluate, and forecast each indicator, that is built, will be proposed. This approach will allow not only making informed and formal decisions, as well as using it in various spheres of human activity. The practical implementation of the approach based on the use of the proposed algorithm will be considered. The indicators will be based on data of state statistics and the statistics that are offered directly on the website of statistics of the Crimean region.

1. Problem Statement

Over the last decade in the world the "indicator thinking" is distributed more and faster. Indicators and indices are an important tool for the exchange of ideas and opinions. The sustainable development indicators are indicators with the help of which the level of development of a certain enterprise, region, Megapolus and prospects of their further journey can be estimated. There is also a position that an indicator can be considered as value, which involves many different interpretations. The indicators as the characters can and describe in the quantitative language not only the degree of quality, but also a measure of the magnitude of the process. They can help to measure and assess progress in achieving the objectives of sustainable development, to provide early warning and public awareness to prevent critical state and losses in the economy, problems in the social and environmental spheres. Usually, the separate indicators refer to some of the more common system of assessment, in which they reflect the individual components of sustainable development or even the certain edges of these components.

In the environmental field of the research, we can interpret the indicator as a measure that allows speaking about the state or change of the environmental component of sustainable development [Zgurovsky, 2007]. Environmental indicators are used to substantiate the decision made with quantitative assessment. They allow to interpret the changes and identify deficiencies in environmental management, and to facilitate access to information for the different categories of users. So the indicators of the state of environment inform the public and draw attention to certain environmental threats.

Although indicators and indices are different, but the following criteria are common [Zgurovsky and Boldak, 2011]:

- The sensitivity;
- The ability to interpreted easily and unambiguously;
- To combine environmental, economic and social aspects if it is necessary;
- The scientific validity;
- The quantitative expression;
- The representativeness.

Considering the above criteria the approach to the building of the indicator of the environmental component on the basis of needed for research logical groupings of data using a variety of available data is proposed.

2. Development of formalization of vector's indicators of sustainable development

Approach to formalization of indicators of sustainable development implies the use of this sequence of procedures:

1) The selection of indicator which will characterize the specific area of one of the directions of sustainable development (economic, environmental, social);
2) Grouping by specific characteristics of the data sets, which influence the dynamics, selected at the stage 1 of the indicator formation;
3) Forming a database for a specific period on the basis of the discrete samples;
4) Recovery of functional dependencies by the discrete samples;
5) Analysis of the results based on the recovered dependence.

According to the above procedures 1 - 3, any indicator, which is being built, depends on the available database on various fields of human activity. Suppose that we have some data set, with the quantity N, which we want to include to the future indicator. Let's divide this set of data on M logical groups by subject or area. Here, it should be noted, that grouping is not proportional, that is not necessary that in each group $M_i, i = \overline{1,n}$ there is the same number of data sets, and more precisely (N/M).

In the analysis of the data group, one or more options from the total number, which will be considered as the main characteristics of a particular area, should be selected. As a result of search and analysis these sets of data groups - $\left\{Q^j, M_i^j \middle| j = \overline{1,k}\right\}$ will be obtained, where $Q^j, j = \overline{1,k}$ - data samples, that according to the researcher can better describe the state of a certain region, industry, environment, etc.; $\left\{M_i^j \middle| j = \overline{1,k}\right\}$ - a set of data groups that can affect Q^j.

For the further work on indicator's building it is required for each group M_i to build some display $f_i : R^l \to R^1$ (where l – the number of samples belonging to the group M_i). This mapping should clearly characterize this set with the given input data set. That is, for each group M_i, there is a function-description $\overline{f_i}$. The next step is the transition to the main index Q^j. To show the dependencies between data groups and the main index, we build a mapping $F_j : R^k \to R^1$, which will show the connection between the groups of data Q^j.

After the above operations, the hierarchical structure of linked data (Figure 1), which reflects the relationship between samples of initially presented data and main indicators that were selected at the stage of forming the logical groups, is received.

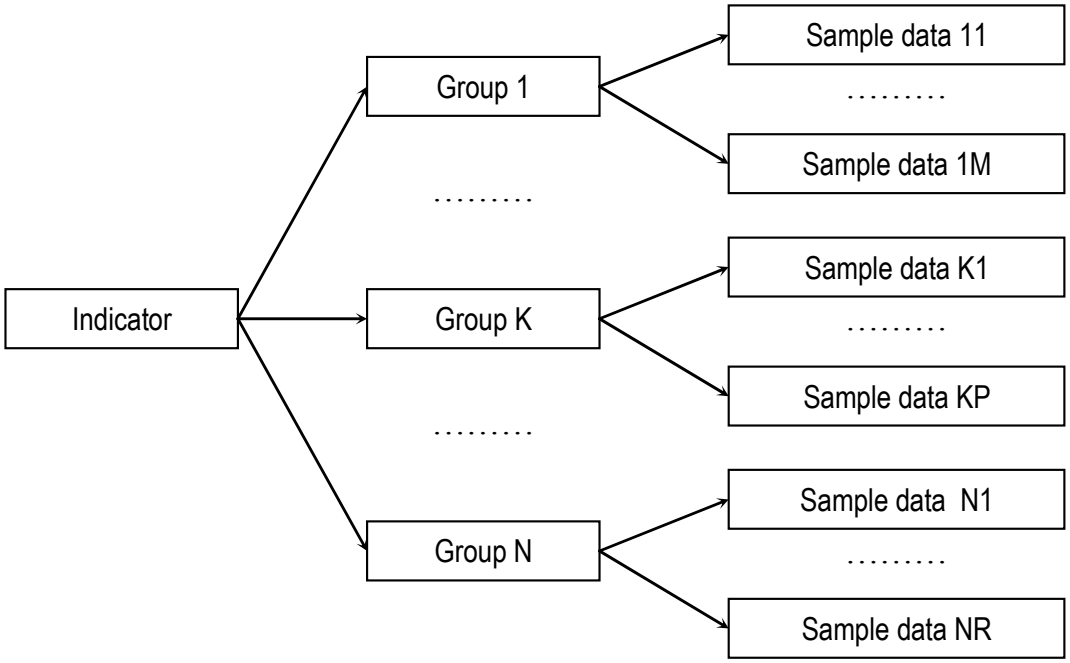

Figure1. The hierarchical structure of linked data

At the 4th step of the procedure the approach to recovery of functional dependencies, defined by discrete samples in terms of conceptual uncertainty, is used [Pankratova, 2002]. The mathematical expression for the building of the indicator is formed as a hierarchical multilevel system of models [Pankratova, 2010]. At the upper level, the model, which is determining the dependence of the approximating functions on the variables x_1, x_2, x_3 is realized. Such a model in the class of additive functions, where the vectors x_1, x_2, x_3 are independent, is represented as the superposition of functions of the variables x_1, x_2, x_3:

$$\Phi_i(x_1, x_2, x_3) = c_{i1}\Phi_{i1}(x_1) + c_{i2}\Phi_{i2}(x_2) + c_{i3}\Phi_{i3}(x_3), i = \overline{1,m} \quad (1)$$

where the functions $\Phi_{i1}(x_1), \Phi_{i2}(x_2), \Phi_{i3}(x_3)$ are a particular data samples. The coefficients c_{i1}, c_{i2}, c_{i3} of the functions indicate the influence of this or that group of factors included in the indicator. At the next level the building of the functional dependency of the groups, based on what they include, is conducted. At this level the functional dependency is based on varying degrees of polynomials.

At the second step of indicator formation, models that determine the dependence $\Phi_{is}(s = 1,2,3)$ on the components of the variables x_1, x_2, x_3, respectively, and represented as

$$\Phi_{i1}(x_1) = \sum_{j_1=1}^{n_1} a_{ij_1}^{(1)}\Psi_{1j_1}(x_{1j_1}), \Phi_{i2}(x_2) = \sum_{j_2=1}^{n_2} a_{ij_2}^{(2)}\Psi_{2j_2}(x_{2j_2}),$$
$$\Phi_{i3}(x_3) = \sum_{j_3=1}^{n_3} a_{ij_3}^{(3)}\Psi_{3j_3}(x_{3j_3}). \quad (2)$$

are formed.

At the third hierarchical level, models that determine the functions $\Psi_{1j_1}, \Psi_{2j_2}, \Psi_{3j_3}$ are formed, choosing the structure and components of the functions $\Psi_{1j_1}, \Psi_{2j_2}, \Psi_{3j_3}$ being the major problem. The structures of these functions are similar to (2) and can be represented as the following generalized polynomials:

$$\Psi_{sj_s}(x_{j_s}) = \sum_{p=0}^{P_{js}} \lambda_{j_s p} \varphi_{j_s p}(x_{sj_s}), s = 1,2,3. \quad (3)$$

In some cases, in forming the structure of the models, it should be taken into account that the properties of the unknown functions $\Phi_i(x_1, x_2, x_3), i = \overline{1,m}$ are influenced not only by a group of components of each vector x_1, x_2, x_3 but also by the interaction of their components. In such a case, it is expedient to form the dependence of the approximating functions on the variables x_1, x_2, x_3 in a class of multiplicative functions, where the approximating functions are formed by analogy with (I)-(3) as a hierarchical multilevel system of models [Pankratova, 2010]

$$[1+\Phi_i(x)] = \prod_{s=1}^{S_0} [1+\Phi_{is}(x_s)]^{c_{is}}; [1+\Phi_{is}(x_s)] = \prod_{j_s=1}^{n_s} [1+\Psi_{sj_s}(x_{sj_s})]^{a_{ij_s}^s};$$
$$[1+\Psi_{sj_s}(x_{sj_s})] = \prod_{p=1}^{P_{j_s}} [1+\varphi_{j_s p}(x_{sj_s})]^{\lambda_{j_s p}}. \quad (4)$$

We will use the Chebyshev criterion and for the functions $\varphi_{j_s p}$ we will use biased Chebyshev polynomials $T_{j_s p}(x_{j_s p}) \in [0,1]$. Then the approximating functions are found on the basis of the sequence $\Psi_1, \Psi_2, \Psi_3 \to \Phi_{i1}, \Phi_{i2}, \Phi_{i3} \to \Phi_i$ which will allow obtaining the final result by aggregating the corresponding solutions. Such an approach reduces the procedure of forming the approximating functions to a sequence of Chebyshev approximation problems for inconsistent systems of linear equations that allow aggregating the indicator.

Due to the properties of Chebyshev polynomials, the approach to forming the functional dependences makes it possible to extrapolate the approximating functions, set up for the intervals $[\hat{d}_{j_s}^-, \hat{d}_{j_s}^+]$ to wider intervals $[d_{j_s}^-, d_{j_s}^+]$, which allow forecasting the analyzed properties of a product outside the test intervals.

3. Formation of the indicator «population morbidity»

On the basis of the analysis of available statistical information for research the indicator “population morbidity” in Ukraine is selected. For calculations in the period 2003-2011 the data sets of the first time registered cases of the disease in the following groups: neoplasm’s, diseases of nervous system, diseases of the circulatory system, diseases of the respiratory organs, are selected.

The indicator "population morbidity" will be defined by the four components of the vector $y = (y_i | i = 1,4)$, that will be recovered: Y1 – neoplasm’s, Y2 - diseases of the nervous system, Y3 - diseases of the circulatory system, Y4 - diseases of the respiratory organs. According to the method, this was basis of the approach, let use a hierarchical structure for building these indicators and restore functional dependencies.

According to the above approach on formalization of indicators of sustainable development the next step in the formation of the indicator will be grouped according to specific features of data sets that affect the chosen directions (group) of the indicator of population health. In the process of research and analysis of existing data, the following groups were allocated:

- The influence of air quality;
- The impact of water quality;
- The effect of the number of green spaces.

Based on the available data, for the characteristics of groups, which are set by discrete samples, the dynamics of atmospheric emissions (X11 - total emissions of polluting substances in atmospheric air; X12 - the total number of enterprises, which are registered), the volume of recycled and consistently used water (X21 - industry, million m3 per year; X22 - agriculture), the main types of lands, total, thous. hec. (X31 - forests and other forest-covered areas; X32 - built-up areas) are selected. Thus the hierarchical structure presented in Figure 2 was received.

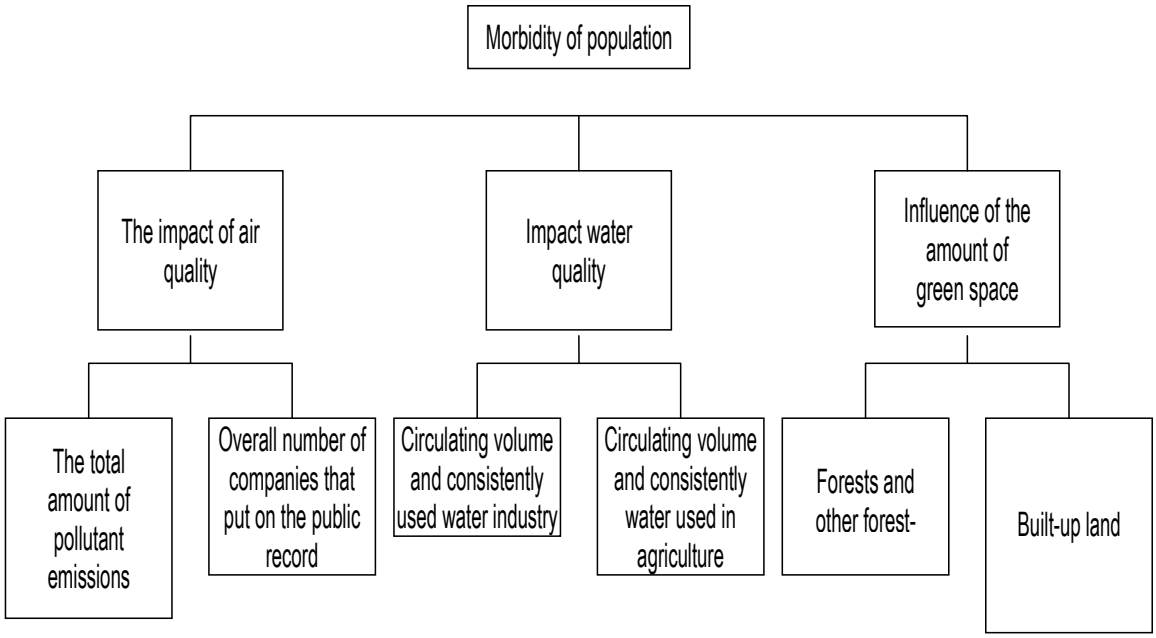

Figure 2. Hierarchy of indicator “Population morbidity”

Moving through the hierarchy shown in Figure 2 from bottom to top we can recover a functional relationship, which will display the chosen indicator. In the result of using the method of recovery of functional dependencies the mathematical representation of the four components of the indicator "morbidity" will be received in this form:

$$\hat{Y}_i(q\ ) = C_{1i}\Phi_{1i}(x_{11}[q], x_{12}[q],) + C_{2i}\Phi_{2i}(x_{21}[q], x_{22}[q]) + C_{3i}\Phi_{3i}(x_{31}[q], x_{32}[q])$$

4. The results of formation of vector’s indicators of sustainable development

The results obtained after the application of the method of recovery of functional dependencies such as below in the form of graphical representations: Y1 – neoplasm’s (Figure 2), Y2 - diseases of the nervous system (Figure 3), Y3 - diseases of the circulatory system (Figure 4), Y4 - diseases of respiratory organs (Figure 5), and their represented functional dependencies

$$\hat{Y}_1(q) = 0{,}459567 \cdot \Phi_{11}(\hat{x}_1[q]) + 0{,}202476 \cdot \Phi_{21}(\hat{x}_2[q]) + 0{,}369966 \cdot \Phi_{31}(\hat{x}_3[q]),$$

$$\hat{Y}_2(q) = 0{,}889136 \cdot \Phi_{12}(\hat{x}_1[q]) + 2{,}273524 \cdot \Phi_{22}(\hat{x}_2[q]) - 2{,}38912 \cdot \Phi_{32}(\hat{x}_3[q]),$$

$$\hat{Y}_3(q) = -0{,}11435 \cdot \Phi_{13}(\hat{x}_1[q]) + 1{,}257481 \cdot \Phi_{23}(\hat{x}_2[q]) - 0{,}18794 \cdot \Phi_{33}(\hat{x}_3[q]),$$

$$\hat{Y}_4(q) = 0{,}357111 \cdot \Phi_{14}(\hat{x}_1[q]) + 0{,}055097 \cdot \Phi_{24}(\hat{x}_2[q]) + 0{,}620032 \cdot \Phi_{34}(\hat{x}_3[q]),$$

$$\Phi_{11} = -0{,}18512 \cdot Poly(\hat{x}_1[q], 0) - 0{,}33002 \cdot Poly(\hat{x}_1[q], 1) - 0{,}48735 \cdot Poly(\hat{x}_1[q], 2) - 0{,}43467 \cdot Poly(\hat{x}_1[q], 3) - 0{,}00666 \cdot Poly(\hat{x}_1[q], 4),$$

$$\Phi_{21} = -0{,}16579 Poly \cdot (\hat{x}_2[q], 0) + 1{,}645967 Poly \cdot (\hat{x}_2[q], 1) + 0{,}406987 \cdot Poly(\hat{x}_2[q], 2) + 0{,}199115 \cdot Poly(\hat{x}_2[q], 3) + 0{,}394933 \cdot Poly(\hat{x}_2[q], 4),$$

$$\Phi_{31} = -0{,}06039 \cdot Poly(\hat{x}_3[q], 0) + 1{,}514136 \cdot Poly(\hat{x}_3[q], 1) + 0{,}360911 \cdot Poly(\hat{x}_3[q], 2) + 0{,}102391 \cdot Poly(\hat{x}_3[q], 3) + 0{,}185751 \cdot Poly(\hat{x}_3[q], 4),$$

where Poly(x,N)– the Hermite polynomial of specified degree- N.

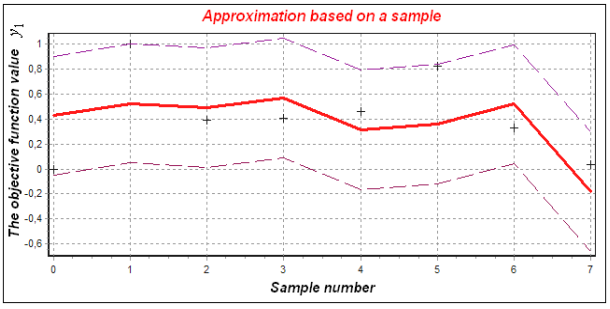

Figure 3. Distribution neoplasm's by the discrete samples

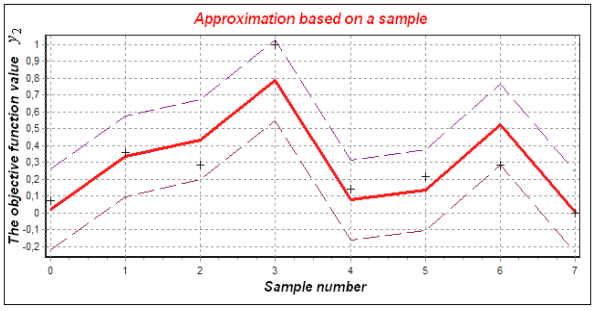

Figure 4. Distribution diseases of the nervous system by the discrete samples

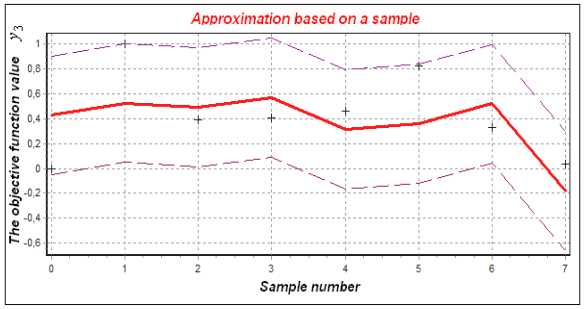

Figure 5. Distribution of diseases of the circulatory system by the discrete samples

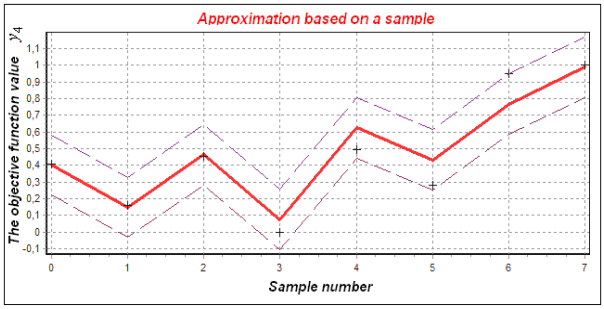

Figure 6. Distribution of diseases of respiratory organs by the discrete samples

Therefore, the obtained result allows us to forecast the behavior of selected indicators (Y1, Y2, Y3, Y4) on the basis of information about the internal parameters. Moreover, having received the functional dependencies, it is expedient to work with them not as with functions of forecast, but in the context of functions control, i.e. changing the input parameters of the model to determine the expected result, which will allow, on the basis of previous experience, to make, in a certain sense, the best management decisions. This applies not only to the above indicator "Morbidity", but also the other necessary for the research and decision-making indicators.

Such scheme of a research will be able to allow not to spend all efforts and financial resources on diseases overcoming, namely to spend these efforts on prevention, although this requires not a shallow analysis of the

available in open sources information, but the cooperation with experts in health care, who will be able to determine the main factors of influence on the health of the population.

Conclusion

To demonstrate the approach operation in this direction the indicator of morbidity of Ukrainian citizens, established during the period of 2003 - 2011 years, was selected. In the result the functional dependencies of these indicators from a number of parameters that affect them were obtained. The procedure for the formation of the indicator using common hierarchical structure was proposed. This approach allows tracking relationships between parameters at individual levels of interaction. This result is achieved by the recovery of the main functional dependencies on the basis of the characteristics of the groups, which contribute some error in the calculations, but this is offset by the achievement of the connection between the parameters in a hierarchy.

On the basis of the research of indicators "Morbidity", „Diseases of respiratory organs" the problem of emissions the pollutants into air and water, which greatly affect the number of diseases that occur in people during the year, was established. In addition, it was investigated the indicator “the volume of fishing”, which also indicates the environmental problems of the region, as the quantity of fish, which is available for fishing, depends on the total population of the species in the region. In its turn, the population depends on the purity of the environment in this case it is water. Particularly the purification of drinking water and elimination of solid waste disposal, as well as reducing emissions from different transport in the atmosphere, deserve a special attention.

In the course of analysis of environmental problems on the basis of the indicators a number of recommendations for improving the environmental status of the region of Crimea were developed:

- To implement new technologies of cleaning fumes at the enterprises, which are the main sources of atmospheric air pollution;
- To improve the quality of wastewater treatment in communities;
- To ensure the appropriate level of wastewater treatment with the established rules;
- To organize the land use, prevent the destructive effects of natural and anthropogenic factors on the state of soils;
- To increase the efficiency of technologies of cleaning the industrial waste water and utilization of its sediments;
- To ensure the environmentally safe storage and disposal of hazardous waste, the maximum possible disposal of waste by its alternative or re-use;
- To promote the development of material-technical base and information infrastructure of the regional monitoring system;
- To position a tourism as one of the main areas of employment and incomes;
- To promote the development of the tourism sector in the region.

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Major Fields of Scientific Research: System analysis, Decision support systems, Foresight, Scenarios, Strategic planning, Information technology, cognitive modeling, sustainable development

TIME MANAGEMENT BASED ON TWO-MACHINE FLOWSHOP SCHEDULING WITH UNCERTAIN JOB PROCESSING TIMES

Yuri N. Sotskov, Natalja M. Matsveichuk, Andrei A. Kasiankou, Frank Werner

Abstract: *The purpose of this article is to initiate a research in one of the main parts of time management, which is an extremely useful activity that implies an effective use of personal time. Namely, we propose to include optimal scheduling algorithms into time management techniques. Specifically, we consider a time management system including two persons, one of which is a supervisor. In scheduling theory, such a processing system may be modeled as a two-machine flowshop with the objective of minimizing the makespan. Due to a specificity of the scheduling process for a person, it is assumed that the job processing times may be uncertain before scheduling. Moreover, for time management, it is necessary to consider on-line scheduling along with usual off-line scheduling for a set of jobs to be completed by a person during a day.*

Keywords: *Scheduling, flowshop, time management.*

ACM Classification Keywords*: Management.*

Introduction

Despite of the large number of publications on time management and its great popularity in many countries, a definition of time management varies in different sources. In [Hellsten, 2012], the following definition of time management has been provided: "Time management is the analysis of how working hours are spent and the prioritization of tasks in order to maximize personal efficiency in the workplace. In more specialized sources, and depending on the scope of the notion of the term may be supplemented". An ultimate goal of time management is to increase the efficiency of time usage by a person. Time management deals with a set of rules, methods, and principles that may be used to increase the personal efficiency due to a better time usage. The main steps for personal time optimization includes setting goals, compiling lists of tasks, and personal planning in short and long time periods. The variety of literature on time management does not mean that there already exists a theoretical framework containing a basic set of statements, formal definitions, rules, and methods such that are sufficient for all people and that this knowledge allows every person to know how to manage his time effectively. The modern literature on time management presents mainly empirical rules, using which can help some persons to manage their time more efficiently. However, if these rules do not help a concrete person, it is difficult to assert whether this is a result of improper performance of the proposed time management rules and techniques, or these rules and proposed time management technology are not suitable for the particular person.

After studying techniques of time-management and starting to implement them, a person may need a variety of supporting tools. For example, following the time management recommendations and principles, a person may need to make a list of tasks that expose their priorities, sort them according to their urgency, possible profit, time needed, etc. Of course, one can use a pen and a sheet of paper to do this. Indeed in many cases it will be justified if suddenly urgent tasks are appeared, then one can write the tasks on the sheet of paper and then execute the tasks. However, if the most amount of information that a person uses when planning working time is quite large, it is necessary to use more sophisticated tools, e.g., electronic devices and their software. Today, there are a wide variety of computer applications, which are more or less designed to help a person to manage time to execute his to-do-list. Unfortunately to the best of our knowledge, all these computer systems cannot construct an optimal

schedule for executing to-do-list. If a person is a leader of a team and works with a few other people, then it is needed to use a computer application such that time optimization takes into account the subordination of the team members.

Literature review

The literature dealing with time management can be divided into two main parts: the popular literature and scientific articles. Books on time management, brochures, popular science articles and materials of numerous seminars on time management are included in the popular literature, which provide a variety of information about time management, such as recommendations, expert advices, analysis, and applications of advertising time management. Despite of the large number of publications on time management and its popularity [Jackson, 2009] – [Macan, 2010], the definitions, terminology and content of time management in a variety of references vary widely. With certainty, it can be argued that the basic principles of time management are as follows: the need for setting the general and immediate goals and objectives for a person, planning (long-term and short-term) work, and compiling lists of works to be performed at a certain time.

The existence of a large number of references does not mean that currently a deep theoretical basis of time management is already developed, which would contain a complete set of models, provisions, definitions and methods, which are sufficient so that a top executive could successfully use existing tools of time management planning for the working time. The literature on time management provides descriptions of empirical rules, which are intended to help a person to manage their working time. If the efficiency of the worker does not increase as a result of the implementation of the recommended tools and rules of time management, it is usually impossible to ascertain whether this is a result of improper performance of the proposed rules and techniques of time management, or whether it is a result of the fact that this method of time management for a particular individual is generally ineffective.

A number of articles evaluate the effectiveness of a particular method of time management. It should be noted that, as a scientific discipline in the articles on time management, psychology is often used, so in most scientific papers, time management is considered in the context of individual empowerment and human psychophysical characteristics. For example, in [Jackson, 2009], a methodology and principles of time management are provided, the use of which is intended to increase the effectiveness of human activity. In [Woolfolk, 1986], an experiment conducted in a college is described in detail, in which the effect of time management on the productivity of students is assessed. In the experiment, the students were divided into groups, one of which offered a course on time management. In another group of students, together with a course on time management, workshops on time management were conducted (compiling lists of tasks, planning their implementation). In the control group of students, lessons on time management were conducted. The experimental results showed convincingly that in addition to improving students' knowledge, sessions on time management had a positive impact on the performance of the students in their training at the college and the completion of all training plans and assignments.

In [Ho, 2003], the results of studies were considered, which showed that four students in the learning process differently interpreted and applied the same time management recommendations. In [Kelly, 2003], the question of how to use time management can influence the level of anxiety and concern of a person was investigated. The studies found that structuring and streamlining the working time as well as the timely setting goals and objectives lead to a decrease in the level of nervousness and anxiety of a person. In [Macan, 2010], the impact of procedures for the preparation of plans, setting goals and priorities for the development of objectives of human memory was examined. In [Keniga, 2013], the efficacy of "quiet time" (the time of the supervisor that is free of calls, visitors, letters, etc.) is assessed and it has been experimentally found that the use of "quiet hours" leads to improved performance of the leader. In [Zampetakis, 2010], the effect of time management on the creative activity of a person was examined. The study showed that the application of the principles of time management has a positive impact on the creative process. An application of time management to the management of various public events was considered in [Ahmad, 2012]. The study showed that there is a close relationship between the efficiency of social events and the use of technology for their time management. Time management is especially useful in the cases of deadlines and public events when the event requires to perform a large amount of work. Many scientific

articles describing experiments were focused on the study of the influence of an individual empowerment and human psychophysical characteristics on the development and effective use of time management techniques.

In scheduling theory, models and algorithms have been developed to construct optimal (or approximate) schedules for a deterministic or stochastic systems consisting of a single machine or multiple identical or different machines. For the use of existing tools in the planning of employment rights, deterministic algorithms for solving problems that are investigated in the classical scheduling theory are insufficient. The specificity of an optimal planning of the working time is that in practice, the governing employee has to solve previously unscheduled tasks. A person needs to take into account changes of the situation in a timely manner to overcome problems that require a rapid adjustment of the current schedule of the tasks related to changes as a set of planned works, and sometimes with the emergence of new non-standard problems and issues.

Practical problems of time management are characterized by an uncertain duration of the planned tasks and works because in a schedule for a person, it is often not possible to accurately determine the duration of all jobs (tasks, works) to be scheduled. However, it is generally possible to determine accurate lower and upper bounds of the jobs, i.e., it can be assumed that intervals of possible values of the planned duration of the procedures are known in advance. In this regard, for time management acceptable methods for constructing schedules for service systems with uncertain (interval) numerical parameters are important. Feature systems serving time management should be considered at various stages of preparation and implementation schedules, either directly for the statement of the problems of working time planning or in scheduling algorithms for a working day or longer periods of time. The allocated time management problem can be solved at a large extent by using appropriate models and methods for solving (in some sense) uncertain scheduling problems that have been considered in the last decade [Sotskov, 2010; Sotskov, 2014]. The classical deterministic formulation and the solution methods for the corresponding scheduling problems have been modified by taking into account the uncertainty of the length of an operation which turned out to be for solving practical time management. Studies of service systems such as "master – subordinate employer" ones are necessary and of particular interest when an interval for the duration of the works is given. In this case, one needs to solve the problem of scheduling the work performed for the serving system, in which a chief may delegate certain tasks to subordinative person, and the flow of work is directed in one direction: from the main worker to directly subordinate employees. In the next section, we formulate the formal problem setting and present the possible approaches to its exact or approximate solution.

Flowshop scheduling with two machines and interval job processing times

The scheduling problem for time management can be formulated in the following way. There are two employees, a supervisor (or master) and a subordinate person, and a set of jobs to be processed (during a working day, or during a week, etc.). First, every job has to be processed by the master (the first operation on the job). For example, the master poses the task, outlines its solution, defines the stages of the job, and then sells the job to a subordinate person. Then a subordinate employee has to process the job given to him by his supervisor (the second operation on the job) and after that the whole job is completed. An important feature for a time management schedule is that an exact processing time of the human job may be unknown. Usually, only a lower bound and an upper bound for the processing time of each job are known before scheduling. In time management, we are dealing with a real person and not with a machine. It is always possible to set a reasonable limit for the processing time of each job, at the worst, one can set the lower bound to be equal to zero and the upper bound to be equal to the length of the planning horizon (e.g., to the length of the working day). Another important point is the scheduling goal: we can assume that all necessary jobs should be completed as soon as possible.

Now we can formulate the problem in terms of scheduling theory as follows. Let two machines $\mathcal{M} = \{M_1, M_2\}$ be given to process $n \geq 2$ jobs $\mathcal{J} = \{J_1, J_2, ..., J_n\}$, which have to follow the same machine route. Each job $J_i \in \mathcal{J}$ has to be processed first by machine M_1 and then by machine M_2 without preemption on each machine. All the n jobs are available to be processed from time 0. The factual processing time of job $J_i \in \mathcal{J}$ on machine $M_j \in \mathcal{M}$ is denoted as p_{ij}. The processing time p_{ij} is unknown before scheduling. In the realization of the process, p_{ij} may take any real value from the (closed) interval $[p_{ij}^L,\ p_{ij}^U]$, $p_{ij}^L < p_{ij}^U$, where the lower bound p_{ij}^L

and the upper bound p_{ij}^U are fixed before scheduling, but the probability distributions of the random processing times between these lower and upper bounds are unknown. Let $C_i(\pi)$ denote the completion time of job $J_i \in \mathcal{J}$ in the schedule π, and the criterion C_{max} denotes the minimization of the schedule length $C_{max}(\pi)$:

$$C_{max} = \min_{\pi \in \Omega} C_{max}(\pi) = \min_{\pi \in \Omega} \{\max\{C_i(\pi) \mid J_i \in \mathcal{J}\}\},$$

where Ω denotes the set of semi-active schedules [Sotskov, 2014] with the cardinality $|\Omega| = (n!)^2$. In a semi-active schedule, the processing of each job $J_i \in \mathcal{J}$ starts as early as possible (provided that the order of the jobs $\mathcal{J}$ for processing is determined in the schedule). Such a two-machine minimum-length flowshop scheduling problem with *interval* processing times is called an *uncertain* problem and is denoted by $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$.

Let $T = \{p \mid p_{ij}^L \le p_{ij} \le p_{ij}^U,\ J_i \in \mathcal{J},\ M_j \in \mathcal{M}\}$ be the set of all possible vectors (scenarios) $p = (p_{1,1}, p_{1,2}, \ldots, p_{n1}, p_{n2})$ of the job processing times. For a fixed vector $p \in T$, the uncertain problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ turns into the classical deterministic problem $F2||C_{max}$ associated with the vector p of job processing times. The problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ corresponds to the above time management scheduling problem. The machine M_1 corresponds to the master employee while the machine M_2 corresponds to the subordinate. Concerning interruptions, we assume that, by processing any job, the employee processes it up to the end without an interruption. Of course, in a real life, the employees can be interrupted during the processing of jobs, but this can only lead to an increase of the processing time (the employee will need to "tune" this job again after each interruption). Moreover, interruptions cannot reduce the C_{max} value for the problem $F2||C_{max}$ [Sotskov, 2014]. The above processing times p_{ij} are uncertain. In this paper, we assume that any processing time cannot be determined accurately (there always exists at least a computational error). So, in time management, the inequality $p_{ij}^L < p_{ij}^U$, $J_i \in \mathcal{J}$, $M_j \in \mathcal{M}$ holds. Therefore, for finding an optimal order of the job execution by the master employee and the subordinate, we can use the results obtained for the uncertain flowshop problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$. This problem has been investigated in [Matsveichuk, 2014; Matsveichuk, 2009; Matsveichuk, 2011] for the case of $p_{ij}^L \le p_{ij}^U$. Next, we present some results, which are modified for the case under consideration with $p_{ij}^L < p_{ij}^U$. Let $S = \{\pi_1, \pi_2, \ldots, \pi_{n!}\}$ be the set of all permutations of the n jobs from set $\mathcal{J}$: $\pi_k = (J_{k_1}, J_{k_2}, \ldots, J_{k_n})$, $\{k_1, k_2, \ldots, k_n\} = \{1, 2, \ldots, n\}$. The set S defines all *permutation* schedules that *dominate* the set Ω of semi-active schedules for the problem $F2||C_{max}$ associated with each vector p. Thus, the set S of permutation schedules is *dominant* for the uncertain problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$. There exists at least one optimal semi-active schedule with the same sequence of the jobs on both machines M_1 and M_2 [Sotskov, 2014] (i.e., the master employee and the subordinate process the jobs in the same order). Therefore, it is sufficient to look for an optimal schedule among the set S of permutation schedules [Sotskov, 2014]. Since each permutation $\pi_k \in S$ uniquely defines the set of the *earliest* completion times $C_i(\pi_k)$ of the jobs $J_i \in \mathcal{J}$ for the problem $F2||C_{max}$, we identify a *permutation* $\pi_k \in S$ with a *permutation schedule* defined by π_k. The set of all permutation schedules has the cardinality $|S| = n!$. Next, we restrict further the set of permutations that are sufficient to be examined while solving the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$.

In [Johnson, 1954], it was proven that a permutation $\pi_i = (J_{i_1}, J_{i_2}, \ldots, J_{i_n}) \in S$ with

$$\min\{p_{i_k 1}, p_{i_m 2}\} \le \min\{p_{i_m 1}, p_{i_k 2}\}, \tag{1}$$

$1 \le k < m \le n$, is optimal for the deterministic problem $F2||C_{max}$. Each permutation π_i satisfying condition (1) is called a Johnson permutation. We consider a *minimal dominant set* of permutations instead of the whole set S.

Definition 1. *The set of permutations $S(T) \subseteq S$ is called a J-solution (or a minimal dominant set) to the uncertain problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$, if for each vector $p \in T$, set $S(T)$ contains at least one permutation that is a Johnson one for the deterministic problem $F2|p|C_{max}$ associated with the vector p of job processing times, provided that any proper subset of set $S(T)$ is not a J-solution to problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$.*

Off-line phase of scheduling (constructing a minimal dominant set)

From Definition 1, it follows that minimal dominant set $S(T)$ contains at least one optimal schedule $\pi_k \in S(T)$ for each vector $p \in T$ of the job processing times, and the set $S(T)$ is a minimal set (with respect to inclusion) which possesses such a property. Thus, to solve problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ exactly, one can restrict the search within the set $S(T)$ which has often a smaller cardinality than the set S.

The next criterion characterizes the case when $|S(T)| = 1$, i.e., there is an optimal permutation $\{\pi_k \in S\}$ for the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ (for the problem $F2||C_{max}$, associated with any vector $p \in T$). Let us consider the following partition of the set $\mathcal{J} = \mathcal{J}_1 \cup \mathcal{J}_2 \cup \mathcal{J}^*$, where $\mathcal{J}_1 = \{J_i \in \mathcal{J} \mid p_{i1}^U \le p_{i2}^L, p_{i2}^U > p_{i1}^L\}$, $\mathcal{J}_2 = \{J_i \in \mathcal{J} \mid p_{i1}^U > p_{i2}^L, p_{i2}^U \le p_{i1}^L\}$, $\mathcal{J}^* = \{J_i \in \mathcal{J} \mid p_{i1}^U > p_{i2}^L, p_{i2}^U > p_{i1}^L\}$.

Theorem 1. [Matsveichuk, 2014] *There exists a permutation $\{\pi_k \in S\}$ which is optimal for problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ if and only if a) for any pair of jobs J_i and J_j from the set $\mathcal{J}_1$ (from the set $\mathcal{J}_2$, respectively) either $p_{i1}^U \le p_{j1}^L$ or $p_{j1}^U \le p_{i1}^L$ (either $p_{i2}^U \le p_{j2}^L$ or $p_{j2}^U \le p_{i2}^L$), b) $|\mathcal{J}^*| \le 1$ and for job $J_{i^*} \in \mathcal{J}^*$ (if any), the following inequalities hold: $p_{i^*1}^L \ge \max\{p_{i1}^U \mid J_i \in \mathcal{J}_1\}$, $p_{i^*2}^L \ge \max\{p_{j2}^U \mid J_j \in \mathcal{J}_2\}$.*

Theorem 1 characterizes the case when there exists an optimal order of the jobs in spite of the unknown actual processing times. In such a case, a minimal dominant set $S(T)$ is a singleton: $|S(T)| = 1$.

In general case, for the uncertain problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$, there often does not exist a single permutation of the n jobs $\mathcal{J}$, which remains optimal for all possible realizations of the job processing times. On the other hand, the cardinality of the set $S(T)$ may be large. The following claim has been proven in [Matsveichuk, 2014].

Theorem 2. [Matsveichuk, 2014] *If $\max\{p_{ik}^L \mid J_i \in \mathcal{J}, M_k \in \mathcal{M}\} < \min\{p_{ik}^U \mid J_i \in \mathcal{J}, M_k \in \mathcal{M}\}$, then $S(T) = S$.*

On the base of Definition 1, one can fix the order $J_v \to J_w$ of the jobs $J_v \in \mathcal{J}$ and $J_w \in \mathcal{J}$ while solving the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$. Fixing the order of two jobs is possible if, for each vector $p \in T$, there exists a Johnson permutation for the deterministic problem $F2|p|C_{max}$ associated with the vector p of the job processing times with the same order of these two jobs.

Theorem 3. [Matsveichuk, 2014] *There exists a J-solution $S(T)$ to the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ with the fixed order $J_v \to J_w$ of the jobs $J_v \in \mathcal{J}$ and $J_w \in \mathcal{J}$ in all permutations $\pi_k \in S(T)$ if and only if at least one of the following conditions hold:*

$$p_{v1}^U \le p_{v2}^L \text{ and } p_{v1}^U \le p_{w1}^L, \tag{2}$$

$$p_{w2}^U \le p_{w1}^L \text{ and } p_{w2}^U \le p_{v2}^L. \tag{3}$$

Next, we show that the set $S(T)$ may be represented in a compact form by a dominance digraph with the set $\mathcal{J}$ of vertices and that it takes $O(n^2)$ time to construct such a dominant digraph. Let $\mathcal{J} \times \mathcal{J}$ denote the Cartesian product of the set $\mathcal{J}$. Due to Theorem 3, by testing inequalities (2) and (3) for each pair of jobs $J_v \in \mathcal{J}$ and $J_w \in \mathcal{J}$, one can construct the following binary relation $\mathcal{A}_\prec \subseteq \mathcal{J} \times \mathcal{J}$ on the set $\mathcal{J}$.

Definition 2. [Matsveichuk, 2014] *The inclusion $(J_v, J_w) \in \mathcal{A}_\prec$ with $v \ne w$ holds if and only if there exists a J-solution $S(T)$ to the uncertain problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ such that job $J_v \in \mathcal{J}$ is located before job $J_w \in \mathcal{J}$ (i.e., $J_v \to J_w$) in all permutations $\pi_k \in S(T)$.*

From Definition 2 and inequality $p_{ij}^L < p_{ij}^U$, it follows that the binary relation $\mathcal{A}_\prec$ on the set $\mathcal{J}$ is antireflective, antisymmetric, and transitive, i.e., it is a strict order. The binary relation $\mathcal{A}_\prec$ defines a dominance digraph $(\mathcal{J}, \mathcal{A}_\prec)$ with the vertex set $\mathcal{J}$ and the arc set $\mathcal{A}_\prec$. The relation $(J_v, J_w) \in \mathcal{A}_\prec$ will be represented as $J_v \prec J_w$. It takes $O(n^2)$ time to construct the digraph $(\mathcal{J}, \mathcal{A}_\prec)$ by testing inequalities (2) and (3) for each pair of jobs from the set $\mathcal{J}$.

Theorem 4. [Matsveichuk, 2014] *Let $\mathcal{J} = \mathcal{J}^* \cup \mathcal{J}_1 \cup \mathcal{J}_2$. There exists at most one component with a cardinality greater than one in the dominance digraph $\mathcal{G}$.*

Theorem 4 means that all the components of the dominance digraph $\mathcal{G}$ (except at most one) are isolated vertices. A permutation $\pi_k = (J_{k_1}, J_{k_2}, \ldots, J_{k_n}) \in S$ may be considered as a total order of the jobs $\mathcal{J}$. A total order defined by the permutation π_k is called a *linear extension* of the partial order $\mathcal{A}_\prec$, if each inclusion $(J_{k_u}, J_{k_v}) \in \mathcal{A}_\prec$ implies the inequality $u < v$. Let $\Pi(\mathcal{G})$ denote the set of permutations $\pi_k \in S$ defining all linear extensions of the partial order $\mathcal{A}_\prec$. In particular, if $\mathcal{G} = (\mathcal{J},)$, then $\Pi(\mathcal{G}) = S$. This case is characterized in Theorem 2.

On the other hand, if $|\mathcal{A}_\prec| = \frac{n(n-1)}{2}$, then $\Pi(\mathcal{G}) = \{\pi_k\}$. A criterion for such a case is given in Theorem 1.

Theorem 5. [Matsveichuk, 2014] *For any vector $p \in T$, the set $\Pi(\mathcal{G})$ contains a Johnson permutation for the problem $F2|p|C_{max}$ associated with the vector p of job processing times.*

Corollary 1. [Matsveichuk, 2014] *There exists a J-solution $S(T)$ to the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ such that inclusion $S(T) \subseteq \Pi(\mathcal{G})$ holds.*

The permutation $\pi \in \Pi(\mathcal{G})$ is called *redundant* if there exists a J-solution $S(T)$ for the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ such that $\pi \in \Pi(\mathcal{G}) \setminus S(T)$. The pair of jobs $J_i \in \mathcal{J}$ and $J_j \in \mathcal{J}$ is called a *conflict pair* of jobs, if neither relation $J_i \preceq J_j$ nor $J_j \preceq J_i$ holds. Due to Definition 2, both conditions $(J_i, J_j) \notin \mathcal{A}_\prec$ and $(J_j, J_i) \notin \mathcal{A}_\prec$ hold for a conflict pair of jobs J_i and J_j. Let the inclusion $J_j \in \mathcal{J}^*$ hold. We denote two sets:

$$\mathcal{J}_j' = \{J_q \in \mathcal{J}_2 \mid \min\{p_{j1}^U, p_{j2}^U\} < p_{q2}^U\} \bigcup \{J_r \in \mathcal{J}_1 \cup \mathcal{J}^* \mid \min\{p_{j1}^U, p_{j2}^U\} \le p_{r1}^L\}; \quad (4)$$

$$\mathcal{J}_j'' = \{J_w \in \mathcal{J}_1 \mid \min\{p_{j1}^U, p_{j2}^U\} < p_{w1}^U\} \bigcup \{J_u \in \mathcal{J}_2 \cup \mathcal{J}^* \mid \min\{p_{j1}^U, p_{j2}^U\} \le p_{u2}^L\}. \quad (5)$$

Lemma 1. [Matsveichuk, 2014] *If inclusions $J_j \in \mathcal{J}^*$, $J_q \in \mathcal{J}_j'$, and $J_w \in \mathcal{J}_j''$ hold, then each permutation of the form $\pi_g = (\ldots, J_q, \ldots, J_j, \ldots, J_w, \ldots) \in \Pi(\mathcal{G})$ is redundant.*

Due to Lemma 1, testing whether permutation $\pi_g \in \Pi(\mathcal{G})$ is a redundant permutation takes $O(n)$ time. Let $\Pi^*(\mathcal{G})$ denote the set of permutations remaining in the set $\Pi(\mathcal{G})$ after deleting all redundant permutations according to Lemma 1.

Theorem 6. [Matsveichuk, 2014] $\Pi^*(\mathcal{G}) = S(T)$.

It is clear that testing the condition of Theorem 6 takes $O(n)$ time. Due to Theorem 6, a J-solution can be constructed by deleting all redundant permutations from the set $\Pi(\mathcal{G})$. Since the obtained set $\Pi^*(\mathcal{G})$ is uniquely defined, the following claim is correct.

Corollary 2. *The relation $\mathcal{A}_\prec$ defines a unique J-solution $\Pi^*(\mathcal{G}) = S(T)$ to the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$.*

There are two phases in the scheduling process due to time management specificity, namely, the off-line phase (the schedule planning phase) and the on-line phase (the schedule execution phase). The information about the lower and upper bounds for each uncertain processing time is available at the beginning of the off-line phase while the local information on the realization (the actual value) of each uncertain processing time is available once the corresponding operation (f a job on a machine is completed. In the off-line phase, based on the knowledge about the bounds of the processing times, one can construct the digraph $\mathcal{G}$ which is a compact form of the strict order $\mathcal{A}_\prec$ and defines a unique J-solution $S(T)$ of the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$ under consideration.

If $|S(T)| = 1$, then we have one permutation which is optimal for all variations of the job processing times. In this case, the scheduling process stopped at the off-line phase. The employees can process the jobs according to the constructed permutation, and they always obtain an actually optimal schedule (for the actual processing times).

If $|S(T)| \ge 1$, then for different vectors $p \in T$, different permutations from $S(T)$ may be optimal. In the next section, we describe how to use the strict order $\mathcal{A}_\prec$ and the J-solution $S(T)$ at the on-line phase of scheduling to reach an optimal permutation for the actual vector of the job processing times.

Schedule realization (on-line phase of scheduling)

The result of the off-line phase is a digraph $\mathcal{G} = (\mathcal{J}, \mathcal{A}_{\prec})$ that represents a compact representation for J-solution $S(T)$ of the problem $F2|p_{ij}^L \le p_{ij} \le p_{ij}^U|C_{max}$. Aim of the on-line phase is to select factually optimal permutation of the jobs (solution) from the set $\Pi^*(\mathcal{G}) = S(T)$. Thus, the result of the on-line phase is a linear order on the set $\mathcal{J}$ (one permutation π_i from the J-solution $S(T)$). Therefore at the on-line phase, a scheduler has to solve more complicated scheduling problem. A scheduler has to use additional information about the fulfilled jobs. Note, that at the off-line phase a scheduler has a lot of time for scheduling but a little information. In contrast to off-line phase, at the on-line phase of scheduling a scheduler has an additional information about the course of the process but a little time for scheduling. Note that classical scheduling is usually solved only at the off-line phase.

The set $S(T)$ is only workpiece of the actual schedule, since it will be realized only one permutation of the given jobs. Our approach shows how one can use a set $S(T)$ at the on-line stage to select a schedule, which is the optimal for the factual processing times. We use the following definition of permutation dominance.

Definition 3. $[\mathrm{Matsveichuk},\ 2009]$ *The permutation $\pi_u \in S$ dominates the permutation $\pi_k \in S$ with respect to T if the inequality $C_{max}(\pi_u, p) \le C_{max}(\pi_k, p)$ holds for any vector $p \in T$ of the job processing times. The set of permutations $S' \subseteq S$ is called dominant with respect to T if for each permutation $\pi_k \in S$, there exists a permutation $\pi_u \in S'$ which dominates the permutation π_k with respect to T.*

At the on-line scheduling phase, we consider the following case: *the actual value p_{ij}^* of job processing time p_{ij} is available at the time-point $t_i = c_j(i)$ when job J_i is completed by machine M_j.* We note that this case is valid for almost all uncertain scheduling problems. A minimal set of jobs $\mathcal{J}_c \subseteq \mathcal{J}$ is called a *conflict set* of jobs if, for each job J_i from the set $\mathcal{J} \setminus \mathcal{J}_c$, the relation $J_i \prec J_j$ holds for all jobs from the set $\mathcal{J}_c$ (the relation $J_j \prec J_i$ holds for all jobs from the set $\mathcal{J}_c$). We consider the case when an arbitrary number of jobs are conflicting at the same on-line decision-making time-points.

Let the partial strict order $\prec$ over the set $\mathcal{J} = \mathcal{J}^* \cup \mathcal{J}_1 \cup \mathcal{J}_2$ be as follows: $(J_1 \prec \ldots \prec J_k \prec \{J_{k_1}, J_{k_2}, \ldots, J_{k_r}\} \prec J_{k+1} \prec \ldots \prec J_n)$. In this case, the set of r jobs $\{J_{k_1}, J_{k_2}, \ldots, J_{k_r}\} \subset \mathcal{J} = \mathcal{J}^* \cup \mathcal{J}_1 \cup \mathcal{J}_2$ is conflicting at the time-point $t_k = c_1(k) \ge 0$. All permutations from the set $S(T)$ look as follows: $(J_1, J_2, ..., J_k, ...)$, i.e., their initial parts are the same until job J_k. Then the master employee can start to execute the schedule and processes the jobs from the set $\{J_1, J_2, ..., J_k\}$. At the time-point t_k, the scheduler (the master employee) has the choice between conflicting jobs for being processed next (immediately after the job J_k). Let at the time-point t_k, the subordinate employee (which corresponds to machine M_2) operate the job J_l.

At the time-point $t_k = c_1(k)$, the set of feasible vectors $T(t_k) = \{p \in T \mid p_{i1} = p_{i1}^*,\ p_{j2} = p_{j2}^*,\ 1 \le i \le k,\ 1 \le j < l\}$ of the job processing times will be used. We can calculate the lower bound $c_2^L(k)$ for the actual value $c_2(k)$ in the following way (see Fig. 1):

$$c_2^L(k) = c_2(l-1) - c_1(k) + \max\{p_{l2}^L,\ c_1(k) - c_2(l-1)\} + \sum_{l+1 \le j \le k} p_{j2}^L.$$

We can calculate the following upper bound $c_2^U(k)$: $c_2^U(k) = c_2(l-1) - c_1(k) + \sum_{l \le j \le k} p_{j2}^U$.

Lemma 2. $[\mathrm{Matsveichuk},\ 2009]$ *Let the partial strict order $\prec$ over the set $\mathcal{J} = \mathcal{J}^* \cup \mathcal{J}_1 \cup \mathcal{J}_2$ be as follows: $(J_1 \prec \ldots \prec J_k \prec \{J_{k_1}, J_{k_2}, \ldots, J_{k_r}\} \prec J_{k+1} \prec \ldots \prec J_n)$. If the inequality*

$$\sum_{i=1}^{s+1} p_{k_i 1}^L \le \sum_{j=0}^{s} p_{k_j 2}^U$$

holds for each $s = 0, 1, \ldots, r$, where $p_{k_0 2}^L = c_2^L(k) - c_1(k)$, then the permutation $\{J_1, \ldots, J_k, J_{k_1}, J_{k_2}, \ldots, J_{k_r}, J_{k+1}, \ldots, J_n\}$ is dominant with respect to $T(t_k)$.

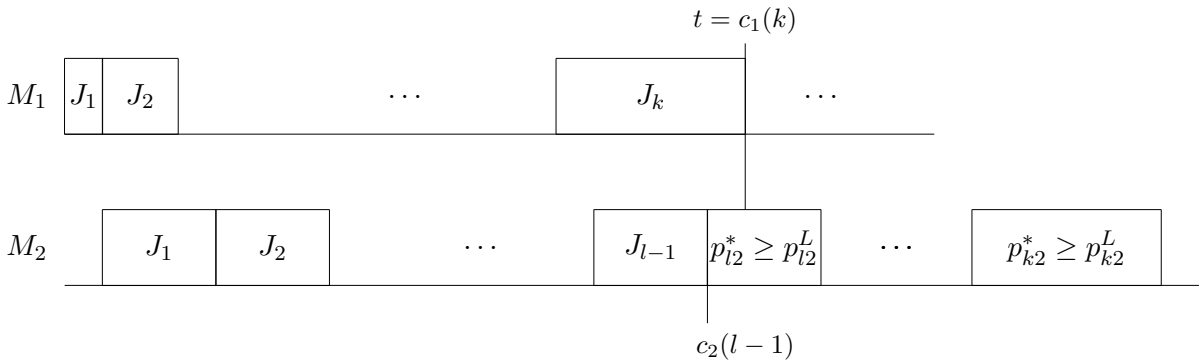

Figure 1: The initial part of an optimal schedule for the jobs from the set $\{J_1, J_2, \ldots, J_k\}$

Lemma 3. [Matsveichuk, 2009] *Let the partial strict order $\prec$ over the set $\mathcal{J} = \mathcal{J}^* \cup \mathcal{J}_1 \cup \mathcal{J}_2$ be as follows: $(J_1 \prec \ldots \prec J_k \prec \{J_{k_1}, J_{k_2}, \ldots, J_{k_r}\} \prec J_{k+1} \prec \ldots \prec J_n)$. If the conditions*

$$\sum_{i=m}^{s} p^L_{k_i 1} > \sum_{j=m-1}^{s-1} p^U_{k_j 2}, \ m = 1, 2, \ldots, s,$$

$$\sum_{i=s+1}^{m} p^U_{k_i 1} \leq \sum_{j=s}^{m-1} p^L_{k_j 2}, \ m = s+1, s+2, \ldots, r, \qquad \sum_{i=s+1}^{r+1} p^L_{k_i 1} \geq \sum_{j=s}^{r} p^U_{k_j 2}$$

hold, where $p^U_{k_0 2} = c^U_2(k) - c_1(k)$, then the permutation $\{J_1, \ldots, J_k, J_{k_1}, J_{k_2}, \ldots, J_{k_r}, J_{k+1}, \ldots, J_n\}$ is dominant with respect to $T(t_k)$.

Thus, we propose to solve the problem $F2|p^L_{ij} \leq p_{ij} \leq p^U_{ij}|C_{max}$ in two stages as follows. The first step (off-line stage) is the construction of the digraph $\mathcal{G}$ and the check of the conditions of Theorem 1. If there is a permutation, which is a J-solution of the problem $F2|p^L_{ij} \leq p_{ij} \leq p^U_{ij}|C_{max}$, then the solution of the problem is finished at this stage. In the opposite case, we have to go to the second step (on-line stage). At this stage, the employer can start with processing some jobs which are ordered until the first decision point. Then the employer check the conditions of Lemmas 2, 3, and order the conflict jobs by using the actual processing times of the already processed jobs. In our approach, to solve the problem $F2|p^L_{ij} \leq p_{ij} \leq p^U_{ij}|C_{max}$ at the decision point a scheduler indicates the master employee what job to process next. After that, the execution of jobs may be realized until the next decision point, which use the new additional information about actual processing times of the jobs, processed between these adjacent decision points.

Time management software

The computer application to manage a list of tasks (jobs) is designed to optimize the working time of the manager by a more rational use. As a method by which this can be achieved, the list of the proposed operations are arranged and evaluated by certain criteria, so that the final list is optimal according to a chosen criterion (e.g., C_{max}). A functional application will provide the possibility to introduce the input (initial) data, to construct an optimal schedules, to monitor the schedule, and adjust the schedule.

As a schedule for a person implies the need to know what a job it is better to do next in the current moment and since a personal schedule is often dynamically changed in a time, the most important features of the graphical user interface should be informative and interactive. A variety of a schedule needs a graphical representation of schedules under interactivity such that flexible feedback must be available to inform the user about certain schedule changes and provide an option of doing the required action and realize a job. Finally, one should pay attention to integrate the principles and approaches of time management into the computer application to maximize the use of

a personal time. By an integration of time management, it should be understood to systematize the most common "technique" in a compact and user-friendly application. The design and implementation of a personal schedule should be such that the user does not need to think a lot about the technical details of time management and at the same time an application should allow the user a more efficient use of his time.

The computer application to manage the tasks of a person based on the model "supervisor – subordinate employer" is a distributed application of a "client-server" (see previous section). This is due to the need to implement the interaction mechanism of a large number of multiple users on a single system, i.e., the behavior, where each user should have access to the shared data, to be able to modify them to a necessary extent, and be able to inform the other users (other members of the team). With some modifications, the architecture used in our application as the client and on the server side is as follows. Next, we enumerate each of the layers.

- The layer of the data can be represented by a database that will be used for storing and processing the data, or third-party services, such as data sources. In our case, we use the server database on the server, and a local database as the client. The server database is used for the treatment of the general application data, while the local database is used to store the temporary data on the client, and when the connection to the server is not possible.
- The data access layer is represented by one or more executable libraries and serves to interact with the database, namely, to access, update, and delete data.
- The layer of the domain is represented by one or more executable libraries that are used to describe the application model, the interaction with the data access layer, the implementation of key business scenarios, to implement the communication with various algorithms for constructing schedules, and a proper implementation of the algorithms for constructing schedules, monitoring schedules, adjusting schedules, and statistical calculations.
- The layer of services is represented by one or more executable and libraries used to implement the functional interfaces provided by the server, through which third-party systems can access the functionality implemented by the server.
- The auxiliary layer (proxies), which is represented by one or more executable libraries, serves to integrate with the services of the server. The layer logic of the representations represented by one or more executable library implements the logic representations. In this layer, there will be also the implementation of the data synchronization mechanism for the client and server.
- The presentation layer, which is an implementation of a graphical user interface. There are independent libraries that provide a so-called "cross-cutting ", i.e., it is involved at every level of the application. This includes such features as security authentication, authorization of users, error handling, and system logging application events.

The application is developed based on the platform NET Framework 4.5 in the language of C# 5.0 with the following products and technologies: MS SQL Express 2012 - as the server database; Compact Edition - as the local database; (Windows Communication Foundation) - the technology of the development service (in this case, web services) Web server for deploying and running WCF services; WPF - a graphical subsystem for rendering user interfaces in Windows-based applications.

We consider the functional application to build schedules for the client and server side. The main feature is that the backbend does not have a GUI, but it implements all the basic logic, to which the end user will receive access from the client. The basic logic of the server presented an algorithm for constructing schedules, monitoring schedules, as well as the functional user authentication, the user registration and the user management. The client application to build schedules for a person in the hierarchy "leader - subordinate" will provide a different functionality depending on the user's role in the application, namely to be the supervisor or the subordinate. This is due to the fact that for different user roles, the application, except for the general functionality, there will be available a functionality which

is specific for each role. The different application functionality will be contained in separate modules that can be connected to the application. The common functionality for all users is as follows: authentication and authorization; user registration; construction schedule; settings; notification service. The common scenario for all users when one first starts the application process is the user registration process and the user authorization. These operations are performed on the server via web services. If the user is already registered in the system, every time one starts the application, it must be authorized. After the user registration and authorization in the application, the functional configuration becomes available, by means of which the user can specify individual settings: personal settings (personal data), application settings, configure time management, which will then be taken into account in the construction schedule. All the settings except for the application settings are stored on the server.

The functional manager has the full functionality for the application management: the user management; to enter the information about the tasks on the basis of which it will be built and the schedule that will be used during the work; constructing schedules; the manual and automatic assignment of tasks performed by users of the schedule; monitoring the implementation schedule. The user management is carried out in a separate module. Here the head is able to manage both a user that has been created, and to create new ones. Under the control of already established means, the users can view their public setting, time management settings, view tasks that are performed by the user, password recovery, as well as to remove a user from the application. In the future, statistics associated with each user can be realized. The task management module provides a standard mechanism for "create, edit, delete." The GUI data entry forms used are input and output - tables. The schedule management module includes functional construction schedules, to assign tasks to users, and to monitor the implementation schedule. This is the main application module. The process of constructing a schedule consists of several steps.

- Receiving raw data from the database; receiving the settings of the subjects involved in the implementation schedule (head, subordinates).
- Loading libraries containing the implementation of algorithms that perform a schedule directly. These libraries can be developed dynamically and added to the system without the need for the development of algorithms to be integrated into an application. Algorithms for constructing schedules can be changed in the settings ‘Application’;
- Constructing a schedule and the automatic assignment of the right of workers to execute appropriate tasks, they can send a notification.

The user functional at this stage of the development is a minimal set of operations required to perform the task schedules, namely: view tasks necessary to run, including all information that is necessary for their implementation; the opportunity to arrange changes in the status of tasks. After completing the process of the head of a schedule, the slave receives a set of tasks assigned to it and which should be processed. These tasks appear with him in the task list with the status "Not Started." At the beginning of the task, the employee must change the status of the work to "In Progress." If for some reason the employee does not change the status of the implementation, the system will do this automatically based on the time parameter for the task. At the completion of the work, the subordinates can mention the work done and how to proceed to the next step, or specify the reasons why it cannot be done, and put its execution. In both cases, executives receive a proper notification.

Conclusion

It should be noted that the use of this application will not be considered as a binding set of instructions. Its main purpose is to give the user some tools to build a list of assigned works in the order that would minimize the length of a schedule. Used for time management, the mathematical apparatus is designed to provide sufficient grounds for the correctness of technology time-management-specific tasks and preferences of a particular user. It does not aim to express analytically a model for the behavior of a particular user.

Currently in the United institute of informatics problem of the National academy of sciences of Belarus, it is developed a software on a modern platform, which will be implemented approaches presented in the second part of the article.

The following briefly present components of the program, which will be realized in this year and is designed for small businesses (small teams in which there is one leader and one or more subordinates).

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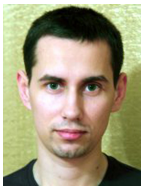

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DIRECT AND DUAL PROBLEM OF INVESTMENT PORTFOLIO OPTIMIZATION UNDER UNCERTAINTY

Yuri Zaychenko, Inna Sydoruk

***Abstract**: The problem of forming an optimal portfolio of securities under uncertainty was considered. The main objective of portfolio investment is to improve the investment environment, giving securities such investment characteristics that are only possible in their combination. Careful processing and accounting of investment risks have become an integral and important part of the success of each company. However, the global market crisis of recent years has shown that the existing theory of optimization of investment portfolios and forecasting stock indices themselves exhausted and needed overhaul of the basic theory of portfolio management. Therefore the fuzzy sets theory was used for getting an optimal portfolio.*

The direct problem with the use of triangular, bell-shaped and Gaussian membership functions and dual problem by using the fuzzy sets theory were considered in this work. In direct task we define structure of a portfolio which will provide the maximum profitableness at the set risk level. In dual task we define structure of a portfolio which will provide the minimum risk level at the set level of critical profitableness. The input data for the optimization system were predicted by using the Fuzzy Group Method of Data Handling (FGMDH). The optimal portfolios for asset were determined. The comparative analysis of optimal portfolio obtained by using of different membership functions was fulfilled. Investment portfolio optimization system is an effective tool for the operational management of portfolio investments. This is an opportunity to carry out scientific and reasonable management of their investment portfolio with the ability to reject the planned loss of possession or overvalued risky assets, which increases business efficiency and maximize gain on the stock market.

***Keywords**: membership function, fuzzy sets theory, optimal portfolio, investments, stock securities, fuzzy number, FGMDH.*

***ACM Classification Keywords**: G.1.0 Mathematics of Computing– General – Error analysis; G.1.6 Mathematics of Computing – Numerical Analysis – Optimization - Gradient methods, Least squares methods; I.2.3 Computing Methodologies - Artificial Intelligence - Uncertainty, "fuzzy", and probabilistic reasoning.*

Introduction

The investment process is the adoption of a decision by the investor in securities, in which investments are made, and the amounts and timing of investment.

The main objective of portfolio investment is to improve the investment environment, giving securities such investment characteristics that are only possible in their combination.

Careful processing and accounting of investment risks have become an integral part and important part of the success of each company. However, more and more companies have to make decisions under uncertainty, which may lead to unintended consequences and, therefore, undesirable results statement. Particularly serious consequences may have the wrong decisions on long-term investments. Therefore, early detection and adequate and the most accurate assessment of risk is one of the biggest problems of modern investment analysis.

Historically, the first and the most common way to take account of uncertainties is the use of probability. The beginning of modern investment theory was in article H. Markowitz, "Portfolio Selection", which was released in 1952. Mathematical model of optimal portfolio of securities was first proposed. Methods of constructing such portfolios under certain conditions based on theoretical and probabilistic formalization of the concept profitability and risk. Thus, the theory is the classical theory of Markowitz portfolio construction of stocks, after which most of the remaining theories are only modifications of the base.

However, the global market crisis of recent years has shown that the existing theory of optimization of investment portfolios and forecasting stock indices themselves exhausted and needed overhaul of the basic theory of portfolio management.

Important investment fuzzy sets theory was created about half a century ago in the fundamental work of Lotfi Zadeh [Zadeh, 1999]. This theory was coming into use in the economy in the late 70's. By using fuzzy numbers in the forecast parameters decision making person not required to form a point probability estimates.

Investment portfolio optimization system - is an effective tool for the operational management of portfolio investments. This is an opportunity to carry out scientific and reasonable management of their investment portfolio with the ability to reject the planned loss of possession or overvalued risky assets, which increases business efficiency and maximize gain on the stock market. And thanks to the results obtained using FGMDH system devoid of subjective risk experts. For now calculate input values yield component of the portfolio is automated, and therefore denied the need to involve experts.

Problem statement of portfolio optimization

The purpose of the analysis and optimization of an investment portfolio is research in area of portfolio optimization, and also the comparative analysis of structure of the effective portfolios received at use of model Markovitz and fuzzy-set model of a share portfolio optimization.

Let us consider a share portfolio from N components and its expected behavior at time interval $[0, T]$. Each of a portfolio component $i = \overline{1, \mathrm{N}}$ at the moment T is characterized by its financial profitableness $\mathrm{r_i}$ (evaluated at a point T as a relative increase in the price of the asset for the period) [Zaychenko, 2008].

The holder of a share portfolio – the private investor, the investment company, mutual fund – operates the investments, being guided by certain reasons. On the one hand, the investor tries to maximize the profitableness. On the other hand, it fixes maximum permissible risk of an inefficiency of the investments. We will assume the capital of the investor be equal 1. The problem of optimization of a share portfolio consists in a finding of a vector of share price distribution of papers in a portfolio $x = \{\mathrm{x_i}\}, i = \overline{1, \mathrm{N}}$ of the investor maximizing the income at the set risk level (obviously, that $\sum_{i-1}^{N} x_i = 1$).

In process of practical application of model Markovitz its lacks were found out:

1. The hypothesis about normality profitableness distributions in practice does not prove to be true.
2. Stationary of price processes also not always is in practice.
3. At last, the risk of actives is considered as a dispersion standard deviation of the prices of securities from expected value i.e. as decrease in profitableness of securities in relation to expected value, and profitableness increase in relation to an average are estimated absolutely the same.

Though for the proprietor of securities these events are absolutely not the same.

These weaknesses of Markovitz theory define necessity of use of essentially new approach of definition of an optimum investment portfolio.

Let review the main principles and idea of a method.

The risk of a portfolio is not its volatility, but possibility that expected profitableness of a portfolio will appear below some pre established planned value.

- Correlation of assets in a portfolio is not considered and not accounted;
- Profitableness of each asset is not random fuzzy number. Similarly, restriction on extremely low level of profitableness can be both usual scalar and fuzzy number of any kind. Therefore optimize a portfolio in such statement may mean, in that specific case, the requirement to maximize expected profitableness of a portfolio in a point of time T at the fixed risk level of a portfolio;
- Profitableness of a security on termination of ownership term is expected to be equal r and is in a settlement range. For i-th security:

  $\bar{r}_i$ – Expected profitableness of i-th security;

  r_{1i} – The lower border of profitableness of i-th security;

  r_{2i} – The upper border of profitableness of i-th security.

  $r_i = \left(r_{1i}, \bar{r}_i, r_{2i}\right)$ – Profitableness of i-th security is triangular fuzzy number.

Then profitableness of a portfolio:

$$r = (r_{\min} = \sum_{i=1}^{N} x_i r_{1i}; \bar{r} = \sum_{i=1}^{N} x_i \bar{r}_i; r_{\max} = \sum_{i=1}^{N} x_i r_{2i}) \tag{1}$$

where x_i - weight of i-th asset in portfolio, and

$$\sum_{i=1}^{N} x_i = 1, \quad 0 \le x_i \le 1 \tag{2}$$

Critical level of profitableness of a portfolio at the moment of T may be fuzzy triangular type number $r^* = \left(r_1^*; \bar{r}^*; r_2^*\right)$.

Fuzzy-set approach with triangular membership functions

To define structure of a portfolio which will provide the maximum profitableness at the set risk level, it is required to solve the following problem (3):

$$\{x_{opt}\} = \{x\} \mid r \to \max, \quad \beta = const \tag{3}$$

where r is profitableness , β is a desired risk, vector's components x satisfy (2).

The most expected value risk degree of a portfolio is defined:

$$\beta = \begin{cases} 0, \ if \ \ r^* < r_{\min} \\ R\left(1 + \dfrac{1-\alpha_1}{\alpha_1} \ln(1-a_1)\right), \ if \ \ r_{\min} \le r^* \le \tilde{r} \\ 1-(1-R)\left(1 + \dfrac{1-\alpha_1}{\alpha_1} \ln(1-a_1)\right), \ if \ \ \tilde{r} \le r^* < r_{\max} \\ 1, \ if \ \ r^* \ge r_{\max} \end{cases} \tag{4}$$

where

$$R = \begin{cases} \dfrac{r^* - r_{\min}}{r_{\max} - r_{\min}}, & if \quad r^* < r_{\max} \\ 1, & if \quad r^* \geq \mathrm{r}_{\max} \end{cases}$$

$$\alpha_1 = \begin{cases} 0, & if \quad r^* < r_{\min} \\ \dfrac{r^* - r_{\min}}{\tilde{r} - r_{\min}}, & if \quad r_{\min} \leq r^* < \tilde{r} \\ 1, & if \quad r^* = \tilde{r} \\ \dfrac{r_{\max} - r^*}{r_{\max} - \tilde{r}}, & if \quad \tilde{r} < r^* < r_{\max} \\ 0, & if \quad r^* \geq r_{\max} \end{cases} \tag{5}$$

Having recollected also, that profitableness of a portfolio is:

$$r = (r_{\min} = \sum_{i=1}^{N} x_i r_{1i};\ \tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i;\ r_{\min} = \sum x_i r_{2i}),$$

where $\left(r_{1i}, \overline{r_i}, r_{2i}\right)$ – profitableness of i-th security, we receive the following problem of optimization (6) - (8):

$$\tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \to \max \tag{6}$$

$$\beta = const \tag{7}$$

$$\sum_{i=1}^{N} x_i = 1,\ x_i \geq 0,\ i = \overline{1, N} \tag{8}$$

At a risk level variation β 3 cases are possible. We will consider in detail each of them.

1. $\beta = 0$

From (4) it is evident, that this case is possible when $r^* < \sum_{i=1}^{N} x_i r_{i1}$.

We receive the following problem of linear programming:

$$\tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \to \max \tag{9}$$

$$\sum_{i=1}^{N} x_i r_{i1} > r^* \tag{10}$$

$$\sum_{i=1}^{N} x_i = 1,\ x_i \geq 0,\ i = \overline{1, N} \tag{11}$$

Found result of the problem decision (9)-(11) vector $x = \{x_i\},\ i = \overline{1, N}$ is a required structure of an optimum portfolio for the given risk level.

2. $\beta = 1$

From (4) follows, that this case is possible when $r^* \geq \sum_{i=1}^{N} x_i r_{i2}$.

We receive the following problem

$$\tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \to \max \text{ , } \sum_{i=1}^{N} x_i r_{i2} \le r^* \text{ , } \sum_{i=1}^{N} x_i = 1,\ x_i \ge 0,\ i = \overline{1,N} \text{ .}$$

Found result of the problem decision (9)-(11) vector $x = \{x_i\}$, $i = \overline{1,N}$ is a required structure of an optimum portfolio for the given risk level.

3. $0 < \beta < 1$

From (4) it is evident, that this case is possible when $\sum_{i=1}^{N} x_i r_{i1} \le r^* \le \sum_{i=1}^{N} x_i \tilde{r}_i$, or when $\sum_{i=1}^{N} x_i \tilde{r}_i \le r^* \le \sum_{i=1}^{N} x_i r_{i2}$.

а) Let $\sum_{i=1}^{N} x_i r_{i1} \le r^* \le \sum_{i=1}^{N} x_i \tilde{r}_i$. Then using (4) - (5) problem (6) - (8) is reduced to the following problem of nonlinear programming:

$$\tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \to \max \text{ ,}$$

$$\left(\left(r^* - \sum_{i=1}^{N} x_i r_{i1} \right) + \left(\sum_{i=1}^{N} x_i \tilde{r}_i - r^* \right) \cdot \ln \left(\frac{\sum_{i=1}^{N} x_i \tilde{r}_i - r^*}{\sum_{i=1}^{N} x_i \tilde{r}_i - \sum_{i=1}^{N} x_i r_{i1}} \right) \right) \cdot \tag{12}$$

$$\cdot \frac{1}{\sum_{i=1}^{N} x_i r_{i2} - \sum_{i=1}^{N} x_i r_{i1}} = \beta, \tag{13}$$

$$\sum_{i=1}^{N} x_i r_{i1} \le r^* \tag{14}$$

$$\sum_{i=1}^{N} x_i \tilde{r}_i > r^* \tag{15}$$

$$\sum_{i=1}^{N} x_i = 1,\ x_i \ge 0,\ i = \overline{1,N} \text{ .} \tag{16}$$

б) Let $\sum_{i=1}^{N} x_i \tilde{r}_i \le r^* \le \sum_{i=1}^{N} x_i r_{i2}$. Then the problem (6) - (8) is reduced to the following problem of nonlinear programming:

$$\tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \to \max \tag{17}$$

$$\left(\left(r^* - \sum_{i=1}^{N} x_i r_{i1} \right) - \left(r^* - \sum_{i=1}^{N} x_i \tilde{r}_i \right) \cdot \ln \left(\frac{r^* - \sum_{i=1}^{N} x_i \tilde{r}_i}{\sum_{i=1}^{N} x_i r_{i2} - \sum_{i=1}^{N} x_i r_{i1}} \right) \right) \cdot \tag{18}$$

$$\cdot \frac{1}{\sum_{i=1}^{N} x_i r_{i2} - \sum_{i=1}^{N} x_i r_{i1}} = \beta$$

$$\sum_{i=1}^{N} x_i r_{i2} > r^* \tag{19}$$

$$\sum_{i=1}^{N} x_i \tilde{r}_i \le r^* \tag{20}$$

$$\sum_{i=1}^{N} x_i = 1,\ x_i \ge 0,\ i = \overline{1,N} \tag{21}$$

The R-algorithm of minimization of not differentiated functions is applied to the decision of problems (12) - (16) and (17) - (21). Let both problems: (12) - (16) and (17) - (21) solvable. Then to the structure of a required optimum portfolio will correspond a vector – $x = \{x_i\}\ i = \overline{1,N}$ the decision of that problem (12) - (16), (17) - (21) the criterion function value of which will be greater.

Fuzzy-set approach with bell-shaped membership functions

In case of using bell-shaped MF we should solve the problem of portfolio optimization where parameter $r_i = (r_{1i}, \bar{r}_i, r_{2i})$, the profitability of the *i*-th asset, is fuzzy number with bell-shaped form $\mu(x) = \dfrac{1}{1 + \left(\dfrac{x-a}{c}\right)^2}$, as shown in Figure 1:

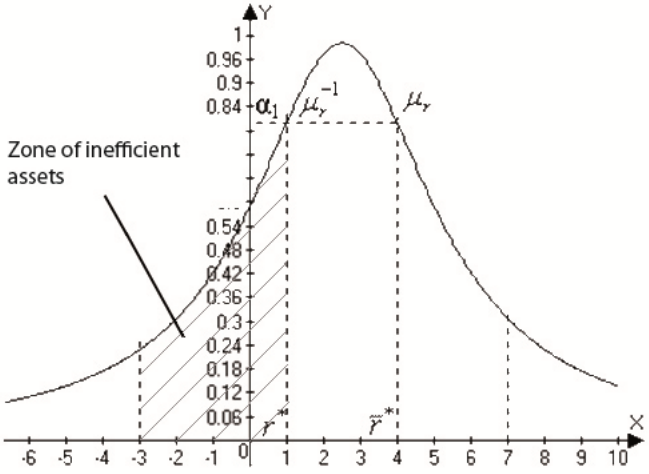

Figure 1. Clear efficiency criterion for the bell-shaped MF

In this case:

$$\alpha_1 = \begin{cases} \dfrac{1}{1 + \left(\dfrac{r^* - \tilde{r}}{r_{\max} - r_{\min}}\right)^2}, \text{ïðè}\quad r_{\min} < r^* < r_{\max} \\ 0, \text{ïðè}\quad r_{\min} > r^* \text{ ³ } r^* > r_{\max} \\ 1, \text{ïðè}\quad r^* = \tilde{r} \end{cases} \tag{22}$$

$$\beta = \begin{cases} 0, \ \text{ïðè} \quad r^* < r_{\min} \\ \frac{1}{2}\alpha_1 + \frac{1}{2}\frac{r^* - \bar{r}}{r_{\max} - r_{\min}} * L, \ \text{ïðè} \quad r_{\min} < r^* < \bar{r} \\ 1 - \left(\frac{1}{2}\alpha_1 + \frac{1}{2}\frac{r^* - \bar{r}}{r_{\max} - r_{\min}} * L \right), \ \text{ïðè} \quad \bar{r} < r^* < r_{\max} \\ 1, \ \text{ïðè} \quad r^* > r_{\max} \end{cases} \tag{23}$$

Where α1 we can find from (22), L is $L = \arcsin\left(\sqrt{a_1}\right) - \sqrt{a_1 - a_1^2}$

In order to determine the structure of the portfolio, which will provide maximum return with the given level of risk, we need to solve the problem (3) where r and β are determined from formulas (22), (23).

$$\beta = \begin{cases} 0, \text{ïðè} \ \ r^* \le r_{\min} \\ \frac{1}{2}(\alpha_1 - \alpha_0) + \frac{1}{2}\frac{(r^* - \tilde{r})}{(r_{\max} - r_{\min})} * L + \frac{(r^* - r_{\min})}{(r_{\max} - r_{\min})} * \alpha_0, \text{ïðè} \ \ r_{\min} \le r^* \le \tilde{r} \\ 1 - \left(\frac{1}{2}(\alpha_1 - \alpha_0) + \frac{1}{2}\frac{(r^* - \tilde{r})}{(r_{\max} - r_{\min})} * L + \frac{\left(r_{\max} - r^*\right)}{\left(r_{\max} - r_{\min}\right)} * \alpha_0 \right), \text{ïðè} \ \ \tilde{r} < r^* \le r_{\max} \\ 1, \text{ïðè} \ \ r^* > r_{\max} \end{cases} \tag{24}$$

where

$$\alpha_0 = \begin{cases} \frac{1}{1 + \left(\frac{\tilde{r} - r_{\min}}{r_{\max} - r_{\min}} \right)^2}, \text{ïðè} \ \ r_1 \le r^* \le \tilde{r} \\ \frac{1}{1 + \left(\frac{r_{\max} - \tilde{r}}{r_{\max} - r_{\min}} \right)^2}, \text{ïðè} \ \ \tilde{r} < r^* \le r_2 \end{cases} \tag{25}$$

$$L = \arcsin\left(\sqrt{\alpha_1}\right) - \arcsin\left(\sqrt{\alpha_0}\right) - \sin\left(\arcsin\left(\sqrt{\alpha_1}\right) - \arcsin\left(\sqrt{\alpha_0}\right)\right) * \cos\left(\arcsin\left(\sqrt{\alpha_1}\right) + \arcsin\left(\sqrt{\alpha_0}\right)\right) \tag{26}$$

Optimization problem consists of tasks (3), (23) - (26).

Fuzzy-set approach with Gaussian membership functions

In case of using Gaussian MF we should solve the problem of portfolio optimization where parameter $r_i = \left(r_{1i}, \bar{r}_i, r_{2i}\right)$, the profitability of the *i*-th asset, is fuzzy number with Gaussian form $\mu(x) = e^{-\frac{1}{2}\frac{(x-a)^2}{c^2}}$, as shown in Figure 2:

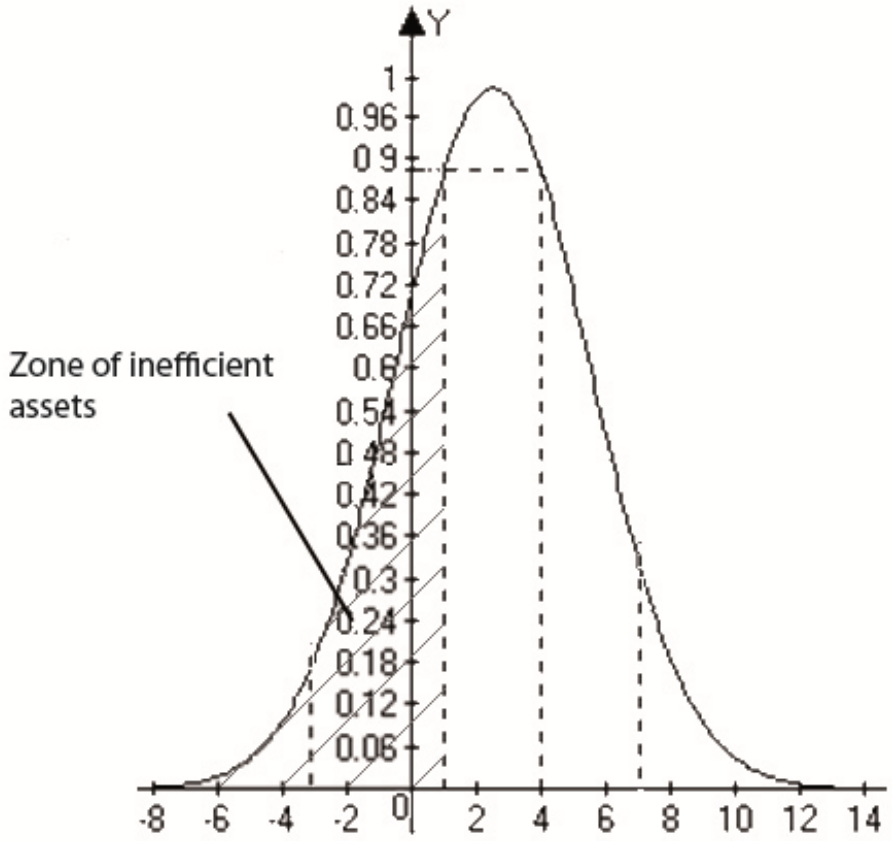

Figure 2. Clear efficiency criterion for the Gaussian MF

In this case:

$$\alpha_1 = \begin{cases} e^{-\frac{1}{2}\frac{\left(r^* - \tilde{r}\right)^2}{\left(r_{\max} - r_{\min}\right)^2}} \\ 0, \text{ïðè} \quad r^* < r_{\min} \text{ ³ } r^* > r_{\max} \\ 1, \text{ïðè} \quad r^* = \tilde{r} \end{cases} \tag{27}$$

$$\beta = \begin{cases} 0, \text{ïðè} \quad r^* \le r_{\min} \\ \frac{1}{2}\left(\alpha_1 - \alpha_0\right) + \frac{\sqrt{\pi}}{2\sqrt{2}} R\left(\hat{O}(R) + \hat{O}\left(\sqrt{\ln\frac{1}{\alpha_0}}\right)\right), \text{ïðè} \quad r_{\min} \le r^* \le \tilde{r} \\ 1 - \left(\frac{1}{2}\left(\alpha_1 - \alpha_0\right) - \frac{\sqrt{\pi}}{2\sqrt{2}} R\left(\hat{O}(R) - \hat{O}\left(\sqrt{\ln\frac{1}{\alpha_0}}\right)\right)\right), \text{ïðè} \quad \tilde{r} < r^* \le r_{\max} \\ 1, \text{ïðè} \quad r^* > r_{\max} \end{cases} \tag{28}$$

where α_0 is very small, α1 we can find from (27), R is:

$$R = \frac{\left(r^* - \tilde{r}\right)}{\left(r_{\max} - r_{\min}\right)} \tag{29}$$

Φ(x) is the Laplace function at x: $\hat{O}(\mathrm{x}) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$

In order to determine the structure of the portfolio, which will provide maximum return with the given level of risk, we need to solve the problem (3) where r and β are determined from formulas (27)—(29).

$$\beta = \begin{cases} 0, \text{ïðè } r^* < r_{\min} \\ \frac{1}{2}(\alpha_1 - \alpha_0) + \frac{\sqrt{\pi}}{2\sqrt{2}} R\left(\hat{O}(\mathrm{R}) + \hat{O}\left(\sqrt{\ln\frac{1}{\alpha_0}}\right)\right) + \frac{\left(r^* - r_{\min}\right)}{\left(r_{\max} - r_{\min}\right)} * \alpha_0, \text{ ïðè } r_{\min} \le r^* \le \tilde{r} \\ 1 - \left(\frac{1}{2}(\alpha_1 - \alpha_0) - \frac{\sqrt{\pi}}{2\sqrt{2}} R\left(\hat{O}(\mathrm{R}) - \hat{O}\left(\sqrt{\ln\frac{1}{\alpha_0}}\right)\right) + \frac{\left(r_{\max} - r^*\right)}{\left(r_{\max} - r_{\min}\right)} * \alpha_0\right), \text{ïðè } \tilde{r} < r^* \le r_{\max} \\ 1, \text{ ïðè } r^* > r_{\max} \end{cases} \tag{30}$$

where

$$\alpha_0 = \begin{cases} e^{-\frac{1}{2}\frac{(\tilde{r} - r_{\min})^2}{(r_{\max} - r_{\min})^2}}, \text{ ïðè } r_{\min} \le r^* \le \tilde{r} \\ e^{-\frac{1}{2}\frac{(r_{\max} - \tilde{r})^2}{(r_{\max} - r_{\min})^2}}, \text{ ïðè } \tilde{r} < r^* \le r_{\max} \end{cases} \tag{31}$$

Optimization problem consists of tasks (3), (27), (29) — (31).

The dual optimization problem

It is necessary to determine the structure of the portfolio, which will provide a minimum level of risk for a given level of profitability of the portfolio.

Obtain the following optimization problem:

$$\min \beta(x), \quad \tilde{r} = \sum_{i=1}^{N} x_i \tilde{r}_i \ge r_{zad} = \mathrm{r}^*, \sum_{i=1}^{N} x_i = 1, \ 0 \le x_i \le 1, \ i = \overline{1, N}, \tag{32}$$

where r and β is determined by the used membership function.

Consider building of optimization problem with using the triangular MF.

It is necessary to solve optimization problem (32) where $\beta(x)$ is determined from the formula (4), (5).

Description of the algorithm of FGMDH

Let's give a brief description of the algorithm.

1. Selection of the overall model view, which will describe the required dependence.
2. Selection of external optimality criteria and freedom of choice.
3. Selection of general form of the support function.
4. Set the counter to zero for the number of models k and the number of series r.
5. Generate a new partial model. Determine the values of the main criteria on it. Assign k = k +1.
6. If $k \geq C_F^2$, than k = 0, r = r + 1. Construct an average criterion of models $N(r)$. If r = 1, then go to step 5, otherwise - to step 7.
7. If $|N(r) - N(r)| \leq \varepsilon$, than go to step 8, otherwise we select the best F models according to the external criteria and go to step 5.
8. Choose the best model from F models by using the regularization criteria. Restoring the analytical form of the best model by using Gödel numbering.

Analysis of the results

The profitableness of leading companies in the period from 03.09.2013 to 17.01.2014 was used as the input data. The companies: Canon Inc. (CAJ), McDonald's Corporation (MCD), PepsiCo, Inc (PEP), The Procter & Gamble Company (PG) , SAP AG (SAP). The corresponding data is presented in the Table 1:

Table 1. The profitableness, %

Companies / Dates	CAJ	MCD	PEP	PG	SAP
06.09.13	0,510	-1,841	1,172	0,772	2,692
13.09.13	-0,880	-0,933	-1,184	-1,139	-0,945
20.09.13	0,990	0,829	-0,889	0,961	-1,509
27.09.13	1,110	0,164	1,012	2,611	-0,582
04.10.13	0,060	1,569	-0,151	-0,569	0,649
11.10.13	-0,410	-0,403	-2,239	-3,741	-3,190
18.10.13	-1,230	-0,507	-2,368	-0,851	-0,477
25.10.13	2,300	-0,201	-1,190	-1,304	-3,979
01.11.13	2,620	-1,961	0,059	0,185	2,494
08.11.13	0,190	0,308	-1,754	-1,451	-0,879
15.11.13	-3,600	0,175	-0,679	-3,136	-1,675
22.11.13	-0,180	-0,635	0,140	-0,449	-0,329
29.11.13	-1,830	1,567	1,066	1,393	-0,510

06.12.13	1,950	-0,300	0,657	-1,416	-0,636
13.12.13	1,650	1,337	2,128	2,843	1,566
20.12.13	-0,060	-1,111	-1,000	-0,184	-2,247
27.12.13	1,560	-0,633	-1,038	-0,861	-1,132
03.01.14	0,880	0,484	0,808	1,890	2,655
10.01.14	1,770	0,052	-1,483	0,422	1,042
17.01.14	**-1,270**	**-0,105**	**0,206**	**0,162**	**0,843**

For forecasting we used the Fuzzy GMDH method with triangular membership functions, linear partial descriptions, training sample of 70%, forecasting for 1 step. The next profitableness to date 17.01.2014 values was gotten (Table 2):

Table 2. The profitableness to date 17.01.2014, %

Companies	Profitableness				MAPE test sample	MSE test sample
	Real value	Low bound	Forecasted value	Upper bound		
CAJ	-1,270	-1,484	-1,246	-1,008	2,2068	0,0295
MCD	-0,105	-0,347	-0,118	0,111	2,5943	0,0091
PEP	0,206	0,001	0,242	0,483	3,0179	0,0177
PG	0,162	0,041	0,170	0,299	1,6251	0,0197
SAP	0,843	0,675	0,867	1,059	2,3065	0,0164

Thus, as the result of application of FGMDH the shares profitableness values were forecasted to the end of 20-th week (17.01.2014):

- Profitableness of CAJ shares lies in the calculated corridor [-1,484; -1,008], the expected value is 1,246%;
- Profitableness of MCD shares lies in the calculated corridor [-0,347; 0,111], the expected value is 0,1179%;
- Profitableness of PEP shares lies in the calculated corridor [0,001; 0,483], the expected value is 0,242%;
- Profitableness of PG shares lies in the calculated corridor [0,041; 0,299], the expected value is 0,17%;
- Profitableness of SAP shares lies in the calculated corridor [0,675; 1,059], the expected value is 0,867%.

In this way the portfolio optimization system stops to be dependent on factor of expert subjectivity. Besides, we can get data for this method automatically, without expert's estimates.

Let the critical profitableness level set by 0,7 %. Varying the risk level we obtain the following results at the end of 2-th week (17.01.2014) for triangular MF. The results are presented in the Tables 3, 4 and the Figure 4:

Table 3. Distribution of components of the optimal portfolio for triangular MF with critical level r *=0,7 %

CAJ	MCD	PEP	PG	SAP
0,05482	**0,00196**	**0,0027**	**0,00234**	**0,93818**
0,06145	0,00113	0,00606	0,0039	0,92746
0,0698	0,00577	0,00235	0,00219	0,91989
0,06871	0,00228	0,0057	0,00244	0,92087
0,07567	0,00569	0,00106	0,00094	0,91664
0,07553	0,00002	0,0029	0,00208	0,91947
0,06774	0,00121	0,006	0,00234	0,92271
0,0764	0,001	0,00612	0,00464	0,91184
0,09072	0,00849	0,00655	0,0039	0,89034

Table 4. Parameters of the optimal portfolio for triangular MF with critical level r *=0,7 %

Low bound	Expected profitableness	Upper bound	Risk level
0,55133	**0,74591**	0,94049	**0,2**
0,53462	0,72954	0,92446	0,25
0,51544	0,71084	0,90624	0,3
0,51894	0,71431	0,90968	0,35
0,5045	0,70018	0,89587	0,4
0,50877	0,70425	0,89973	0,45
0,522	0,71731	0,91262	0,5
0,50197	0,69752	0,89308	0,55
0,46358	0,66014	0,8567	0,6

As we can see on Figure 4 the dependence profitableness - risk has descending type, the greater risk the lesser is profitableness opposite from classical probabilistic methods. It may be explained so that at fuzzy approach by risk is meant the situation when the expected profitableness happens to be less than the given criteria level. When the expected profitableness decreases, the risk grows.

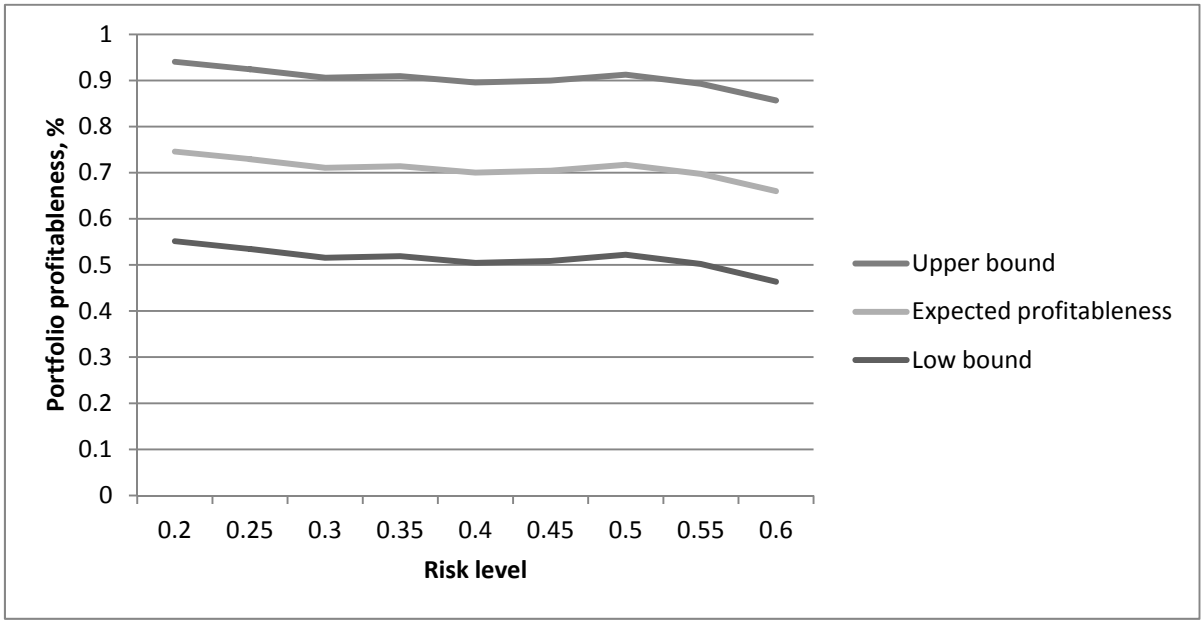

Figure 4. Dependence of expected portfolio profitableness on risk level for triangular MF

The profitableness of the real portfolio is 0,7056 %.This value falls in results calculated corridor of profitableness [0,5346, 0,7295, 0,9245], indicating the highs quality of the forecast.

Now consider the same portfolio using bell-shaped MF (Tables 5, 6, Figure 5).

Table 5. Distribution of components of the optimal portfolio for bell-shaped MF with critical level r *=0,7 %

CAJ	MCD	PEP	PG	SAP
0,00129	**0,0026**	**0,00279**	**0,00316**	**0,99016**
0,00264	0,00249	0,0028	0,0037	0,98837
0,00249	0,00268	0,00246	0,00238	0,98999
0,00209	0,00148	0,00039	0,00024	0,9958
0,00102	0,00105	0,0021	0,00222	0,99361
0,00425	0,00325	0,00343	0,0032	0,98587
0,00128	0,00125	0,00207	0,002	0,9934
0,00084	0,0022	0,0018	0,00163	0,99353
0,00165	0,00105	0,00198	0,00137	0,99395

Table 6. Parameters of the optimal portfolio for bell-shaped MF with critical level r *=0,7 %

Low bound	Expected profitableness	Upper bound	Risk level
0,66568	**0,85777**	1,04986	**0,2**
0,66252	0,85464	1,04676	0,25
0,66372	0,8559	1,04808	0,3
0,6612	0,85335	1,04551	0,35
0,6594	0,85145	1,0435	0,4
0,65816	0,85044	1,04272	0,45
0,63574	0,82782	1,0199	0,5
0,62921	0,82131	1,01341	0,55
0,59079	0,78291	0,97504	0,6

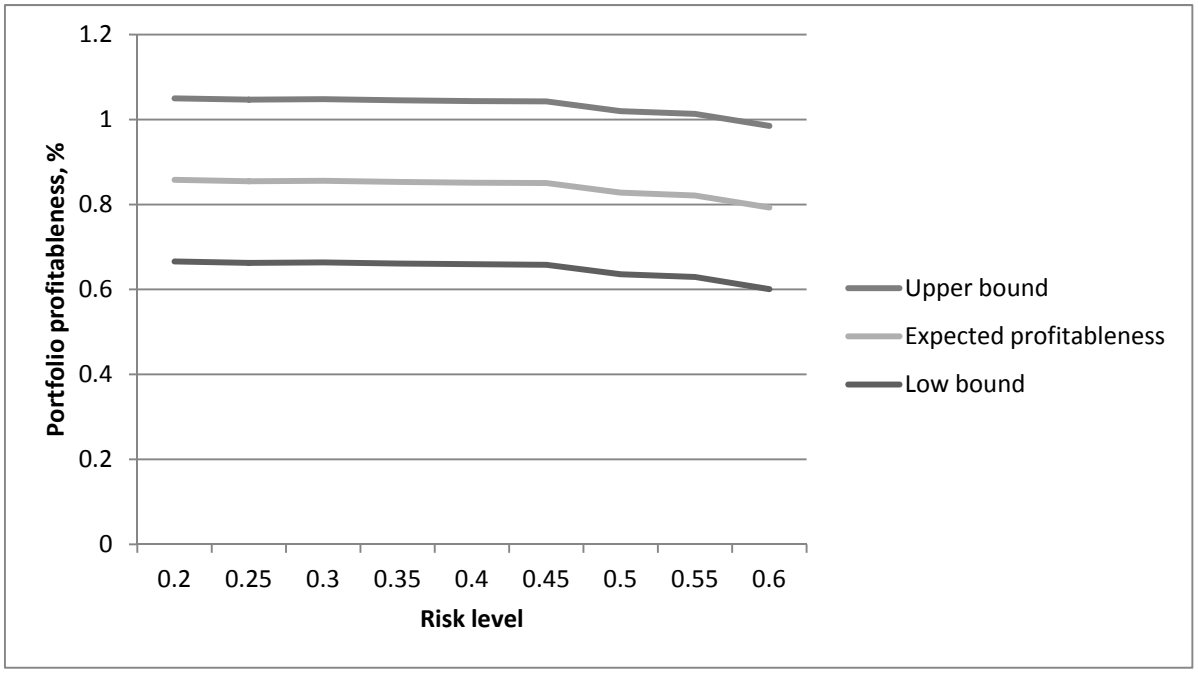

Figure 5. Dependence of expected portfolio profitableness on risk level for bell-shaped MF

The profitableness of the real portfolio is 0,8339 %. This value falls in results calculated corridor of profitableness [0,6657; 0,8578; 1,0499].

Now consider the same portfolio using Gaussian MF (Tables 7, 8, Figure 6).

Table 7. Distribution of components of the optimal portfolio for Gaussian MF with critical level r *= 0,7 %

CAJ	MCD	PEP	PG	SAP
0,0028	**0,00277**	**0,00221**	**0,0021**	**0,99012**
0,0009	0,00126	0,00153	0,00162	0,99469
0,00028	0,00189	0,00232	0,00213	0,99338
0,00193	0,00243	0,00284	0,00278	0,99002
0,00144	0,00096	0,00088	0,00138	0,99534
0,00083	0,001	0,00225	0,00144	0,99448
0,00223	0,0024	0,003	0,00209	0,99028
0,0013	0,00124	0,00129	0,0019	0,99427
0,00261	0,00191	0,00204	0,00239	0,99105

Table 8. Parameters of the optimal portfolio for Gaussian MF with critical level r *= 0,7 %

Low bound	Expected profitableness	Upper bound	Risk level
0,6833	**0,87551**	1,06772	**0,2**
0,66972	0,86178	1,05384	0,25
0,66955	0,86161	1,05368	0,3
0,66468	0,85682	1,04896	0,35
0,64944	0,8415	1,03356	0,4
0,65975	0,85185	1,04394	0,45
0,63439	0,8266	1,0188	0,5
0,63184	0,82389	1,01594	0,55
0,62452	0,81666	1,0088	0,6

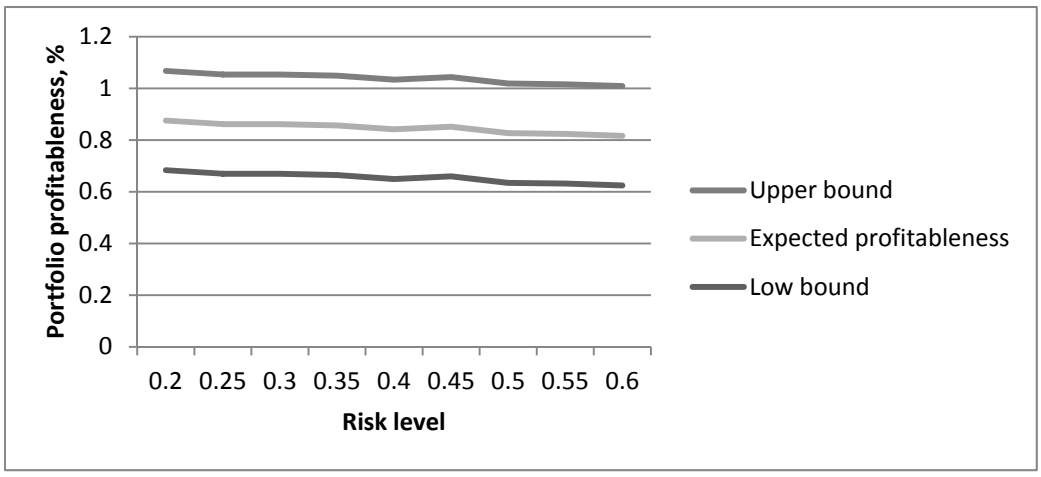

Figure 6. Dependence of expected portfolio profitableness on risk level for Gaussian MF

The profitableness of the real portfolio is 0,8316%. This value falls in results calculated corridor of profitableness [0,6833; 0,8756; 1,0677].

In the above results the optimal portfolio corresponds to the first row of tables. As can be seen from these graphs, the profitableness obtained by using Gaussian and bell-shaped MF is higher than the profitableness obtained using triangular MF. The reason is the looks of used curves. The bell-shaped and Gaussian function is more convex, so an area of inefficient assets is bigger, and the risk of getting into this area is higher.

The optimal portfolio obtained with different MF actually have the same structure, the main part falls on the company SAP, due to high rates of return compared to other companies.

Let's consider the results obtained by solving the dual problem using triangular MF. In this case, the investor sets the rate of return, and the problem is to minimize the risk.

The optimal portfolio is listed in Tables 9, 10, Figure 7:

Table 9. Distribution of components of the optimal portfolio (dual task)

CAJ	MCD	PEP	PG	SAP
0,01627	0,02083	0,02226	0,02231	0,91833
0,01112	0,02085	0,02391	0,02383	0,92029
0,00333	0,01992	0,02517	0,02476	0,92682
0,0021	0,01579	0,02457	0,02344	0,9341
0,00004	0,00921	0,02423	0,02135	0,94517
0,00224	0,00144	0,01825	0,01095	0,96712
0,00044	0,00682	0,02508	0,02058	0,94708
0,0011	0,00917	0,02448	0,02039	0,94486
0,00294	0,01206	0,02533	0,02154	0,93813

Table 10. Parameters of the optimal portfolio (dual task)

Low bound	Expected profitableness	Upper bound	Risk level	Critical rate of return
0,58944	0,78264	0,97584	0,00025	0,6
0,59846	0,79141	0,98437	0,01468	0,65
0,61478	0,80735	0,99991	0,04973	0,7
0,6229	0,81531	1,00772	0,13347	0,75
0,63606	0,82822	1,02037	0,26399	0,8
0,64945	0,84181	1,03417	0,49937	0,85
0,63712	0,82933	1,02153	0,72631	0,86
0,63382	0,82612	1,01843	0,8333	0,87
0,62559	0,81805	1,01052	0,91214	0,88

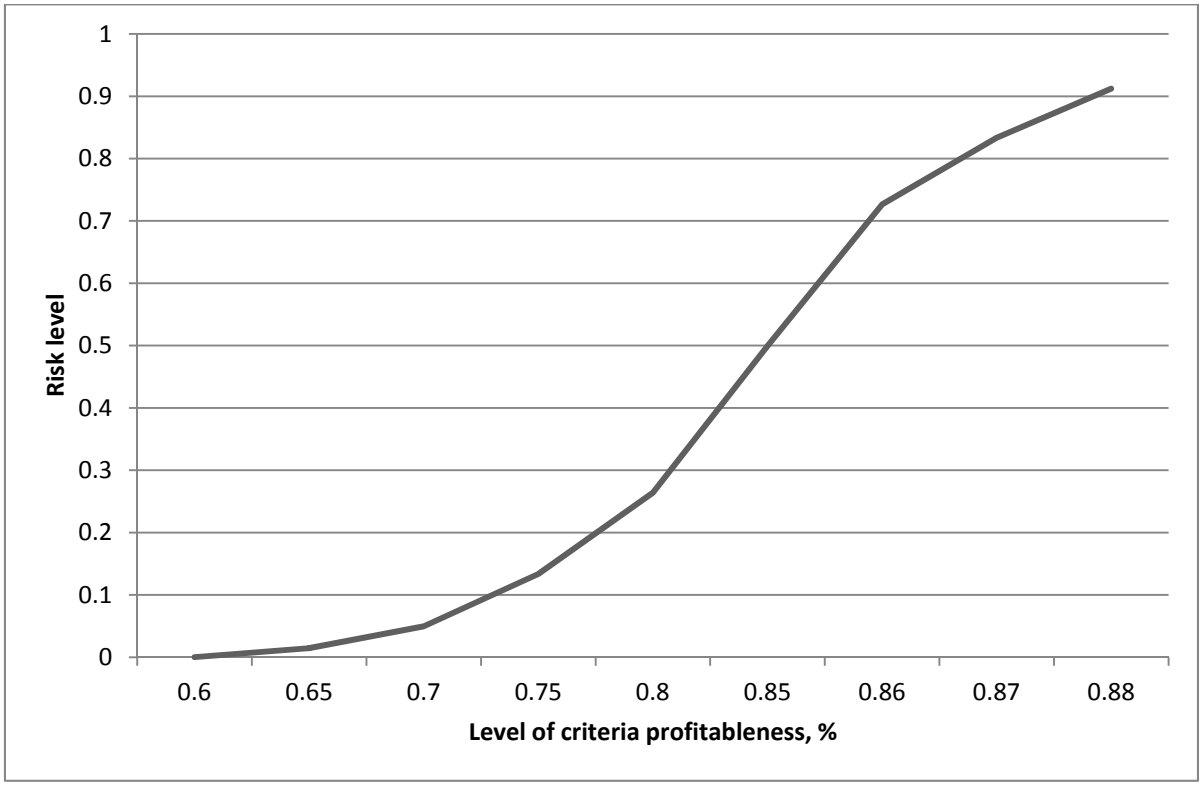

Figure 7. Dependence of the risk level on a given critical return

From these results we can see that the dependence risk - given critical level of profitability takes a growing character, because the growth of the critical profitability increases the probability that the expected return will be lower than a given critical value.

Conclusion

The problem of optimization the investment portfolio under uncertainty is considered in this paper. Particular we use the fuzzy-set approach for solving the direct and dual optimization problem. In the direct problem we used triangular, bell-shaped and Gaussian membership functions. The results of solving the tasks were presented. The optimal portfolio for the five assets was constructed. We got the input to the system by using FGMDH.

As a result of this research we obtained based on fuzzy set-approach mathematical model for the structure of the optimal investment portfolio, devoid of most shortcomings of classical probabilistic models.

- From the results for the direct problem we see that the dependence profitableness - risk has descending type, the greater risk the lesser is profitableness opposite from classical probabilistic methods. It may be explained so that at fuzzy approach by risk is meant the situation when the expected profitableness happens to be less than the given criteria level. When the expected profitableness decreases, the risk grows.
- The profitableness obtained by using Gaussian and bell-shaped MF is higher than the profitableness obtained by using triangular MF. The reason is the looks of used curves.
- The dependence risk - given critical level of profitability takes a growing character, because the growth of the critical profitability increases the probability that the expected return will be lower than a given critical value.

Thus, we create a system that not only automates the search for the optimal portfolio, but also provides a flexible and effective management of portfolio investments.

In future studies planned to consider the problem of optimizing the average return of the portfolio over a given period of time.

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SOME APPROACHES TO THE DEVELOPMENT OF ANALYTICAL MODEL FOR THE RESEARCH OF THE TELECOMMUNICATION TECHNOLOGIES' DEVELOPMENT PROCESS

Galina Gayvoronska, Petr Yatsuk

***Abstract**: The paper is devoted to the problem of the telecommunication technologies' implementation strategy's choice at the cost minimization. Some aspects of the model, displaying the new technologies' implementation process in the telecommunication networks, are researched. An approach to the realization of the value engineering of the network development's costs at the implementation of advanced telecommunication technologies is developed. This approach can be used for the techno-economic evaluation of the network development's options at the transition to the new technologies and allows the designer to select the optimal strategy and time stages of these technologies implementation.*

***Keywords**: telecommunication technology, telecommunication network, development process, life cycle, implementation, modeling, function.*

***ACM Classification Keywords**: B.4 Input/Output and Data Communications, C.2 Computer-Communication Networks, I.6 Simulation and Modeling.*

Introduction

Telecommunication technologies' development process is being represented by sophisticated dependences. Some aspects of their research are given in professor Sokolov's works, particularly quite big attention to this question is paid in his monograph [Sokolov, 2004]. Various aspects of new technologies' implementation to existing networks are examined in several works particularly this problem is research subject of the largest scientists: N.D. Kondratieff, I. Schumpeter, S. Y. Glazyev. Their results indicate the interrelation of telecommunication technologies' (TT) cyclic development and rises/recessions in the countries development. That has a decisive influence on the country competitiveness and its place on the political world stage. Telecommunication technologies represent area where appearance of new information-communication services (ICS) leads to the rapid growth of social development processes. Possibility of TT development process's modeling and accounting of this process change's features will allow adequately assessment of new technologies' potential, choice of the most efficient time and way of their implementation, risk evaluation at the investments, etc.

Laws of various development processes represent research object of specialists in various subject areas. Classification and modeling of these processes make complex engineering-mathematical problem. In order to research telecommunication technologies' development process (TTDP) authors proposed a mathematical apparatus of population dynamics in [Gayvoronska et al., 2013 (1) and 2014 (1)]. Classic works in this area belong to V. Volterra [Volterra, 1931] and P. Verhulst [Verhulst, 1838]. Mathematical development of this apparatus is given in the works of G. Riznichenko [Riznichenko, 2011], A. Rubin [Riznichenko & Rubin, 1993] and A. Bazykin [Bazykin, 1985]. Recent years some scientist have handled this mathematical apparatus in order

to research the life cycle of technologies in various areas such as railways development [Andersen, 2002], cities growth [Capello & Faggian, 2002], labor markets [Chen & Watanabe, 2006], etc.

Authors of this paper also published a number of works devoted to this subject [Gayvoronska, 2005, Gayvoronska, 2006 (1), Gayvoronska, 2006 (2), Gayvoronska, 2006 (3), Gayvoronska & Somsikov, 2006, Gayvoronska & Pavlov, 2006, Gayvoronska, 2006 (4), Gayvoronska, 2007, Gayvoronska, 2012, Gayvoronska & Domaskin, 2013, Gayvoronska et al., 2013 (2), Gayvoronska et al., 2013 (3), Gayvoronska et al., 2013 (4), Gayvoronska, 2001]. This work represents several results of researches continuation in this direction.

Main Part

Statement of the Problem

Problem, considered in the paper, is research of regularities of new telecommunication technologies' implementation process into the existing telecommunication network (TN) by means of mathematical modeling. Several approaches to the TN development model's creation are offered in the paper. They are based on the usage of TT two types, which can be marked as existing TT (ETT) and new TT (NTT). Newly implemented technology can co-exist for some time with the ETT or replace it at once. The proposed model allows analysis of the costs, required for the network upgrade, depending on the NTT implementation scenario. The main purpose of the model is the definition of an optimal scenario for the new TT implementation at the cost parameters' minimization. The developed model can be used for the comparison of different new technologies' implementation scenarios and selection of the most appropriate of them by economic criteria taking into account the technical requirements and restrictions, imposed by the administration of the researched TN. In order to proceed to the stated problems it's necessary to define all their components and create corresponding mathematical abstractions [Zarubin, 2001]. Therefore it's necessary to offer a formalized description for each initial parameter used at the model development.

Researched Time Period

First of all it's necessary to decide how to display the researched time period in the model and solve it will be whether discrete or continuous. In general case, arrival of the requirements to increase the network capacity at the NTT implementation is stochastic process however, for the researched case acceptable results can be obtained with the usage of deterministic time function. The influence of stochastic requirements on the problem of network capacity's optimal extension is researched in [Knuth, 1976] where it's proved that considered stochastic processes can be replaced by equivalent deterministic queries. Network evolution's planning at the any TT implementation is performed for a limited time period.

That is, if T is the researched time period – discrete or continuous set, requirements model should represent some total and univocal correspondence $D: T \to R^{\geq 0}$. Without generality limitation let's suppose that T is number set. Modeling is carrying for the limited time period. That is, if $\underline{t}$ is some moment of the researched period and $\bar{t}$ is moment of research end, $\underline{t} \neq \bar{t}$. Herewith it should be considered that making of the decisions about new technologies' implementation can be done only at the defined moments of the researched period. Set of such time moments makes some decomposition of the actual segment $[\underline{t}, \bar{t}]$ $t \in \tau_{[\underline{t},\bar{t}]}$,

$$\tau_{[\underline{t},\bar{t}]} = \{t_k\}_{k=0}^{h} : \underline{t} = t_0 < t_1 < t_2 < \ldots < t_h = \bar{t}\ , \qquad (1)$$

where $\tau_{[\underline{t},\bar{t}]}$ is decomposition of the segment $[\underline{t}, \bar{t}]$; h is the number of decomposition points; t_k, $k = \overline{0,h}$ are the decomposition points, corresponding to the researched time moments.

Intervals between such moments can be, generally speaking, different, however in order to simplify further calculations let's consider them as equally-spaced

$$\forall k,l = \overline{1,h} \quad t_k - t_{k-1} = t_l - t_{l-1} = \frac{\bar{t} - \underline{t}}{h} = \text{const}. \tag{2}$$

That is sequence $\{t_k\}_{k=0}^{h}$ is arithmetic progression $\forall k = \overline{1,h} \quad t_k = \underline{t} + (k-1)\Delta t$, where $\Delta t = \frac{\bar{t} - \underline{t}}{h}$ is arithmetical ratio.

As it can be observed from the character of the further reasoning and next lemma's proof, this assumption doesn't limit generality.

Lemma. For each segment $[\underline{t}, \bar{t}]$ and its decomposition $\tau_{[\underline{t},\bar{t}]}$ it's possible to create equivalent, from the point of view of solved problem, decomposition $\tau^*_{[\underline{t}^*,\bar{t}^*]}$ of some other segment $[\underline{t}^*, \bar{t}^*]$, satisfying (2).

Proving. Let's suppose that all points t_k are rational numbers. If that isn't so, there is some irrational point t_k and it's possible to choose integer number arbitrary close t_k

$$\forall \varepsilon > 0 \; \exists t'_k \in \mathbb{Q} \; : |t'_k - t_k| < \varepsilon .$$

Since in any case initial measurements have some inaccuracy and result is required only with some accuracy, it's always possible to change irrational t_k to corresponding matched rational t'_k so that to don't let this influence on the modeling accuracy. All considered points t_k are rational, i.e. representable as fractions $t_k = \frac{m_k}{n_k}, m_k \in \mathbb{Z}, n_k \in \mathbb{N}$.

Let's define $\hat{n}$ as least common multiple of all denominators n_k and create new decomposition points $\hat{t}_k$ of which are defined as $\hat{t}_k = \hat{n} t_k$. Considering that points t_k set is limited and forms decomposition, as well as $\hat{n}$ nonnegativeness, $\underline{\hat{t}} \equiv \hat{t}_1 < \hat{t}_2 < \ldots < \hat{t}_h \equiv \bar{\hat{t}}$. As $\hat{n}$ is divided by any $n_k \; \forall k = \overline{1,h} \quad \hat{n} \vdots n_k$, all received new points will be integer numbers, i.e. $\forall k = \overline{1,h} \quad \hat{t}_k \in \mathbb{Z}$. Let's supplement points $\hat{t}_k$ with the rest of the integer numbers from the segment $[\bar{\hat{t}}, \underline{\hat{t}}]$, set of which is marked as $\tilde{\tau}$. Let's settle that network doesn't change in points $\tilde{\tau}$. Let's mark received decomposition $\tau^*_{[\underline{t}^*,\bar{t}^*]}$ as

$$\tau^*_{[\underline{t}^*,\bar{t}^*]} : \underline{t}^* = t^*_1 < t^*_2 < \ldots < t^*_{h^*} = \bar{t}^* . \tag{3}$$

Then for each point t_k of initial decomposition $\tau_{[\underline{t},\bar{t}]}$ there is the only corresponding point $t^*_{k^*}$ in the received decomposition. Considering numeration in (3), k^* can doesn't coincide with k, so let's define supplementary function, representing natural numbers set in itself $\eta : \mathbb{N} \to \mathbb{N}$ where $\eta(k) = k^*$.

Then let's formulate important feature of the received decomposition $\tau^*_{[\underline{t}^*,\bar{t}^*]}$: spacing between any two points $\tau_{[\underline{t},\bar{t}]}$ coincide with spacing between corresponding points $\tau^*_{[\underline{t}^*,\bar{t}^*]}$ with the accuracy up to the fixed scaling coefficient. This means that

$$\forall t_k, t_l \in \tau_{[\underline{t},\bar{t}]} \quad \exists! \, t^*_{\eta(k)}, t^*_{\eta(l)} \in \tau^*_{[\underline{t}^*,\bar{t}^*]} : |t_k - t_l| = |t^*_{\eta(k)} - t^*_{\eta(l)}| \hat{n} . \tag{4}$$

This fact together with the agreement about the network constancy at the supplementary points $\tilde{\tau}$ provides invariability of received results at the change of $\tau_{[\underline{t},\bar{t}]}$ by $\tau^{*}_{[\underline{t}^{*},\bar{t}^{*}]}$ with the accuracy up to the time-scale scaling. That finishes lemma proving. ■

Despite the constructiveness of the given proving, used procedure because of its considerable redundancy isn't well suitable for the practical usage. However, proving indicates the simplifying possibility of sophisticated mathematical structures, used at the network description, without loss of generality and accuracy. It should be noted that not quite formal character of reasoning is related only with the calculations simplifying, which doesn't carry a significant load on the scale of the solved problem.

Let's continue simplifying of arithmetic progression (1) by means $\underline{t} = 0$. This is well-founded as the model doesn't require real dates. Then $\bar{t} = h$ and sequence $\{t_k\}_{k=0}^{h}$ assumes the form $\{0,1,2,\ldots,h\}$. Let's mark so received T as $T = \{k\}_{k=0}^{h} = \{0,1,2,\ldots,h\}$. So T is the model of the researched time period.

Requirements Model

Whatever are the objectives at the network development process's modeling, mandatory element of initial data should be a demand for the network services at the each time moment. For the purpose of the determination of these requirements change's laws different mathematical models are used. Such model should uniquely identify the demand for the usage of specific purpose TT at the each time moment. Requirements, generated by the network at the new TT implementation, characterized by the number $n_i(t)$ of channels required, which are to be provided by the network, and the load intensity $\lambda_{ij}(t)$ on these channels, where $i, j \in T$; $t \in T$. Both parameters are time functions and are defined as following:

- $n_i(t)$ is number of the channels, demanded at the connection direction from the node $i \in I$ at the time $t \in T$;
- $\lambda_{ij}(t)$ is load (in Erlangs) on the link group from the node $i \in I$ to the node $j \in I$ at the time $t \in T$.

Herewith whatever is the model it can reflect reality only with some accuracy. So, let's use asymptotical marking [Brain, 1961] in order to describe real growth process of the network.

On this assumption, speaking about the requirements model and displaying the real process, let's understand asymptotically accurate estimation of the real process of the network development $D^{*}(t) = \Theta(D(t))$, which by definition means

$$\exists c_1, c_2, t_0 \in R^{+}, : \forall t \in T : t > t_0$$
$$0 \le c_1 D(t) \le D^{*}(t) \le c_2 D(t)$$

This relationship ensures that since some time point real value of the demand for the TT usage will be concluded between two limiting curves - curves of demand model. Such approach allows describing the most important from the point of view of researched problem characteristics of the process such as rate and relative value of the TT implementation's growth, extreme and excesses points, limitations and so, without digressing on the minor fluctuations of the real process.

Definition $\Theta(D(t))$ assumes that functions $D^{*}(t)$ and $D(t)$ are asymptotically nonnegative, i.e. nonnegative at the big enough values of the argument t. That corresponds to the researched process. Moreover, since functions $D^{*}(t)$ and $D(t)$ can be considered as strictly positive, parameter t_0 can be excluded from the definitions by change of the constants c_1 and c_2 so that to let inequality be true at small t too. Notation

$D^*(t) = \Theta(D(t))$ includes in itself two estimates: upper and lower. They can be distinguished by means of additional markings $O(D(t))$ and $\Omega(D(t))$ [Abramowitz & Stegun, 1965].

Let's speak that $D^*(t) = O(D(t))$ if $\exists c \in R^+, : \forall t \in T 0 \le D^*(t) \le cD(t)$ is true.

Let's understand $D^*(t) = \Omega(D(t))$ as $\exists c \in R^+, : \forall t \in T 0 \le cD(t) \le D^*(t)$.

The researched model of new telecommunications technologies implementation

Let's consider the network during the time period T = {0, 1, 2, ..., h}. At the model analysis let's assume that the link group capacity can be any positive real numeric value and their number corresponds to the network users requirements. The development model uses the irreversibility assumption, which consists in the fact that once the new TT is implemented, no further funds addition for ETT are made, and assumption that as soon as NTT becomes available, there are no restrictions on its implementation.

At the overwhelming majority of the works, devoted to TN optimization, requirements model for the network development is described by a linear time function $D(t) = b + kt, k \neq 0$, where b is shift parameter, k is angular coefficient. There is carried out economic analysis of the TT development model at the linear requirements function in [Gayvoronska, 2001, Gayvoronska & Somsikov, 2002]. But authors in [Gayvoronska & Somsikov, 2006, Gayvoronska & Domaskin, 2013] show that usage of the logistic function

$$D(t) = \Theta\left(\frac{1}{1 + a^{-t}}\right) \tag{5}$$

is more convenient to describe the developing processes at the growth limitations. Logistic function shown at the Figure 1 has an inflection point.

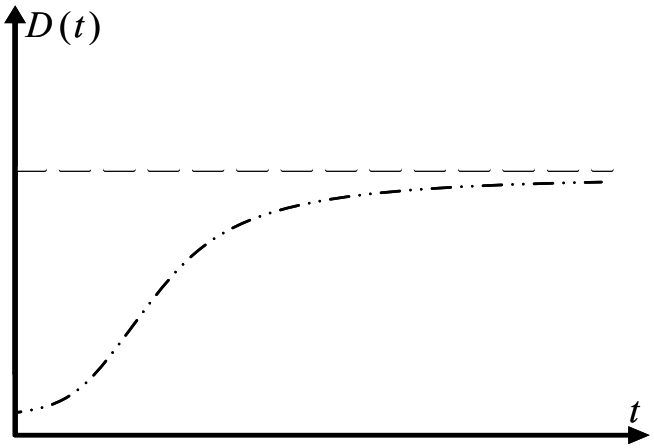

Figure 1. Logistic function

Function is convex downwards to the inflection point. This quite well characterizes the initial phase of the TT development process. Function becomes convex upwards after the inflection point. This corresponds enough to the market saturation. Another advantage of the logistic function is quite simple graph adaptation to the simulated process by usage of the coefficients and constants. Let's consider this process. For this purpose let's pass from the notations, used in (5), where coefficients impact on the function character is hidden, to the

designation $D^*(t) = D(t) \pm c, c \in \mathbb{R}$, reflecting the coincidence between the real process and the model up to the some error.

In that case logistic function generally will be defined as

$$D(t) = \frac{a}{1 + be^{-ct}}, \quad a, b, c \in \mathbb{R}.$$

Here *a* coefficient corresponds to the limit of the saturation value

$$\lim_{t \to +\infty} D(t) = \frac{a}{1 + b \lim\limits_{t \to +\infty} e^{-ct}} = a.$$

In view of the fact that

$$D(0) = \frac{a}{1 + b},$$

b coefficient is used for the description of the process initial conditions.

That is, if $\tilde{D}_0$ is initial value of the requirements and $\tilde{a}$ is the saturation value, it's enough to choose

$$\tilde{b} = \frac{\tilde{D}_0}{\tilde{a}} - 1$$

and then there will be

$$\tilde{D}(0) = \frac{\tilde{a}}{1 + \tilde{b}} = \frac{\tilde{a}}{1 + \left(\frac{\tilde{D}_0}{\tilde{a}} - 1 \right)} = \tilde{D}_0, \ \tilde{D}(t) \xrightarrow{t \to +\infty} \tilde{a}. \tag{6}$$

for the

$$\tilde{D}(t) = \frac{\tilde{a}}{1 + \tilde{b} e^{-ct}}.$$

Coefficient *c* characterizes the growth rate at the *t* increase. Using combinations of constants *a*, *b* and *c*, it's possible to receive a variety of the logistic function behaviors. This together with the asymptotic nature of its behavior makes it well suitable for these processes modeling.

If the absolute increase of the TT development indicator is proportional to the achieved development level and at the same time there are some factors, working in the opposite direction, such situation can be described by the expression $\frac{dY}{dt} = (c - \psi)Y$, where ψ is coefficient, taking into the account rate of CTT physical and mental aging. Assuming that *c* = const and $\psi = \psi_1 Y$, we obtain

$$\frac{dY}{dt} = (c - \psi_1 Y)Y = c\left[\frac{1 - \frac{Y}{X}}{\psi_1} \right] Y = c\left(1 - \frac{Y}{a} \right) Y, \tag{7}$$

where $a = \chi / \psi_1$.

At the general case *c* and ψ can be both functions of TT reached development level and time functions. At the linear character of these dependences we have

$c = c_0 + c_1 t + a_0 + a_1 Y \quad \psi = \psi_0 + \psi_1 t + b_0 + b_1 Y$, where c_0, c_1, ψ_0, ψ_1 are the coefficients, characterizing dependence of the functions χ and ψ from the time, a_0, a_1, and b_0, b_1 are the coefficients, characterizing dependence of the functions χ and ψ from the TT development level.

Substitution of (6) in (7) gives

$$\frac{dY}{dt} = [(a_1 - b_1)Y + (c_1 - \psi_1)t + (a_0 + c_0) - (b_0 + \psi_0)]Y . \quad (8)$$

Putting of $\varepsilon = a_1 - b_1$; $\xi = c_1 - \psi_1$; $\eta = (a_0 + \chi_0) - (b_0 + \psi_0)$ into the (9) leads to $\frac{dY}{dt} = \varepsilon Y^2 + \xi tY + \eta Y$. As a result of this Ricardi differential equation is obtained [Gayvoronska et al., 2014 (2)]

$$\frac{dY}{dt} + f(t)Y + \varphi(t)Y^2 = 0 ,$$

where $\varepsilon = 2$, $f(t) = -(\xi t + \eta)$; $\varphi(t) = -\xi$.

Solution of this differential equation gives

$$Y = \frac{e^{\frac{gt^2}{2}} + \eta t}{C - j\int e^{\frac{gt^2}{2}} + \eta t dt}, \quad (9)$$

where c is the constant of integration.

Depending on the specific parameters of the logistic function and the relations between them, different kinds of network development can be obtained [Gayvoronska & Somsikov, 2006]: no development; unlimited growth; unlimited decay; logistical or environmental development. Lack of TT development takes place when $\eta + \xi t + \varepsilon Y = 0$, its usage's unlimited growth meets the condition $\eta + \xi t + \varepsilon Y > 0$, its unlimited decrease is when $\eta + \xi t + \varepsilon Y < 0$. Y = const at the lack of the development, $Y = Ae^{\lambda t}$ at the unlimited growth and $Y = Ae^{-\lambda t}$, where $\lambda = \eta + \xi t + \varepsilon Y$, at the unlimited decay.

The main features of the logistics process are: positive characteristics of the process at the initial time moment; relatively fast growth of the curve at the initial stage of the process; inflection point; slow growth of the curve after the inflection point; asymptotic approximation of the process to the limit of saturation $a = \frac{\eta}{|\varepsilon|}$. Mathematical conditions of the process logistical character are $\varepsilon = 0$, $\xi = 0$, $\eta > 0$, $a > Y(0)$. The first condition, means that the absolute increase of the TT development level and reducing of unmet demands of its usage coincide in time. The second condition shows that the TT demands' reducing process is influenced by other factors. The third condition means that the TT development level at the initial time moment didn't provide all requirements, i.e. process research begins at the time of necessary TT deficit. The fourth condition determines that the saturation state exceeds the initial development level, i.e. requirement of process growth is formulated.

Logistics development is possible only if c and ψ are functions of the TT development level, i.e. $c = f(Y)$; $\psi = f(Y)$. If at least one of these functions is independent of Y and is the time function of the development process, the logistics process passes into the environmental one, where there is dying out instead of saturation at the final stage of the network development. At the usage of the environmental process authors analyzed the usage possibility of the population dynamics' mathematical apparatus for the formalization of the TT development process.

For this purpose authors formalized the concept of the kinetic curve [Gayvoronska et al., 2013 (1), Gayvoronska et al., 2014 (2)] and submitted function $Y(a,b,c;f(t))$ for the consideration. This function describes life cycle of the technology development in time. By the usage of the similar to the mentioned approach for the logistic function it's shown that by means of different values of *a*, *b* and *c* parameters and function $f(t)$ representations it's possible to construct a large family of curves, representing different variants of technologies development, namely: highly oscillatory; sufficiently smooth; with a larger or smaller number of extreme points. Such diversity of the function behavior makes it convenient to use in order to create models for various technologies' life cycle's description.

An important stage in the technology life cycle's modeling is the ability to determine the costs and profits of the network operator at the different stages of the TT development. There is graph of some TT development on the Figure 2. Line $y = D$, where *D* is a constant, corresponds to the period of technology's stable usage. For this case it's possible to determine the costs and profits of the network operator at the initial stage of TT implementation and his possible losses during the period of the technology going to the period of stable development. For this purpose let's solve the equation

$$Y(a,b,c;f(t)) = D. \tag{10}$$

According to the function graph at the Figure 2, t_1, t_2, t_3 will be the roots of the equation. Then by analogy with approach given in [Gayvoronska, 2001] it's possible to determine network operator's costs at the separate stages of the TT development.

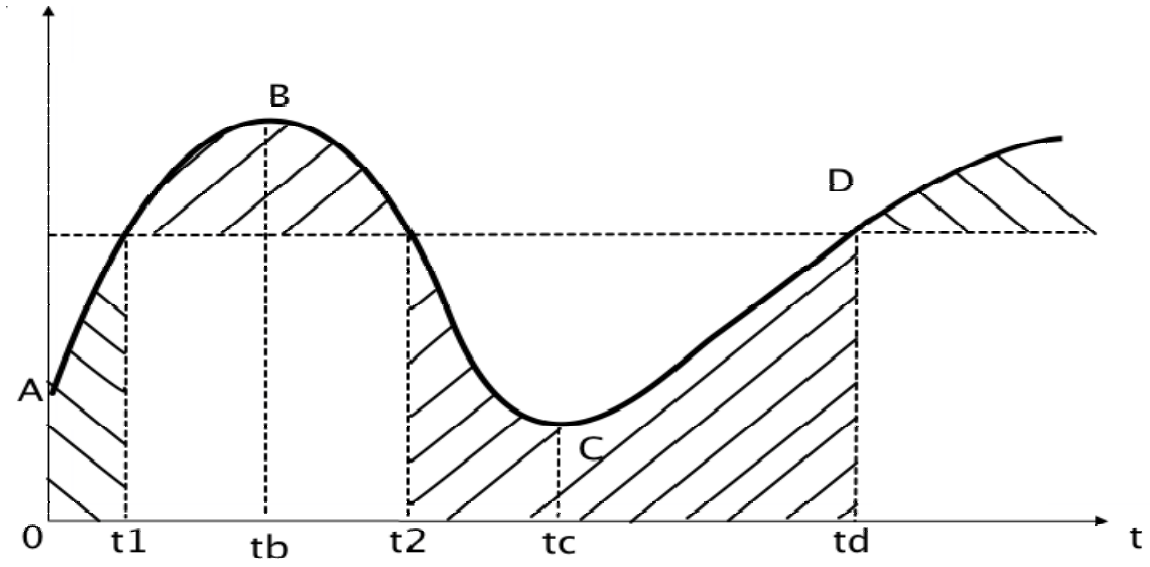

Figure 2. Estimation of the TT usage's economical aspects

Costs at the initial stage of the TT implementation can be received from the equation

$$D_{[0;t_1]} = \int_0^{t_1} Y(a,b,c;f(t))dt. \tag{11}$$

Profits at the TT rapid implementation, which are exceeding the average level,

$$D_{[t_1;t_2]} = \int_{t_1}^{t_2} Y(a,b,c;f(t))dt \ . \tag{12}$$

At the passing to the "disappointment" period and TT usage's decay operator looses make

$$D[t_2;t_d] = \int_{t_2}^{t_d} Y(a,b,c;f(t))dt \ . \tag{13}$$

Stable, rather small in comparison with the "exaggerated expectations" period, network operators' profit at the technology going out from the "disappointment" period can be determined as

$$\lim_{k\to\infty}\left(\int_{t_d}^{k} Y(a,b,c;f(t))dt\right) \tag{14}$$

in assumption about convergence of this improper integral.

Conclusion

Each technology at the moment of its analysis is at the definite point of its development. Even knowing exactly the market size for the researched technology (in monetary or other estimation), it's difficult to predict the market development for each particular technology, if it isn't already at the stage of steady decay. In order to make required decisions about the telecommunication technologies' development it's necessary to pay attention to four aspects. The first aspect understands of the technology's general life cycle. The second aspect is determination of the current stage of technology development. The third aspect is the collection and processing of statistical information concerning the technology implementation. The fourth aspect is forecasting of the concrete technology's users' number on the base of the collected statistical data.

The approach proposed in this paper can be used for modeling of any new technology's implementation into the existing telecommunication network. Direction of further research is the final formation of the analytical model for the estimation of technology's concrete development stages and decision making about the necessity and timing of its implementation. If the technology is already widely used, then the problem of its life cycle's estimation arises. All these questions should be answered by means of the researches results carried out with the usage of the proposed model.

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DIDACTIC DESIGNING OF RESOURCE SUPPORT FOR TRAINING ENVIRONMENT

Elena Vakhtina, Alexander Vostrukhin

***Abstract**: Designing of the training environment with expected qualities is considered as a multidimensional technology of Didactic design, which represents the aggregate of methodology and designing tools, and also methods and designing organization means. The functional model of the training environment development as a Didactic system and the tool of its realization – the logic-semantic model of a Didactic cycle are presented in the article. These models orient a teacher in search of new ways of solving training problems in the changing conditions of the educational practice. Didactic designing of educational resource for the interdisciplinary training module "Microprocessor technics" is offered as an example.*

The scientific novelty of the offered decision consists in allocation of the teacher activity elements in the process of designing an educational resource: constant interaction with professional environment of activity in the form of researches and (or) applied development, selection and systematic ordering of a material from various sources of the information, adaptation of this material to the learning process, creation and development the means of training.

***Keywords:** environment-based approach, didactic design, didactic system, didactic cycle, didactic multidimensional instruments, educational resource, training module, microprocessor technics, microcontroller, programming*

***ACM Classification Keywords:** J.2 Physical Sciences and Engineering – Electronics, Engineering, 1.2.6 Learning – Concept learning.*

Introduction

Educational practice for the last 15-20 years has essentially changed technically and technologically. Internet-technologies as the global information resource and communication means created unique conditions for the connection of national education systems in uniform educational space in which the concept systems of standards and technologies are formed. As the educational practice is realized in the educational environment, it is possible to affirm that this environment as the pedagogical system has stepped on the new qualitative level – information-educational. The Information-educational Environment (IEE) differs from the traditional one, first of all, by presenting new tools, formation the other space of students and teachers interaction. It is known, that this "interaction" is the subject of pedagogics as a science. The necessity in understanding the changes of pedagogical reality impels scientists to address for studying its sociocultural conditionality. It explains the increased interest of teachers, psychologists, sociologists for the training environment: factors, technologies, threats and IEE possibilities are studied.

Didactic Designing is a Systematic Approach for the Projecting of the Training Environment

So-called environment-based approach (E. Glaserfeld, J. Dewey, J. S. Manuylov, L. I. Novikova, V. A. Yavsin, etc.) [1 – 5] was developed in pedagogy. It can be considered not only as a conceptual direction but also as technology of the mediated management of the person formation and development process. It is known that the

environment, on the one hand, is an essential condition of the person development, and, on the other, is itself subject to change under the influence of human activities. Design is a special project activity, which is directed on the subject environment formation with certain functional and aesthetic qualities. The natural continuation of design development is replenishment of its basic directions: Industrial, Architectural, Landscape, Textile and others with Didactic design (D-design). There were all conditions for its occurrence: level of modern science and technics development, requirements of professional and educational societies. Vivid example of D-design establishment is formation of the educational environment within the limits of universal cultural space of the Internet. There is the integration of engineering (engineering methods of constructing and designing), system-activity (technological) approach in pedagogic and achievements of pedagogical sociology and psychology. Behaviourism (B. F. Skinner) [6], cognitive psychology (B. S. Bloom., J. Piaget, R. C. Clark) [7 – 9], social constructivism (L. S. Vygotsky, J. S. Bruner, A. S. Palincsar) [10 – 12], connectivism (G. Siemens) [13], the theory of contextual training (A. A. Verbitsky) [14], didactic multidimensional technology (V. E. Steinberg) [15], etc. can be considered as the basic theoretical and methodological harbingers of D-design.

Design in education extrapolates methods and means of design culture to all levels of vocational training with the purpose of their optimization [16]. We understand “Didactic design” as a technology of projecting the training environment (didactic environment) with the specified functional, socio-economic, ergonomic and aesthetic qualities. Didactic environment is a specially organized, aimed at the creation of a complex of didactic conditions facilitating the acquisition by the students of the certain knowledge and skills in a specific academic discipline, in which the objectives, content, methods and organizational forms of training become mobile and accessible for change (V. S. Lednev) [17]. Note that the objectives, content, methods and organizational forms of training are the elements of the Didactic system (D-system), i.e. the changes are taking place in the framework of the D-system.

V. P. Bespal□ko writes that "... everyone Didactic process has quite certain basic opportunities over quality of formation of students knowledge, skills and experience during given time" [18]. This means that if we aim to receive results of training of a required level and qualities, we should develop the D-system, which functioning will ensure the necessary orientation and intensity of pedagogical process.

Let's consider the model of D-system development (Figure 1). The process of the D-system development occurs over the spiral trajectory. There are four phases in the process: modeling, designing, constructing and operation [19, 20].

In the first phase "modeling" – on the basis of changes of conditions and factors of professional activity and occurrence of the new requirements to preparation of the specialists the changes of components of the working prototype-1 of D-system are predicted, and the model of the following prototype-2 is created [21]. In the second phase "designing" the contents and technological blocks of academic discipline (module) within the framework of the prototype-2 are developed. The third phase "constructing" provides check-approbation of the prototype-2 (the didactic project of academic discipline/module) and its correction on the basis of the received experimental data. The fourth phase "operation" consists of three stages: introductions, works and assessment of the D-system prototype-2 in educational process. It is necessary to note, that the scheme presented on the Fig.1 corresponds to functional model ADDIE (Analyze, Design, Develop, Implement, Evaluate) most popular in pedagogical design.

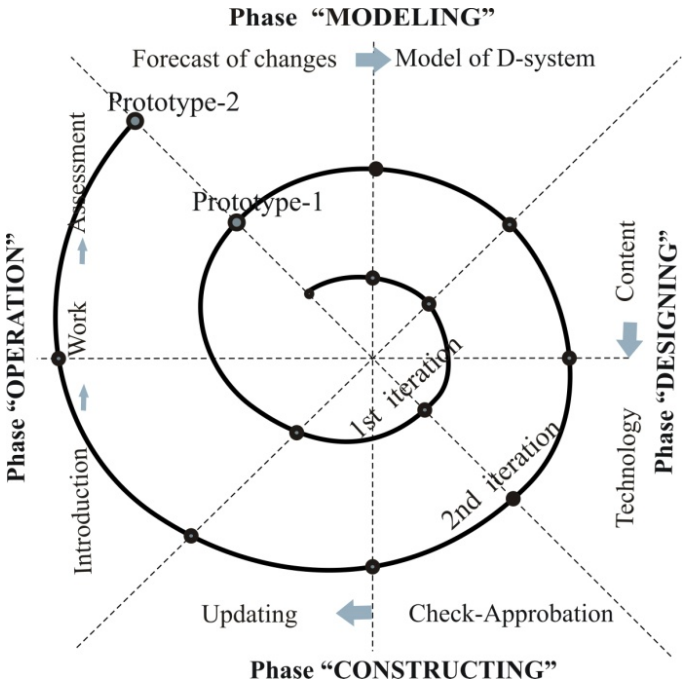

Figure 1. The spiral scheme of D-system development

The cyclic nature of the design process (analysis, forecast, project) and the cyclic functioning of the designed objects (the content of training and the technology of its mastering) determined the cyclic organization of D-design [22]. As a tool for D-design can be used the developed by us logic-semantic model of Didactic cycle (D-cycle) Figure 2. For its creation we applied the Didactic Multidimensional Instruments (V. E. Steinberg) [15].

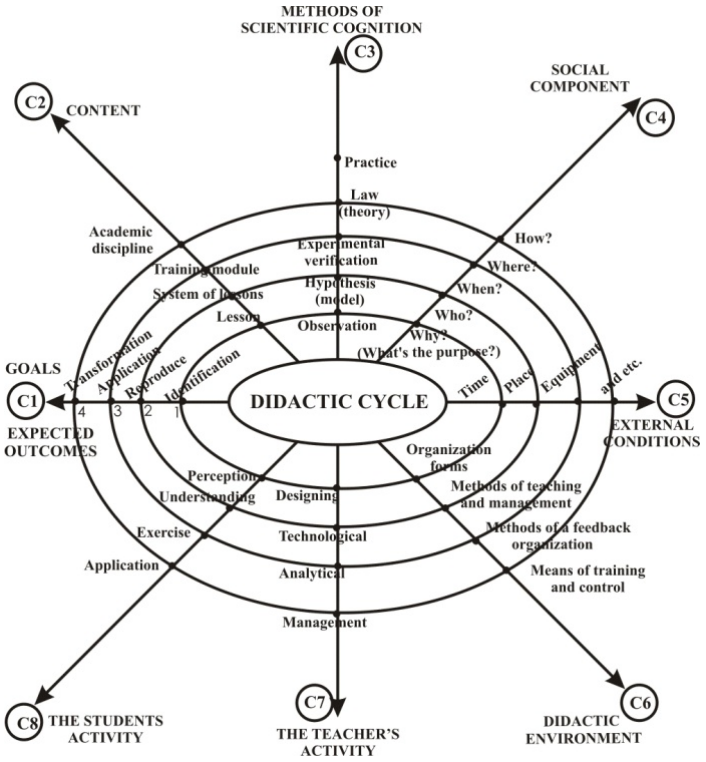

Figure 2. The logic-semantic model of D-Cycle

Under the D-cycle, we mean content-organizational unit of the educational process, preserving its essential characteristics. Depending on the "scale" in the study process of academic discipline highlight the following D-cycle: a separate lesson, the system of lessons over the topic, module, and the discipline as a whole. Since the D-cycle is the complete part of the learning process and at the same time is a fragment of cognitive activity, then it presents all components of the educational process in the appropriate "scale". From this it follows that in the basis of the model of «D-cycle», there should be objective, inherent for the cycles of different "scales" essential characteristics. To highlight them, we have combined two of the universal cycles: knowledge and management. Knowledge cycle: from the alive contemplation to the abstract thinking and from it to the practice, this defines the structure of the study process. Management cycle begins with statement of the training activity purposes and ends by the evaluation of their achievement results. As a result, we received two blocks of essential characteristics: the first is the "formation of content ", which includes the goals axis (C1), content of training (C2), methods of scientific cognition (C3), with the allocation of a social component (C4), for the harmonious coordination with the second "procedural block", which includes external conditions (C5), didactic environment (C6), the teacher's activity (C7) and the students activity (C8) Figure 2.

Designing of an Educational Resource for the training module "Microprocessor Technics"

We used the model of D-cycle as a tool for implementing the spiral scheme of D-system development on the example of an educational resource for the training module "Microprocessor Technics" [23]. This ER is a component of training environment which determines professional development of the engineer student.

We consider the training module as the functional unity of the content of training and technology of its mastering. The actuality of the module is especially high due to several reasons:

1) It is interdisciplinary and potentially innovative. Innovations in the technician and technologies are created now on an interdisciplinary basis as a result of integration of knowledge from various areas;
2) It is actually innovative. The last achievements of engineering and science are embodied in its content. Studying of this content involves using of information technologies.

However, now the experts in the field of vocational education [24, 25] mark a backlog (Educational Gap) in technologies of engineering education from a level of technologies in modern technical and information spheres of activity (including "microprocessor systems").

Phase "Modeling"

As known, modeling of the educational module on the basis of the prognostic results of training expressed as competences, is finding a solution of a "back task" in the conditions of interaction of the competency-based approach with other approaches developed in pedagogic and psychology. We will consider one of solutions of the problem. Concerning the purpose and results of training we will lean on the competency-based approach; the content of training – on the system-based approach; the organization of the training – on the technological and person-centered approaches; means of training – on the system-based and structure-based approaches.

The training purposes at the competency-based approach are set by the competences which are formed by studying of different disciplines (modules) of educational program. These competences are defined as the result of decomposition of the universal and professional competences and they are formulated in narrower terms of knowledge's, skills and experience. In other words, the disciplinary competences represent the results of training expressed through such components as knowledge's, skills and experience.

To gain the competences on the training module "Microprocessor Technics" the student should *know*:

- Appointment and scope of microprocessor devices;

- The basic types of microprocessors and architecture of computers;
- Microprocessor systems and microcontrollers;
- Programming languages the Assembler and (or) C;
- The integrated medium for creation and debugging of programs.

Should *be able:*

- To carry out the proved choice of the microprocessor (microcontroller) for the solution of an engineering problem in the field of measurement, management and automation of technological process;
- To project the microprocessor device (its hardware and software);
- To debug its work.

Should *own*:

- Skills of working out the microprocessor device for the solution of an engineering problem in the field of measurement, management and automation of technological process.

The competency-based approach orientation on the results makes comparable only qualifications, whereas the content of education including separate discipline (module) is defined by each university on its own, as Y. E. Babichev notices [26]. The competences orient a teacher on selection in the contents of discipline (module) of the practice-focused problems developing the student in the professional and social plan.

Phase "Designing"

As the integration mechanism providing transition of the content of training from a product of social experience to the personal experience, we used pedagogically designed educational resource (ER) – training-methodical and hardware-software complex (Figure 3). Training-methodical part of ER includes the textbook reflecting structure and the content of the training module [27]. Hardware-software block of ER consists of developed programs and hardware for their realizations – microcontroller test bench (laboratory) [28], allowing to develop practical skills of solution of creative engineering tasks.

Figure 3. Educational Resource for the training module "Microprocessor Technics"

About selection of the textbook content. Solving this question, we based on factors known in the pedagogics, determining the content of training: the purpose and personal activity in the training process.

The purposes of the considered educational module are described above. Each of them corresponds the block of the content. We will define the dominant purpose which will unite these blocks. As in the future almost all technical devices will work under control of the microprocessors, which work on the basis of a software, so it becomes a necessary part of engineering activity. However mechanical and electrical students do not have special skills in programming. Programming is often compared with art - its ability "to inhale life and intelligence into a dead semi-conductor crystal". Therefore it is necessary to study the programming first of all. The textbook, in which the questions of programming in the Assembler language of the AVR-microcontrollers of Atmel Corporation were considered, has been written for this purpose. We will explain such choice of the content.

The microcontroller (MC) of the AVR family of Atmel Corporation represents the single-crystal micro-computer with the restricted (reduced) instruction set. It is intended for management by various objects and processes. MC contains the processor, the memory, parallel and serial ports of data input-output, a set of the peripherals: timers/counters, analog-to-digital converters (ADC), pulse-width modulators (PWM), analog comparators (AC), etc. It is possible to construct on the basis of MC a multipurpose program-controlled digital system with inclusion of a minimum quantity of additional components.

According to the data of Internet quizzes (http://radioded.ru) AVR microcontrollers by Atmel Corporation are the most popular among hardware designers. By the ratio of price-efficiency-power consumption they are world leaders and industrial standard. Programming of these MC can be carried out in two languages the Assembler and C in the medium of AVR Studio, which is free and always accessible on site of Atmel Corporation (http://www.atmel.com).

There are a lot of manuals about AVR microcontrollers now where you can find examples of structures of different devices. However, the majority of them do not implement typical functions of information and measurement systems. Examples of programming of such functions, like conversion of physical properties and quantities into digital code, data input from sensors and keyboard, data output on the indicator, formation of managing signals by executive devices, etc. are carried out in the our teaching manual in order to fill this lack.

It is impossible to disagree with the opinion of the experts in the field of microprocessor technics - V. B. Brodin and A.B. Kalinin, that "the professional systems of designing should be used as training means, because the use of purely educational means deforms a designing technique and leads to necessity of the subsequent restudying". Therefore we use the Assembler language as the basic tool for the professional working out of programs. This language provides detailed elaboration at level of instructions, what allows using resources of the crystal as much as possible. The Graphic Assembler (Algorithm Builder) is adapted for MC AVR (http://www.algrom.net). The program is developed as algorithm; its logic structure becomes evident. Visibility of logic structure reduces probability of mistakes and reduces time of working out.

Phase "Constructing"

We have considered the fact that students receive a different level of education at the same content of training. A. A. Verbitsky explains it like, if the training content is defined by products of social experience, that the education content defines that level of development of the person, his subject and social competence, which is formed in the process of fulfillment of training-informative activity and can be fixed as its result at present time. In his concept of contextual training he offers at preparation of specialists "consistently model the content of

professional activity of specialists with of its subject-technological side (a subject context) and social side (a social context) in forms of students' activity" [14].

Therefore we offer to study programming in the training module on a concrete example of an automatic regulator of temperature (temperature regulator) – the microcontroller test bench. Temperature is the most often met quantity which is controlled in various technological processes. It is not of the principle difference what quantity to control. Distinction consists only in sensors of corresponding quantities and actuation mechanisms. On the basis of a temperature regulator the realization of the basic typical functions of control systems is possible: input of the information from the sensor and the keyboard, processing of the information and its output on the indicator, the control by an actuation mechanism, and fulfillment of various laws of automatic regulation.

Phase "Operation"

A student is given an engineering task – to develop the concrete device. Solving this problem he should use fundamental and applied knowledge from various adjacent areas: physics, computer science, electronics, metrology, automatics etc. Getting a practical result in the form of the working device is showing that the competences claimed by modern engineering activity are formed.

As a result of introduction of the ER "Microprocessor Technics" in the learning process of StSAU and STIS a number of measuring devices for non-electric quantities (temperature, humidity, dielectric permeability, frequency of rotation, etc), which are patented in Russia, are realized on its basis during degree designing and participation in competitions "UMNIK" and "START" (2010-2013) .

Assessment of support efficiency for training environment by means of the ER "Microprocessor Technics" were carried out over results of its work in learning process of students by criteria, selected in [22]: 1) Indicators of changes in integrative qualities of students knowledge: $К_e^{av}$ efficiency, $К_s^{av}$ system a city and $К_r^{av}$ knowledge reliability and their selective dispersion σ_e^2 , σ_s^2 and σ_r^2 ; 2) The parameter defining cognitive activity was the indicator of performance by a students' group of all learning projects during a semester $П_a$.

After the mathematical processing of the experimental data we received positive growth of relevant criteria's indicators.

Conclusion

According to the key idea of social constructivism, which lies in the fact that knowledge cannot be transferred to the student in finished form, and you can only create pedagogical conditions for their successful mastering. These conditions are shaped by the training environment, systematic designing of which is implemented by the didactic multidimensional technology. Functional model of this technology has a cyclical organization: modeling, designing, constructing and operation. The logic-semantic model of D-cycle can be used as a tool.

ER as a component of the training environment should be developed in unity of training module content and means for its mastering (studying, training, control and self-control). Only in this case, students obtain necessary and sufficient pedagogical support for their training activities.

The ER "Microprocessor Technics" developed by the authors is a system of actual content represented in the textbook in form of practice-oriented task with didactic support of solving and tools - programming environment and language, the set of programs of typical functions of information-measurement systems and microcontroller

test bench (laboratory). So, questions of innovative products development in education in frames of D-systems of new generation can be solved by means of didactic design.

In general, educational resources developed for formation of competence in the area of design and applications of microprocessor-based equipment are in demand in modern engineering education. Each of existing Russian and foreign scientific schools offers its own solution for design of resources like that. The best ones will be determined by conformity of their didactic opportunities with modern requirements of engineers' preparation and ergonomic requirements.

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SMPR TRAINING-METHODOLOGICAL SYSTEM FOR SUPPORT THE TRAINING COURSES ON DECISION-MAKING THEORY

Oleksii Voloshyn, Daniil Kovaliov

***Abstract**: The software for support the training courses on decision-making theory in the form of an educational, methodological and evaluating system is considered. The systems purposes, its design, structure and functionalities are described. The article turns attention to the latest extensions of the system, such as the rules of fuzzy inference during the process of complex user's knowledge estimation. The perspectives of future work are also discussed.*

***Keywords:** protection system, e-learning, decision-making theory, evaluation, team development.*

***ACM Classification Keywords**: D.2.13 Reusable Software - Reuse models.*

Introduction

The SMPR software system for support the training course "Systems and Methods for Decision Making", which is taught at the Cybernetics Department of the Kyiv Taras Shevchenko University for 3-year students majoring in "Computer Science" and corresponds to training aids [Voloshyn, 2001, 2006, 2010], is represented in the report.

The software development had been started in 2005-2006, the first version of SMPR-06 software system, presented at the conference MeL-2006 and published in [Voloshyn, 2007], was designed as a set of separate software modules implementing some algorithms for solving decision-making theory (DMT) tasks according to [Voloshyn, 2001, 2006]. Software modules (developed by students at laboratory classes) operated independently, were implemented in different programming languages and had arbitrary structure and visual interfaces.

Version of SMPR-08 system [Voloshyn, 2010] provided the opportunity of modules interaction through forming of uniform requirements to their software implementation realized in programming language C # using platform .NET, development frameworks MS Visual Studio and technology for team development SVN [Gamma, 2006]. More than 50 students had participated in the development of all SMPR versions. SMPR-08 system can be called "training-methodological and demonstration-testing" due its functional content. Along with the demonstration of a specific task solution DMT user could verify the solution of a task and getting a grade "correct" or "incorrect".

Student knowledge assessment function is realized in SMPR-10 (represented at MeL-2010, Kiev, 2010, published in [Voloshyn, 2012]), the system's interface is enhanced, particularly in the using of description languages – Ukrainian, Russian, English and Chinese (individual modules). SMPR-10, as the application for training aid [Voloshyn, 2010], has been used in a number of higher educational establishments of Ukraine (in particular, Kiev, Odessa, Uzhgorod, Cherkasy, Chernihiv, and others (e.g., [Bondarenko, 2011, 2012], [Solomitskyi, 2012; Gaivoronskaya, 2013]) as support for training courses in decision-making theory, using training aids [Voloshyn, 2001, 2006, 2010].

SMPR-12 version, represented in the report, can be considered as the "commercial" version of the system. Compared to SMPR-10, two main functions was added to SMPR-12: 1) student's knowledge assessment on the

entire DMT course, output in “clear” or “fuzzy” form [Voloshyn, 2010]; 2) second function is related to the protection of the system against unauthorized usage.

The authors have planned to modernize the system in the next SMPR version, by transferring it to the Internet environment; they are also planning to publish the training aid in Russian and English (and in the future - in Chinese). Ideally, SMPR software should be a part of online educational project, which is being developed in the walls of the Kiev Taras Shevchenko University, like the world-famous projects courser.org, udacity.com etc.

General information about SMPR software system

System consists of a core and a set of specialized modules, which are responsible for solution of certain class tasks. The core creates modules functioning environment with ability of solving tasks in parallel and sharing data between modules. It consists of the common interfaces, data exchange standards, boost and information systems about module.

The core comprises a buffer that is the intercommunicator between modules. Buffer can manipulate various source data, as well as the results of their processing. It is the "environment" of the system-level data, i.e. data that can be accessed by any module. At the architectural level, the buffer is represented as a special class providing the interface for data download, store and validate for interior modules. The core of the system is not specified for specific algorithms of a particular course. Specifics of a task are provided only by the set of exterior modules, which is available to be used by the core. This facility of the system core allows to use it as the basis for development of training-methodological systems for various training courses possessing structure “tasks class – their solution methods” with the ability to exchange data between classes. Structure of a module responsible for a particular class of tasks is constructed in such way that the core can automatically detect not only the presence of the module, but also some of its characteristics (period of usage, number of attempts to use, etc.). The system is designed with possible enhancement of its functionality by adding new classes of tasks and methods for solving existing tasks. A new module project implementing abstract classes inserted at the design stage is creating to extend the list of classes of tasks to be solved. The formed project is compiled into a library that is added to the plug-in folder (padding) of the system. New function will be added automatically to the main menu of the projects after the software package start-up. Adding of new tasks solution methods is implemented slightly differently. It needs familiarization with the abstract class of a specific module. Each project of a module, as well as project pattern, has a special folder containing files with tasks solution methods classes for specific modules. Adding of a new method performs as addition of a new file in the folder where method class will be implemented, then the entire project must be recompiled. Since the system consists of a core and a number of modules provided in the form of plug-ins, the presence or absence of a single module does not affect the operation of other modules of the system. The scheme of the individual modules is shown in Figure 1.

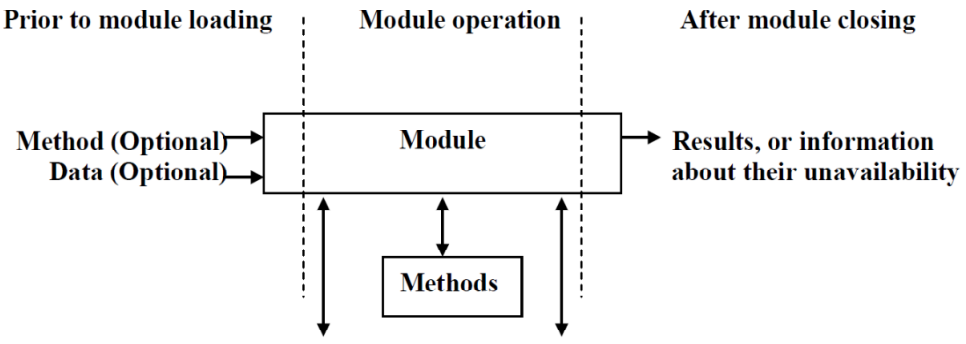

Figure 1. The scheme of the module

Each topic is presented as a separate module in a separate window. Data can be entered both from the keyboard and the program buffer. Each module has a test system designed to knowledge test. The system is laid down 8 DMT course sections (according to [Voloshyn, Maschenko, 2010]:

1. Conflicts and compromises; 2. Multi-criteria optimization; 3. Cooperative decision-making (DM); 4. Voting methods; 5. Expert evaluation, 6. DM in uncertainty conditions; 7. DM in fuzziness conditions; 8. Collective utility functions and topic "Psychological tests" [Karelin, 2007].

The authors hope that colleagues (teachers and students) from other universities (primarily in Ukraine and Russia) will use SMPR software system in the learning process, its toolkits (core) will be used to include new algorithms and improvements (redesign, treatment, substitution) which are already available in the system.

The functionality of the main window of the system

"Crown" of the program includes bookmarks: 1) "File" allowing quick program closing; 2) "Modules" allowing to start any module; 2) "Language" allowing to switch interface to one of the four languages (Ukrainian, Russian, English, Chinese); 3) "Help", which has two divisions: 3.1) "About program" calling window with full information about developers of the project and their contacts; 3.2) "Modules" opening additional menu. It is attached to each of the connected modules, contains information about usage of the module and theoretical material.

Example of operation of module “Conflicts and compromises”

Let’s consider operation and interface of the module "Conflicts and compromises" (Figure 2). Using options you can set the specification for task to be solved. Input matrix can be defined from keyboard, downloaded from clipboard, or automatically generated, if necessary. Module contains 10 methods each of them can be used. The solution is highlighted in green in the input matrix and displayed in a separate field for convenience.

Each module has a second mode - testing mode and there is an ability to choose methods for testing user's knowledge independently. To enter the answer "click" mouse pointer on the field containing the answer. Button "Check" will indicate correct result and displays the number of points earned. Then this result will be automatically stored in the core of the system for the demonstration of the level of knowledge, on user’s demand.

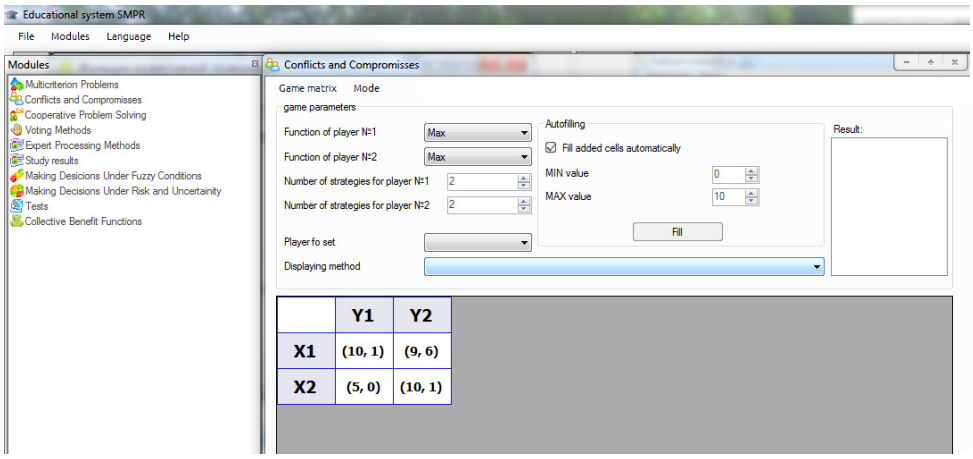

Figure 2. Structure of the module "Conflicts and compromises"

All modules feature by random data filling for quick demonstration or knowledge testing. With user-friendly interface elements you can assign your own values and immediately get a solution. As it was mentioned, each

module may take the value from the program buffer which stores an arbitrary number of values of scalar, vector, and matrix type.

In the tab "Help" there is all theoretical information (problem statement, solution methods, etc.) required for absorption of the material used in the module.

Knowledge monitoring system

Each of the modules of software system is implementing methods offering student problem statement and giving a specific task (for example, finding the optimal strategies according to some criteria). Tasks are generated automatically (to avoid repetitions), and may have different complexity (problem dimension, number of states or participants, etc.).

All information about grades obtained during testing will be stored in the system and can be obtained by user at any time in a form of window with general testing results in all course sections and recommendations in topics to be studied better. All information about grades obtained during testing stored in the system and can be obtained by the user at any time. Window will appear with general results of the course and recommendations on the materials to be studied better.

As far as different modules comprising testing differ significantly from each other in the type and complexity of tasks, mathematical model taking into account parameters tasks is used when developing the system. Along with number of correct answers the following parameters as task complexity and performance are taken into consideration. Limiting values of allowed time and acceptable number of errors will be determined according to complexity of task. To account for the present time, the job evaluation in the form of $R(t) = k(t)\,R$, where R - evaluation without the runtime, $k(t)$ - a factor which is defined as follows:

$$k(t) = \begin{cases} k_1, t < t_1 \\ -\dfrac{k_1}{t_2 - t_1} \cdot t + (k_1 + \dfrac{k_1}{t_2 - t_1} \cdot t_1), t \in [t_1, t_2] \\ 0, t > t_2 \end{cases}$$

That is, if the task was completed faster than required time t_1, student will receives the highest rating, with time increase student will lose points till time t_2, after which he will receive no points for the task. The value k_1 was set to 1, but can be increased (student motivation to perform tasks faster to get more points). Values t_1 and t_2 are determined by experts (taking into account statistics on test results) for each module of the system taking into consideration complexity of the tasks.

The level of task complexity is set by the linguistic variable LV = {very low (VL), low (L), medium (M), high (H), very high (VH)}. Parameter "number of correct answers" is set by NCA variable = {very small (VS), small (S), medium (M), high (H), very high (VH)}. For example, the above values of linguistic variables can be set by intervals between 0% to 50% with discrete 10%. In intervals values of membership functions are linear with values from [0,1].

Let each "credibility value degree level" corresponds to a certain grade, for example, "4-point scale": "unsatisfactory", "satisfactory", "good", "excellent" (as a rule, such grades correspond to the following values in 100-point scale: [0.59] [60.74] [75.89] [90,100]).

SMPR system user is offered a "standard" base of rules for tested person evaluation output, containing, for example, rules of the type - "if VL = H and NCA = S, then grade = "unsatisfactory" with respective "credibility

value degree" (determined by a given algorithm, fuzzy logic inference to be chosen by user from respective base [Zadeh, 1965; Snytyuk, 2008]).

The result of algorithm is a real number in the interval [0,1] or an integer number in the interval [0,100] - "the exact credibility value" for student knowledge grading.

Optionally, the user based on the received accurate ("clear") grade (CG) can get "fuzzy" grade (FG), having selected certain rules from a database of fuzzy inference rules (or through application of "standard" basis) of the following type: "if CG is in the range [60,65], your score = "solid three".

When using a "uniform" grading it can be possible that one student received 76 points out of 100 corresponding to the grading "good" and the other student - 74 points corresponding to the grading "satisfactory."

Despite the difference in only 2 points in the knowledge level, students get different grades, which may be a "cruel joke" in the problem in getting the scholarship. 5-point fuzzy evaluation is less sensitive to minor variations and more in line with teacher's psychology (in the opinion of one of the authors of the article - former student). Membership function (MF) shall be used for fuzzy grading of the following form (Figure 3):

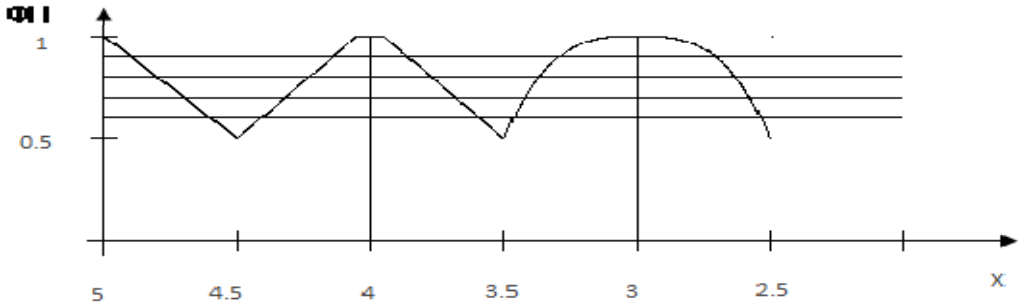

Figure 3. Membership function

MF form can be explained by the following reasons. When student receives "firm" excellent grade having solved all tasks or making one minor error, students can get "firm" good grade when have committed various errors. Fuzzy grade shell is defined as the closest to a clear grading with the level belonged to it. Depending on MF, let's attribute the grading to one of 5 levels.

Thus, a high level (from 0.8 to 1) will correspond to "firm" grading, level (0.5, 0.7) – will correspond to grading "at a stretch." Correlation estimates with an "intermediate" level (0.7, 0.8) for a particular type depends on the psychosomatic characteristics of teacher [Karelin, 2007].

In determining the total grade in the training course we may form the rules basis of grading (or using the standard one built in SMPR system) with output like "you are almost good", for "good" grading you have to study better such-and-such topic".

Protective system

Compared with the version SMPR-10, protection system limiting the possibility of unauthorized copying of software and allowing better care of users has been added to SMPR-12.

Features of the protection system consist of the fact that during the first start the program demands to send a unique identifier to the developer based on which key for the program (Figure 4) will be created. This key will be operating only with a computer that was obtained identifier.

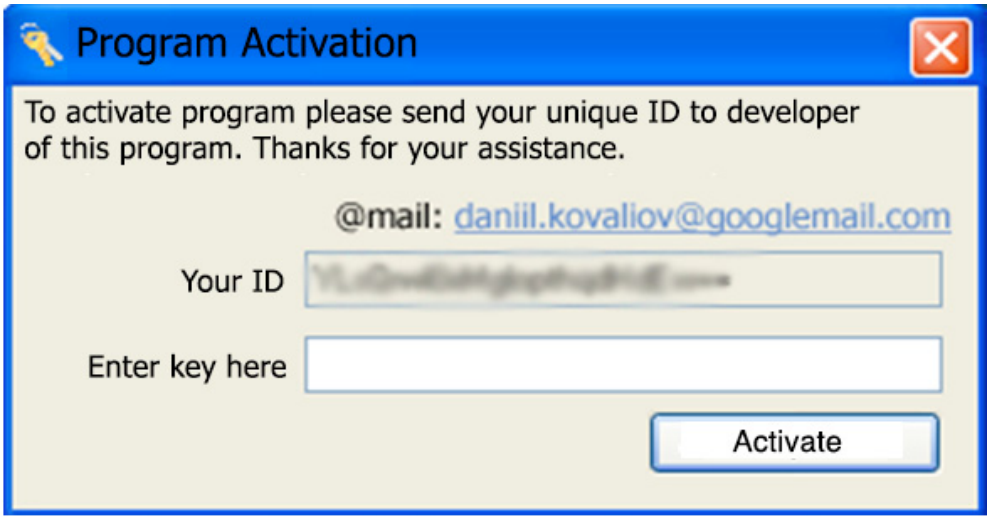

Figure 4. Protection activation system

The protection system is implemented using readout of serial number of hard disk and its encryption in unique code, which the administrator receives from user for example by mail, and, based on it, creates activation key with a special program. Thus, the administrator has a database of the program users. It allows providing updates for them and rendering assistance at any time on application of the program.

Development prospects

The concerned software is planned to be modified in such way that it will be available as an online resource for everyone. Thus, with only a link to the website, any student or teacher wishing to get acquainted with the course "The Theory of Decision Making", will be able to access the SMPR system - its theoretical, practical and test-pieces. Also, with the help of user registration system, it will be possible to perform evaluation of students remotely.

Video lectures recorded by a teacher will be added. They will explain in detail the theoretical part of the material with examples and useful information. Lectures will be subdivided into blocks of topics, each block of 4-5 videos with a total duration of about an hour: thus, mobility and accessibility of lectures be achieved to all comers.

Ideally, the program should be a part of an online educational project, which is being developed at the Kiev National Taras Shevchenko University, like the world-famous projects courser.org, udacity.com and others.

The program code and its platform for such modifications will be significantly changed, as well as web development technology must be enabled to provide GUI site for the functional part of the program.

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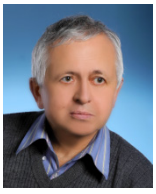

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KNOWLEDGE DEMONSTRATION AND ASSESSMENT SYSTEM "CYBER1"

Tea Munjishvili, Zurab Munjishvili

***Abstract**: The article discusses a computer-based system for knowledge demonstration and assessment „Cyber1" created by Z. Munijishvili, T. Munijishvili, and A. Meladze. The system is used at Batumi State University and Ivane Javakhishvili Tbilisi State University. The article describes the functions of the program and shows its advantages in relation to similar programs available on Georgian market. The practice of the educational institutions and our own experience shows:*

1. The conditions relevant to the compilation of e-textbooks should be created. Our school should initiate it.

2. To this end, an initiative group should be formed at the school to coordinate the creation of the e-textbooks.

3. The textbooks approved by the school should be uploaded.

Using "Cyber1", teachers enter tests and cases studies into the database for the respective subject. The teacher can create audio, video and graphic files and connect them with tests (case studies), can make edits to the database, arrange tests from simple to complex, determined the number of tests and case studies per content area, duration of the exam and passes the product to the exam center.

If the computer stops working during the exam, the last version of the test is auto-saved and time spent on the test is recorded, and the student continues the exam form the point of interruption and with the remaining time.

***Keywords**: Computer systems, Accounting, knowledge system, "Cyber1".*

Introduction

Demonstration and assessment of knowledge through a computer-based system is the only option for improving a learning process. We researched the challenges of the "Cyber1" system designed to allow demonstration and evaluation of the knowledge and skills through a computer-based system at Batumi State University (BSU) [Munjishvili & Munjishvili, 2011; Munjishvili & Munjishvili, 2012]. Authors of the program are Z. Munjishvili and T. Munjishvili.

There are sufficient number of computer-based programs for the demonstration and evaluation of knowledge available on the market. One of the examples is a computer based remote system "Moodle" developed by Microsoft Corporation. According to our information, higher education institutions in Georgia use Moodle or other locally developed programs for the assessment and evaluation of knowledge. Unfortunately, during the research we were unable to locate and collect information on the programs for knowledge demonstration and assessment developed in Georgia.

Computer systems established at Batumi State University are functionally identical to the Moodle. There are some differences (explained in Table 1).

Demonstration and evaluation of knowledge through computer-based systems is effective in combination with the other methods. Even highly sophisticated computer systems are unable to provide opportunities to demonstrate creativity.

Table 1

Name of the System	Functional Capacity
Moodle	It is necessary to train teachers to be able to create tests; If the computer stops working during the exam, the last version of the test does not get saved, only the time spent on the test is recorded (in case of browser issues); the student needs to restart the test. The system is not integrated with other components of the study process; In a standard configuration, it is not possible to type in Georgian language.
"Cyber1"	It is NOT necessary to train teachers to be able to create tests; The teachers enter tests and cases studies into the database for the respective subject. The teacher can create audio, video and graphic files and connect them with tests (case studies), can make edits to the database, arrange tests from simple to complex, determined the number of tests and case studies per content area, duration of the exam and passes the product to the exam center; If the computer stops working during the exam, the last version of the test is autosaved and time spent on the test is recorded, and the student continues the exam form the point of interruption and with the remaining time. The system is integrated with other functional blocks of the study process.

Demonstration and evaluation of knowledge through computer-based systems is one of the determinants in the assessment system. BSU is a good example for the creative use of the computer-based systems, where 60% of the student assessment relies on computer-based tests, while 40% on traditional methods of assessment. Computer-based assessment – 60%-70% - is distributed in the following way: 20%-30% two midterm exams, and 40% for the final exam. Depending on the subject, the final exam is a combination of computer-based and traditional method of assessment: usually 20% - computer-based and another 20% graded through a traditional method.

"Cyber1"

Starting from fall of 2011, BSU uses a computer system – "Cyber1" for mid-term and final exams.

Computer system – "Cyber1" uses the database of open and closed test for the exams. The tests should be relevant to the subject area and content. *Closed test* is a test, where a student has to choose one or more correct answers from N number of multiple choice answers. A test is called *open test,* where a student has to answer open-ended questions. The student may need to calculate results, construct a sentence with word forms provide figures. Sentences may include numbers assigned from the accounting system, logistical transaction and etc. It should be possible to use wrong word forms, abbreviations, different forms of the words, as well as typing in necessary alphabets.

Methodological aspects

Methodological aspects of developing the tests are discussed in respective literature thoroughly [Chelishkova, 2002].

Depending on the content area ratio of open tests may be as high as 100%; for example for subject areas as foreign languages, linguistic speech, etc.

Computer program used at BSU allows:

- To administer mid-term and final exams with large number of students in various subjects simultaneously;
- To conduct exams in a subject by student specialization;
- To select maximum three correct answers from multiple-choice question with seven options of answers;
- To write maximum 30 correct answers in open test for each question (this number may be increased in the future);
- To illustrate any test or ask a question using graphic or video representation. At the departments were international students are enrolled, audio player is used for subjects lie Georgian language vocabulary and grammar, Georgian speech and conversation culture. The student listens to the Georgian word, sentence has to select or provide a correct answer;
- To activate or deactivate the bar showing correct answer when a student responds incorrectly;
- To show warning notes when a word is spelled incorrectly or a sentence is constructed with a mistake. For example, the first type would say – you used a word that is not recognized by the system; a student used the word “analysis” instead of a word “debit”, the second type - you have not answered all questions. In the first example, the system asks the student to clarify, in the second note it reminds the students about the questions that still need to be answered. If a student provides correct answers points are accrued, if not the system suggests a correct answer;
- To type answers in Georgian or Latin alphabet;
- To administer a test in various languages simultaneously for the same subject (in Georgian, English, Turkish, etc.);
- To type word forms, incorrect forms and abbreviations in the answers;
- To evaluate the question with two correct answers with proportional or full scores;
- To assign values to correct answers in simple and complex tests;
- To formulate the test questions according the content area, discipline and specialization of study;
- To print student lists who take an exam;
- To select relevant tests for each student before beginning the administration of a test;
- To rearrange the correct answers in the multiple choice tests to eliminate the correct responses based on probability;
- To review a report at the completion of the exam;
- To renew the test database in the system;
- To minimize the test review time using the automated scoring system;
- To review student appeals simultaneously with the administration of the test through the second review;
- To record data in an electronic journal;

- To organize electronic reports according to the scores in each evaluation component, as well as final scores for a term.

2012/2013 exams were administered using a computer-based system “Cyber1” at all departments in 81 subjects. Approximately 70% of tests were open and 30% were closed (Table 2).

Table 2

№	Department	2012/2013	
		I term (80 subject)	II term (81 subject)
1	Education and Sciences	2596	1395
2	Social sciences, business and law	1228	790
3	Agrarian technologies and ecology	213	137
4	Engineering and Technology	204	77
5	Tourism	626	435
	Total	4867	2834

Audio questions were used for international students to assess knowledge of Georgian language in the following subjects: “Strategies of oral communication” and “Aspects of Communication in Georgian Language”.

Electronic system for planning and managing the learning process relies on the *Information* protection. The databases are protected at technical, programmatic and system level. Special algorithms are used to decode the information in the database.

Discussion

As a result of a universal education, modern teachers have to deal with large numbers of students, with tutorship becoming a problem due to the time frames. Increasing numbers of students have called for a likewise increase of the number of teachers.

Unfortunately, true professionals are not so numerous in any field including instruction. Meanwhile, the inefficient people stand out for their aggressive ways and tenacity. They hold offices and attract the people of the kind. On the face of it, it is a deadlock. Large numbers of students make instruction difficult and, at the same time, increase the number of teachers not all of which are good profeccionals. Therefore, instead of progress, degradation is the ultimate result. There are quite a few certified ignoramuses.

Learning and demonstration of what one knows by means of a computer calls for caution. Computer is no panacea but an element of studying and teaching. “Shota Rustaveli” State University in Batumi, Georgia, exemplifies a creative approach. Mastery of a number of subjects there is assessed by the scale of 100 points, 50 out of which are account for the computer. The final examination results are determined by computer (20 points) and a classical method – (20 points).

It’s hard to define what part the computer should play in displaying and assessing the knowledge. We believe that not even the most sophisticated computer can replace an experienced teacher. We are not sure whether the computer would be OK with Socrates and his followers?

We aim at the preservation of the universal education, higher quality thereof, dealing with a large group of students as if there were just a few of them in it, a slowdown of the influx of inefficient teachers and a creation of a comfortable environment for creative instructors and students.

An intellectual system, which would advise a student about the ways and means of making an appropriate decision, assess the obtained knowledge and, if need be, connect him/her with the lecturer is the call of the day.

The electronic systems employed in instruction make up a conglomerate used for mastering, demonstration and assessment of knowledge. Knowledge can be obtained by means of e-books, video lectures and or a combination thereof. There is no shortage of software designed for mastering, demonstration and assessment of knowledge. For instance, the Microsoft developed Moodle software for e-learning with its learning and knowledge demonstration features.

Learning by means of computer systems

In this report we are focusing on learning, namely by means of computer systems. In any syllabus, independent work makes up 60% of overall studies. A student should familiarize oneself with the learned and forthcoming materials, solve tasks, do sums and analyze the issues raised by the teacher.

To this end, a student should obtain the relevant literature in the native language. The Internet is a world library, which makes it possible to publish texts, as well as the graphic, audio and video information relevant to the individual instruction.

An e-textbook should be well-stuctured. Can the ones in all subjects be structured? There is no cut and dried answer. We asked a professor of geopolicits if a task or a test could be formulated in the way to make the appraisal of a student by his/her answers possible? In a couple of days, the professor brought a picture saying that a student was expected to answer the questions: what event does the picture depict? When did it take place? What happened next? The picture depicted crossing of the Alps by Hannibal.

The example makes it clear that merely everything can be structured and that a one can always set a task relevant to the learned material.

We believe that any issue could be depicted in the e-textbook by way of supply of textual, graphic, audio and video information.

There are various kinds of e-textbooks, all across from the most simple PDF to the more complex HTML files with the sophisticated search engines. It's the same with the video lectures: the ordinary 30-60 min. or topical 15 min. lectures, with the video embedded self-verification open and closed type tests.

The e-learning Moodle system is an instance of comprehensive approach to the problem. It involves compilation of e-textbooks and test training. As the practice has demonstrated, compilation of textbooks and creation of a test-base is a laborious task, which calls for specially trained lecturers, especially where the test and task base is concerned.

The IT Internet University [Munjishvili & Munjishvili, 2012] has found an efficient and simple way of compiling the e-textbooks. Those are created in the HTML format, with the duration of a video lecture not over 30 min. Each lecture ends with questions for self-testing. There are but few textbooks containing a combination of the textual, graphic and video information [Munjishvili & Munjishvili, 2011; Chelishkova, 2002].

Studying involves several elements: familiarization, learning, self-verification and getting clarification of incomprehensible issues.

Reading and listening is not enough. Verification of what one has learned is no less important. The instruction involves feedback. A teacher puts questions, sets tasks on a taught issue, verifies the answers, if necessary, re-

explains, points out the reasons behind a student's mistake and, finally, shows how a task should be solved or solves it himself.

Studying by means of an intellectual system will imply: a user starts studying a subject by selecting the relevant level. A subject is taught by means of e-textbook containing illustrating texts, graphics and videos. Self-verification is an integral part of learning. The system offers to describe a typical situation, which has been discussed and controls the description all along. The result of a user's action is automatically compared to the one in the base. In case of an inaccuracy, the system offers to select another way. The user can follow the system's decision-making.

Learning of a theoretical or a practical issue is a multiple process. The final stage is the appraisal during an examination.

The obtained knowledge is assessed by the relevant software, which is an integral part of the intellectual instruction system. The software contains randomly selected exercises and the answers are verified according to the teacher's tasks. There are two kinds of exercises: first - among the likely answers, a student can select more than one right answer; second – a student should enter the answers by way of book entries, calculations or simple sentences in the Georgian language. There may be several answers to a task.

A wrong answer is displayed in the knowledge base.

The is a multilevel knowledge base. In training or an examination, the teacher determines the number of levels. After a training (an examination) the user familiarizes with its process and the substantiation of the answers. According to the result, the system suggests the most acceptable learning strategy.

After acquiring knowledge and students' self – testing directly with the next teacher, extended studies of material generalization, doing exercises and sums should be accomplished through dialogue. We mainly focus on the software computer system for holding trainings. The article further refers to the computer program of "cybertesting" for exposing knowledge and its estimation system with the help of which the vision of updated education system is achieved (the author of the software package: T. Munjishvili, Z.Munjishvili).

The basis for any software computer system is the multiplicity of material, formed through software education method and tasks and exercises, reflected through it. The number of issues is determinative. Probability selection of few issues among others is implemented during the trainings and estimation. Relativity between the methods of exposing knowledge and estimation with traditional and computer programs may compose the following 1:1, 2:1, 1:2, 1:0, taking into consideration the specifics of certain subject. For example, if the general degree for the intermediate estimation is 60 points, then according to the specifics of the subject 20 points with teachers' traditional methods of estimation (essays, coursework, activities, others) and 40 points by software systems shall be determined and vice - versa.

Any problematic issue should be represented as the entire work of theoretical and practical exercises. The basis for studying theory and its estimation is testing system. As commonly known, the tests presently mean one correct answer per N conjectural answers per question. Practically the following relativity between correct and wrong answers is adopted: 1:2, or 1:3, i.e. one correct answer should be selected for 3 or 4 questions. In terms of such testing, the probability of correct answer by the student increases without deep comprehension. The testing process is complicated, if 2 or 3 correct answers should be selected among N conjectural answers and the relativity between the correct and wrong answers is the following: 1:3. The tests where the multiplicity of conjectural answers is given and the correct answers should be selected among them, is called closed types of tests. These are filed in the following way: (Figure 1).

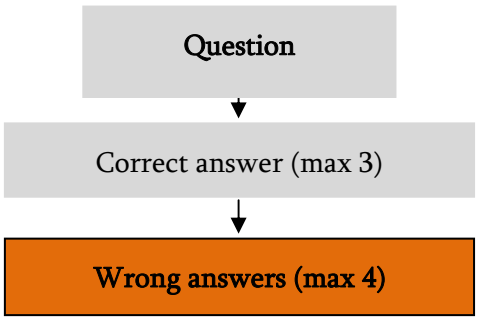

Figure 1. Closed type of tests - structure

The open type of tests is where students are required to write answers and not select them. Here, the number of answers to the task is not actually limited. The answers may be numbers, words, sentences, or their combinations.

Task

The goods have been purchased by credit at GEL 52000 at drawback. The liability should be covered in 30 days. In case of covering the debt in 10 days, the drawback composes 5 per cent. The operation is reflected through pure amount method. The enterprise applies uninterrupted method of stock registration. The buyer did not use the drawback.

Debt: Determine the prime cost of the goods purchased, determine the none-operational income, received through offered drawback, reflect credit debt formation through complicated accounting paragraph and finally reflect covering of credit debt through complicated accounting paragraph.

Solution

52000

2600

Debit 1610 52000 K 8190 2600 Credit 3110 49400

d 3110 49400 Deb. 8190 2600 kr 1210 52000

The first two answers of the task are numbers, while the third and fourth answers represent contestation of numbers and words. Some numbers here are account, while others reflect economic operations. In answers the words – debit, credit – are used in wrong meaning with different alphabetical script (Latin, Georgian).

In foreign language the common form of assignment is represented as a text. In the sentence, there are few words, missing, which should be found by the student. In such a task, there are dozens of answers. The structure of the task (open test) is the following (Figure 2):

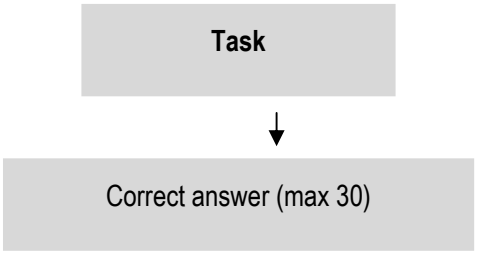

Figure 2. Task structure (open test)

The software system should acknowledge wrong versions in any case and conjugation of the used words, existing in answers, as well as syntax and semantic analysis of the sentence.

Naturally, both tests should be grouped according to the subjects and the number indicated in advance per subject should be accomplished through probability. In this case, the relativity between the number of open and closed tests are essential. The number of open tests should be preferably equal, or maximum twice as much to the closed ones. At the same time, the difference between the estimation points of the open and closed tests is also important. Practically, the point for the correct answer in terms of the closed test should be 4 times less than that for the open ones. The contents of the tests are of great importance. Surface contents of the test is discrediting for exams and education process. Both types of test should be formed of several complications. In training mode advancing from one level of complication to the upper stage should be accomplished with certain criteria.

Conclusion

The software program developed by us and put into operation for further exposure and estimation of knowledge – Cybertesting satisfies all the requirements above. Preparing and holding trainings and exams with "cybertesting" consists of the following stages:

1. Formation of database for tests and organizing dictionary;
2. Formation of assignment for training, intermediate and final test;
3. System functioning: trainings, intermediate tests, final exams;
4. Printing protocol and other information describing the proceeding of examination.

The system is multi languages. The given version includes the realized multi-languages versions – in Georgian, English, German and Russian languages. Encryption of testing and tests with special algorithm is used.

Any task may be illustrated, or published with visual pictures, graphic images or videos. The formation of colloquium and exam assignments together with the duration of exam shall be implemented by the lecturer with the given assignment. The tasks composed on the subject refer to the topics, anticipated by the syllabus. The tasks are composed according to the subjects. For example, the first topic is composed in conformity with the topic of 01001-01030 etc. Let's say, 1 simple task from the first topic should be necessarily submitted among all other tasks presented at the exam, while from the second topic – 1 simple and 2 complicated tasks, etc.

If the formed assignment is designated for the training, then the order number of training will indicate the complication degree of the tasks, designed for the training.

Upon clicking on the respective button of the test window, the system will select the number of tasks per each topic, through probability on the basis of the assignment. Then, the tasks selected from each topic are united, arranged according to probability and delivered to students with the following fields for details: Full name, academic year, group, semester, information about the examination taken: the time allocated per exam, the total number of tasks, among them simple and complicated tasks; maximum points per simple or complicated task. The exam window submits the text of the task, selected through probability, as well as the number of answers and the points attached for correct answers; after that the timer turns on.

In the tasks with open types of tests there are as many fields, as the number of answers is. The fields are enumerated according to the numbers of questions asked. The student should necessarily write the answer in the respective field of the question under the similar number. After answering all questions, the answers are fixed upon pressing the respective button, as the system analyzes the correctness of the answers given and exposes warning notifications. If the task is illustrated with a graphic image or video, then on the right side of the window,

the picture, or video will appear. By clicking on it, the image is enlarged or returns to initial sizes.

The training/exam is ended: as initiated by the student or upon giving answers to all questions or expiration of time limits. In any case, the detailed information about the exam is generated including the following: the points, received by the student, the number of correct, partially correct, or wrong answers and missing tasks, the reason for ending exam. The results of the exams shall be published on the website realized by the RIA Technologies.

Technical basis of the system: Local calculation network, internet, standard configuration computers, while general system software is supported with: WINDOWS XP and further modifications, OFFICE 2007/2010, SQL Server 2005 ,6SQL Server 2008, WINDOWS Server 2008.

This report depicts the first version of Intellectual system for the obtainment of knowledge, with the textbook given in HTML format. A topic is presented by way of a text, graphics and video materials. The textbook is placed on the FTP server. The training adapted knowledge demonstration and appraisal system we developed is an integral part of the textbook. The system is placed on SQL server and operates by means of the client-server hi-tech.

Exploitation of Cyber1 in industrial terms at Shota Rustaveli State University is implemented with multiuser mode, where client is an Access, and server is SQL Server 2008. Because of some reasons at Tbilisi Ivane Jvakhishvili State University at the facility of economics and business in the subjects of financial accounting exams are held in automatic mode – base and part of the client is Access.

Based on our experience in exploitation of Cyber1 with several modes Cyber2 was realized. Difference between Cyber1 and Cyber2 are following: ranking of the exam task by topics and sub-topics, existing of different points and ranking forms for them, number of topics and sub-topics are not determined, existing of the sophisticated mechanism of defense, existing of the semantic analyzer for sentences in Georgian language. Cyber2 is realized in two variants: multiuser mode and automatic working. Program is written on VB.NET 2010. Server in multiuser mode is SQL SERVER 2008, and in automatic Access.

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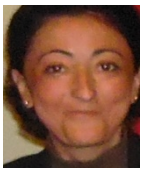

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STRESS DETECTION USING MULTIPLE BIO-SIGNALS

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***Abstract**: Organizations are becoming more and more dependent on computers in their day to day activities. Employees spend hours daily interacting with various software that is needed to finish their work. This human computer interaction (HCI) may induce stress for various reasons such as bad user interface design, slow responses from the software, and much more. Stress will affect the employee's total performance and productivity, which will have a negative impact on their teams and organization. Our purpose is to have an integrated mechanism that will detect stress during HCI. The tool will be a starting point for providing a solution that aims to reduce stress in the HCI aspects at organizations. This study investigates the usage of two bio signals (EEG, ECG,) for the detection of stress during HCI.*

***Keywords**: EEG Biometric, BioSignals, Stress, Multi modal, Human-computer interaction, BrainInformatics*

***ACM Classification Keywords**: Experimentation*

Introduction

Computer usage has become a part of our daily routine, for entertainment and web surfing, buying products, and doing homework and of course for finishing our work. Users often get stressed in their day to day dealing with their computers. During these interactions users find many problems such as slow applications, non-intuitive user interface, lack of documentation, application freezing, etc. These incidents makes the user stressed and specially if there is some time constraint to finish the task. Another interesting scenario which may induce stress is when a person is trying to hack into a computer system. Both scenarios induce stress, but for very different reasons. This study was designed to determine if stress can in fact be reliably measured using a range of biosignals (i.e. EEG, ECG, EMG, GSR, respiration), and further, whether each stress class yields a unique signature. From the biosignals, a set of features are extracted, and instantiated with values that yield a signature for a given user. These signatures were developed by exposing the users to various types of stress inducing environments. By instantiating values for features within two stress inducing scenarios relative to control conditions, the system is able to determine on a per user basis, what type of stress they are currently feeling. Integrating this ability into the IT infrastructure may provide a mechanism that will be able to maintain stress levels within tolerable limits.

The paper is divided as follows, in section two we discuss the medical aspects of the EEG signal. Methodology is discussed in section three. Section four describes the experiment. Results are discussed in section five and conclusions are presented in section six.

Medical Aspects of EEG

The brain contains about 100 billion neurons and weighs around 1.5 KG. Neurons generate electrical signals. The sum of these electrical signals generates an electric field. Fluctuations in the electric field can be measured by devices and this is what we call Electroencephalographic (EEG) [Atwood & MacKay, 1989]. The electrical currents in the brain were discovered in 1875 by an English physician Richard Caton. He observed the EEG from the exposed brains of rabbits and monkeys. In 1924 Hans Berger, a German neurologist, used his ordinary radio

equipment to amplify the brain's electrical activity measured on the human scalp [Berger, 1929]. He announced that weak electric currents generated in the brain can be recorded without opening the skull, and depicted graphically on a strip of paper. The activity that he observed changed according to the functional status of the brain, such as in sleep, anesthesia, and lack of oxygen and in certain neural diseases, such as in epilepsy [Teplan, 2002].

EEG signals are generated from activities in the neurons. When the neurons are activated, local current flows are produced [Guger et al, 2001; Coan & Allen, 2004] EEG measures mostly the currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. Differences of electrical potentials are caused by summed postsynaptic graded potentials from pyramidal cells that create electrical dipoles between soma (body of neuron) and apical dendrites (neural branches), depicted in Figure 1.

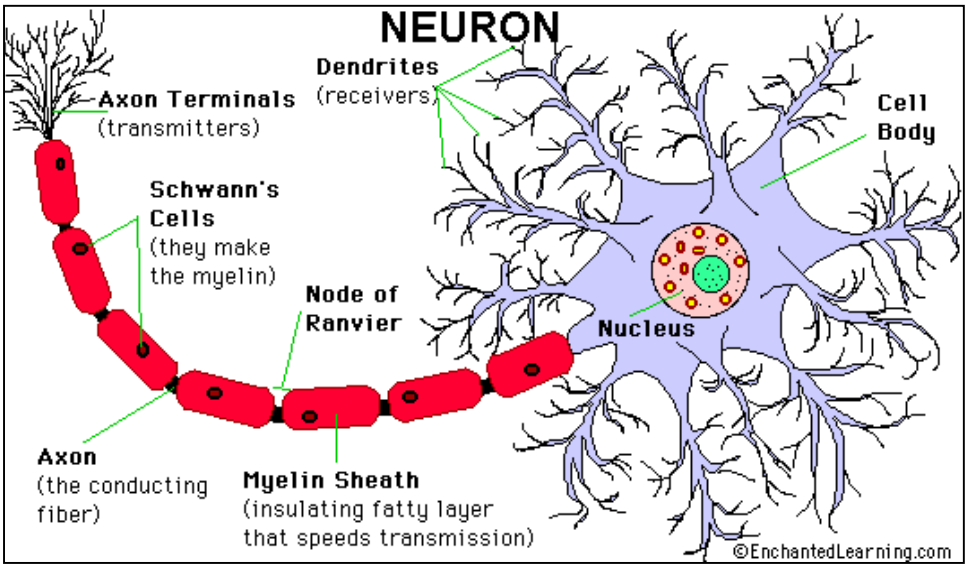

Figure 1. Basic anatomy of a typical cortical neuron, depicting the major input (dendrites), processing center (cell body), and the output region the axon [GIF, 2014]

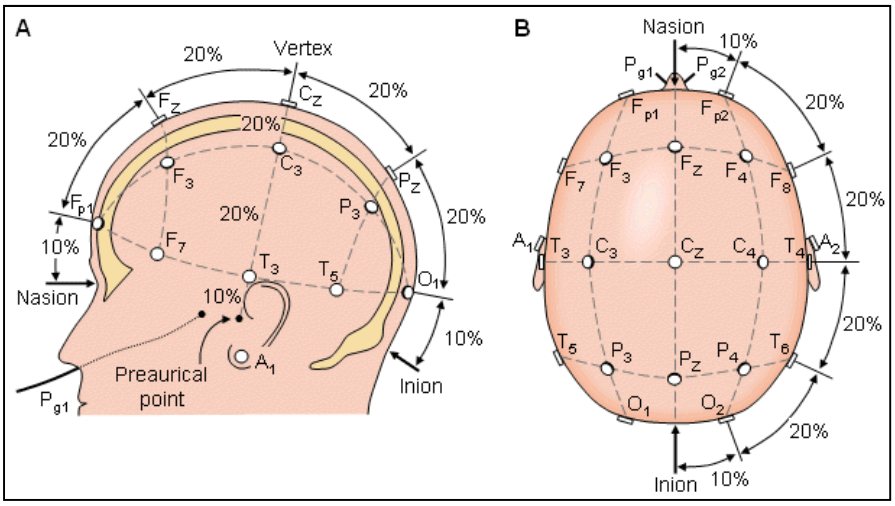

Figure 2. Electrode Placement [Malmivuo & Plonsey, 1995]

A typical EEG Signal capturing device consists of electrodes with conductive media, filters and amplifiers and analogue/digital converters. The internationally standardized 10-20 system is usually employed to record the spontaneous EEG. In this system electrodes are located on the surface of the scalp, as shown in Figure 2 A. The positions are determined as follows: Reference points are nasion, which is delves at the top of the nose, level with the eyes; and inion, which is the bony lump at the base of the skull on the midline at the back of the head. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. Three other electrodes are placed on each side equidistant from the neighboring points, as shown in Figure 2 B [Malmivuo & Plonsey, 1995].

Password Hacking Experiment

We have conducted an investigation on the neurophysiological changes that occur when a person attempts to crack a password. A password cracking scenario was provided to a small cohort of university students and while they were attempting to crack into the password, their EEG was recorded. A monetary reward was given to the fastest person to crack the password.

In this investigation, we asked volunteers (right-handed male university students, aged 20-22) to attempt to crack a password system while we acquired their EEG using the Emotiv headset [Emotiv, 2014]. The electrode positions in the 10-20 system. The subjects volunteered for this study without full knowledge of the actual purpose of the study, though they were told they would be attempting to hack into a computer system. Subjects were asked to sit in a quiet room with normal lighting. The subjects were then fitted with the Emotiv headset after assuming a comfortable position in an armchair placed in front of a laptop computer. Further, we deployed both ECG (3-lead) and a blood pulse volume electrode (placed on the left ear lobe) in order to acquire information regarding heart rate variability. We used the Vilistus system for the ECG and BVP recordings [Vilistus, 2014]. Moreover, the keystroke data was recorded for key stroke analysis.

The experiment started once all of the electrodes (EEG, ECG, and BVP) were positioned and the recording signal was stable. The subjects were asked to relax as much as possible all subjects indicated that the recording equipment was not uncomfortable and did not obstruct their hand motion during typing in any way. The experiment protocol used in this study is depicted in Table 1. Note all phases of this experiment were carried out using a standard 102-keyboard integrated into a laptop. All subjects were filmed during the experiment and all software deployed (the Emotiv TestBench and the Vilistus (v 1.2.38 professional)) and video recording were synchronized to a common clock for subsequent data processing and analysis.

Table 1. Experiment Stages

Task	Duration	Purpose
Reading	1-5 Min	Act as a baseline
Transcriptional Writing	1-5 Min	To discover the Biosignal pattern of writing
Login	-	Baseline for key strokes
Reading	1-5 Min	Return user to baseline
Password Hacking	Max 5 Min	The experiment
Authenticate	-	Baseline for key strokes

Stage 1: Reading a page of text, the user was asked to read a peace of text about body language, the user cannot move to the next stage until at least one minute elapses. The user can stay at most five minutes at this stage. If the user finished reading the article before the five, they can press next for the next stage of the experiment. If the five minutes elapses the user is advanced automatically for the next stage.

Stage 2: The subjects were asked to type in a page of text containing approximately 300 words. This text contained the same text the user read at stage 1. Again the same 1 minute and 5 minute rule described in stage 1 applies here. The screen is divided to two sections the above section show the text and below section for writing. On the top left corner two counters are shown for the user. The word per minute count, which is the user typing speed and the number of errors done. The error is typing text different than the text body. Users are encouraged to type as fast as possible while maintain low error count.

Stage 3: User login, the user is asked to login using his university username and password. This data is used as a baseline for keystroke dynamics.

S**tage 4**: Upon completion of this task, the subjects were asked to read another page of text (which was different from the original page they read) silently. The text is very generic information about how to hack into computer systems, extracted from a website. The behavior and look of stage 4 is exactly like Stage 1.

Stage 5: Once this task was completed, the subjects were then provided with the account hacking scenario. This scenario attempted to reproduce the hacking process as much as possible.

- Before the experiment start the user was presented with the legitimate user profile which includes his name, date of birth, phone number, hobbies and interests;
- The user was told that the password is a combination of the above data;
- The subjects were told that they had to try to hack a 10 character password in 5 minutes;
- Note the hints were presented before the experiment began and were not displayed during the hacking scenario;
- As the subject correctly 'hacked' elements of the password (which were all lower case letters and digits), they were displayed as asterisks '*' in there correct position (see Figure 5 for details) on the screen;
- A timer was positioned on the screen in the upper right hand corner of the screen (in the default color green);
- After the 2-minute mark, the timer digits color was changed to RED;
- The presentation of the time was meant to induce stress in the subjects during the hacking process;
- At the end of the 2-minute mark, 50% of the characters correctly 'hacked' were displayed (half + 1 if the number of hacked entries was odd);
- At the end of the next minute, 50% of the remaining correctly hacked characters were revealed, and at the last minute, all characters were displayed in addition to any newly discovered elements until the test terminated;
- This test phase of the experiment terminated when either the password has been cracked or the timer has expired.

Figure 3 shows sample of the password hacking screens.

Stage 6: the user is asked to login using the hacked username and password. If time elapsed and the user failed to hack the password the password is shown briefly and the user is asked to use them for login.

Stage 7: The subjects were then de-briefed and thanked for their participation.

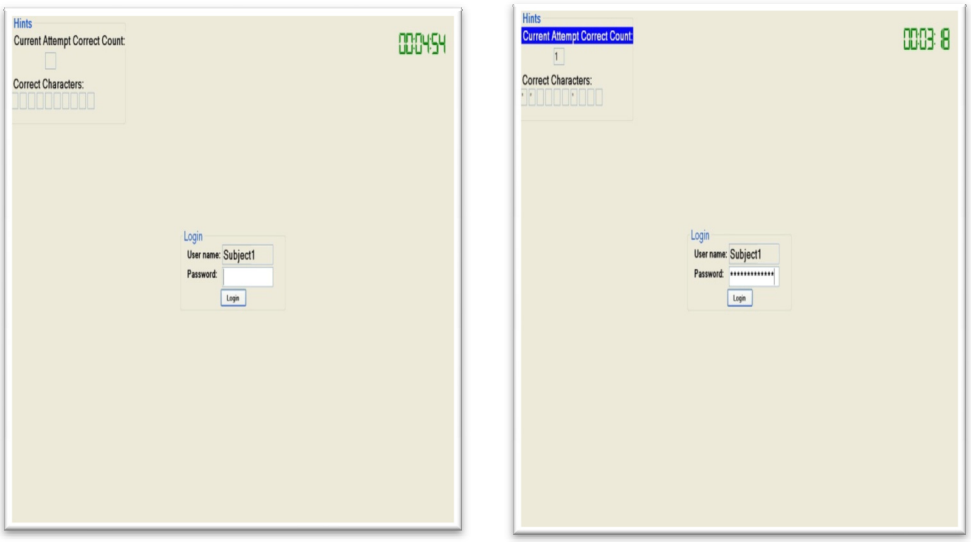

Figure 3. The left hand panel presents the hacking scenario form 6 seconds into the start of the hacking scenario. The right hand panel presents the same subject 81 seconds later, with 2 correctly guessed characters of the password

Between each stage a screen is shown for three seconds that tells the user what's the next stage and gives a user a break between tasks

Data Analysis and Results

Once the test was completed, the data was saved and analyzed off-line using EEGLab (v 9.0.4.6) for the Emotiv EEG data and Matlab (v7.0.6.324, R2008a) scripts were used for analyzing the heart rate variability data acquired from the ECG and BVP electrodes [Emotiv, 2014; EEGLAB, 2014]. The EEG data was obtained using the emotive headset, which contains 14 dry electrodes and 2 mastoid reference electrodes. The electrode positions and 10-20 system labels are depicted in Figure 4. In order to reduce motion artefacts, subjects were requested to sit as still as possible, with elbows placed firmly on the arms of the chair. The EEG was recorded and event markers were generated whenever excessive subject movement was noted. A digital recording of the experiment was also acquired to provide additional criteria for motion artefact detection to enhance the quality of the data. In addition, the BVP and ECG were utilized to assist in motion artefact, detection, and the video recording assisted in eye blink detection and synchronization as well.

Briefly, the EEG data was collected at 128 Hz with mastoid referencing in EDF (European Data Format) format, which can be directly imported into EEGLab (which runs within Matlab). A channel location file was generated which corresponded to the electrode layout for the Emotiv headset, and care was taken to ensure that the electrodes were positioned at the same positions across all subjects.

The first processing stage requires that markers are placed in the data indicating the start, termination point, and the phase boundaries. All recording components were synchronised to a digital clock and audio data was also deployed in order to indicate boundary points. Eyeblinks can be an effective means of placing timer marks in the data – they can be caught on camera as well and serve as useful and frequent time event markers. Timing (event markers) were placed in the datasets (note all recoding modalities were acquired at the same sampling rate of 128 Hz) for subsequent analysis. In the next phase, data cleansing was required in the form of artefact removal. The data was first examined for gross artefact detection manually – any sections of the recording that contained significant artefacts were rejected. All rejected segments were removed from the data and the 'cleansed' data was utilized for further processing.

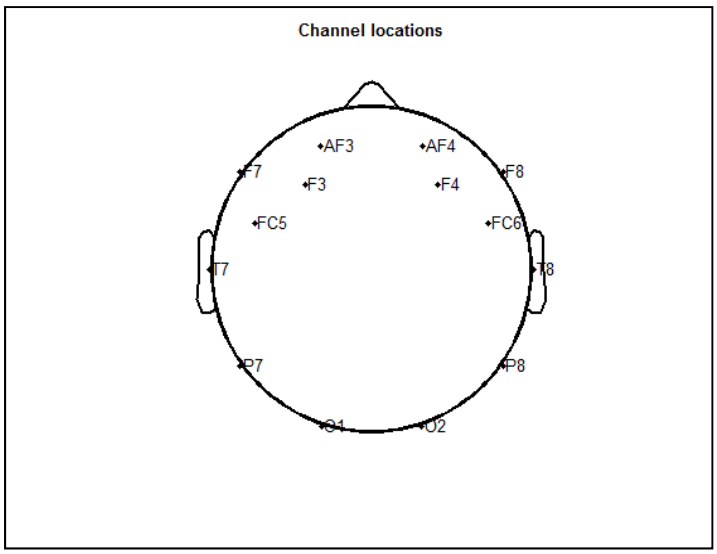

Figure 4. A screenshot of the Emotiv headset electrode position and labeling scheme deployed in this study

The heart rate variability (HRV) was also deployed in order to provide additional information about typing and the 'hacker' tasks. Data for HRV analysis was acquired using both 3-lead electrocardiogram (ECG) and blood volume pulse (BVP) monitoring was performed using a photoplethysmograph (PPG) placed on the left earlobe. All data acquired form HRV determination was band passed filtered (1-50 Hz) prior to further processing.

The data was epoched according to experimental phase in the same fashion as the EEG data, and artefact removal and band pass filtering (0.1-40 Hz) was performed. Any missing elements were filled in with baseline values to maintain temporal correlation with the EEG dataset. The BVP serves as a separate measure of heart rate which recorded the changes in the volume of the underlying vasculature when the heart beats. It is generally considered less susceptible to noise then the ECG and tends to produce more stable data then the ECG. The level of physiological data that can be extracted using BVP is more limited then the ECG in general, as it does not provide cardiac physiology details. It was deployed in this study to determine how well it correlated with the ECG in terms of capturing HRV data. The key advantage to BVP is the simple method used to obtain the data – a simple clip on the ear lobe is typically deployed and could be integrated into a headphone that are currently employed in many mobile phones and portable listening devices.

The EEG analysis focused on a subtraction method, whereby data from phase II – the typing phases was analysed with respect to phase I – the reading phase. Any differences in the recordings between these 2 phases would represent the difference between the tasks – namely the EEG correlates of typing. Likewise, the hacking phase (phase V) data was subtracted from the subtracted phase II data – the typing phase, in order to reveal changes associated with the hacking component. Since this is a preliminary study, aimed at producing an appropriate design methodology, not all possible outcomes were examined. The results from this analysis are presented in the next section.

The HRV was measured using a method which determines the distance between the peaks of each heart beat. The peak of the QRS wave is sought for all heart beats, and the time between peaks is measured (variation in beat-to-beat interval). Variations in beat-to-beat intervals is recorded and used to access the physiological stress the subject may be experiencing [Palaniappan & Krishnan, 2004; Revett et al, 2010]. The experiment of induced hacking was designed to simulate the expected stress levels associated with a time based task and it is reasonable therefore to assume that the subject will experience stress. The deployment of ECG and BVP was designed to determine whether or not this assumption held in our experimental paradigm.

Results

The principal result obtained from this experiment was that the subject did feel that they were under physical stress during the hacking scenario. This result is predicated on changes in HRV which was recorded throughout the experiment. The results in Table 2 depict the average HRV within each of the four phases of the experiment across all three subjects.

Table 2 Heart rate variability presented as the average across all subjects for each experimental phase. HRV was measures as the coefficient of variation (CV) for the last 100 heart beats in each phase.

Table 2. HRV Rate VS Stages

Stage	Reading 1	Writing	Reading 2	Hacking
HRV	0.3%	1.1%	0.5%	3.8%

The HRV was significantly larger ($p < 0.001$) for the phase IV subjects, and this held true across all subjects. The same trend held for the BVP measurements, which indicates a variation on the heart rate of the subject. Further, the subjects self reported that they felt under stress when trying to hack the password.

Further confirmation was obtained by analyzing the video recording of the subjects, which captured the subjects' actions throughout the experiment. All subjects appeared agitated, displaying a variety of facial grimaces and general heightened arousal during the hacking phase relative to the reading and typing phases.

The EEG results indicated significant changes in the power spectrum during various stages of the experiment, which varied across electrodes. The difference between the transcriptional typing and reading phases suggested that the F3 electrode and both occipital electrodes (O1 and O2) especially displayed a high level of activation during transcriptional typing relative to reading alone. The alpha frequency band (8-12 Hz) power was raised significantly relative to the reading alone scenario, with other bands appearing roughly equal in power. The second reading task was not significantly different from the initial reading task (Phase III v Phase I), though there

was a non-significant change in the delta band (1-4 Hz) power spectrum in the occipital field electrodes (O1 and O2). The hacking scenario produced the most significant changes of all phases.

The power spectrum for the more frontally position electrodes (F3 and AF3) were strongly elevated relative to the transcriptional typing phase of the experiment in the alpha band. In addition, there was reduced activation of the occipital electrodes (O1 and O2) relative to the transcriptional typing task (across all frequency bands). Thus a pattern emerged which was consistent across all subjects: hacking yielded a reduced occipital power spectrum across all frequency bands, and yielded elevated activity pattern in the frontal electrodes (F3 and AF3) in the alpha band relative to transcriptional typing and reading.

Table 3 summarizes the changes in spectral power across all major frequency bands for each of the experimental phases. The results are the grand averages across all subjects. These results are for the frontal electrode (F3 and AF3). Note that there are also changes in the occipital electrodes (O1 and O2), as indicated in the text. Note the reading task was assumed to be the control for this experiment.

Table 3. EEG Analysis

Stage 1	Stage 2	Phase 4	Phase 5
Delta - 1.0	Delta - 1.1	Delta - 1.0	Delta - 1.3
Theta – 1.0	Theta – 1.2	Theta - 1.2	Theta - 1.5
Alpha – 1.0	Alpha – 2.6	Alpha - 1.2	Alpha – 4.2
Beta – 1.0	Beta – 1.4	Beta - 1.1	Beta - 1.2

Conclusion

This study had two principal objectives in mind: 1) to record the EEG from subjects while engaged in typing and 2) to determine how the EEG changes when a person is attempting to hack into a computer system by password guessing. The experimental paradigm was designed to incorporate controls for both pure transcriptional typing and the password hacking task. The transcriptional typing component entailed a dictation protocol, where the subjects were asked to type what they were reading in real time. Further, the typing of text was used as a control for the hacking component, which also involves typing. Typing is a very common motor task that involves a series of steps: reading the text, hand positioning, and the actual typing movements. Which parts of the brain are engaged during this task has not been clearly presented in the literature to date (though see [Reiera et al, 2008; Palaniappan & Revett]).

The results presented in this study indicate that there are particular regions of the brain that become activated during transcriptional typing (see [Jönsson, 2007]). The EEG headset contained 14 electrodes (excluding two mastoid references), as such it could certainly be the case that other regions of the brain could yield additional changes that were not recorded in this experiment because of a small electrode set. This can be examined by using a much larger electrode array (we are planning to use a high resolution 128 BioSemi system in the near future to examine this issue in detail).

The actual hacking scenario did produce a change in the overall power spectrum that was reproducible across all subjects. The pattern was based on relative changes in power across frequency bands, a common measure that

reflects the brain activity within a given frequency band. The pattern that emerged in this study was that transcriptional typing produces a unique pattern relative to a passive reading task. This is a novel result and will be explored more fully using a quantitative EEG electrode setup. Furthermore, this study produced results indicating that the actual process of password hacking yields a characteristic signature when examined using EEG, ECG, and PPG. The ECG and PPG results provide information on the stress level of the individual – the heart rate variability is a significant indicator of stress level – and PPG is typically deployed to record physical exertion level – though it is suggested by this study that it can also be used to measure mental exertion as well. The two measures provided physiological evidence that password hacking per se can induce a mental exertion which causes changes in HRV and heart rate generally [EEGLAB, 2014; Palaniappan & Krishnan, 2004; Revett et al, 2010], The EEG data suggests that there is a unique brain activation pattern associated with password hacking that can be recorded using a small electrode helmet such as that available in the Emotiv headset. These results suggest that a profile of a hacker can be deduced readily – based on the physiological responses engendered by the hacking process. Whether these results would hold true for a 'professional' hacker is a point that requires further investigation. The subjects deployed in this study were Nubian hackers and these results may simply reflect their lack of expertise in this task.

What needs to be considered in this work is that whether the experiment had sufficient controls. In the next phase of this work, a more stringent phase II will be produced, where the subject will be asked to reproduce the text corpus in a fixed time period without error. In this study, the subjects were able to complete the transcriptional typing without undue stress. This was by design, as we wished to determine the effects of typing alone. It would be interesting to compare two tasks that involve typing – both eliciting a stress reaction from the subjects, whereby one of the tasks involved hacking. This approach may eliminate stress per se – the stress of task completion from the act of hacking. Clearly, we do not wish subjects whom are under stress to be considered hackers! But if we measure stress – this should result in a general alert being raised. If the stress is associated with access entry activity – then a higher level of alert should be raised. The system indicated in this paper could be implemented autonomously and could then be used to decide whether the stress is due to the intention of the user – to hack into the system – or simply reflects and overworked and under paid employee.

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GAUSSIAN DE-NOSING TECHNIQUES IN SPATIAL DOMAIN FOR GRAY SCALE MEDICAL IMAGES

Nora Youssef, Abeer M.Mahmoud, El-Sayed M.El-Horbaty

***Abstract**: Image de-noising is the elimination of noise from digital images where noise is any undesired information that contaminates an image. De-nosing is achieved through various filtering techniques that not only enhance the image but also keeps all its important details. Filters are categorized into linear (Geometric mean and Harmonic mean filters) and non-linear (midpoint, alpha-trimmed and adaptive local noise reduction filter) techniques. This paper presents applying Gaussian de-noising techniques or algorithms in spatial domain for medical images. Actually, five de-noising techniques are developed on gray scale medical images corrupted by additive Gaussian noise with mean = 0, variance = 1000. In addition, the paper analyzes the de-nosing techniques in terms of MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) for image quality assessment and time complexity for performance assessment. The results showed that the de-nosing technique named Harmonic filter was the best from PSNR prospective and the de-nosing technique named Geometric mean filter was the best form time prospective.*

***Keywords**: Gaussian noise elimination, Linear and non-linear filter*

Introduction

The field of digital image processing refers to processing of a digital image by means of digital computers [Rafael, Richard, 2008]. Today there is almost no area of technical endeavor that is not impacted in some way by digital image processing. Digital image enhancement is the process of making images more useful visually. There are many reasons for doing such operation e.g. highlighting interesting details, removing noise and\or making images more visually appealing for specific application. The word specific establishes the outset that enhancement techniques are problem oriented. Thus for example a method that is quite useful for enhancing X-ray images may not be the best approach for enhancing satellite images taken in the infrared band of the electromagnetic spectrum [Rafael, Richard, 2008]. Actually, enhancement stage is the basic process of medical image processing.

Noise is any undesired information that contaminates an image. Noise appears in image from various sources; the digital image acquisition process, which converts an optical image into a continuous electrical signal that is then sampled, is a primary process by which noise appears in digital image. There are several ways through which noise can be introduced into an image, depending on how the image is created [Salem et al, 2010]. In other words, the noise is introduced in the image due to various reasons such as electronic and photometric disorder, transmission media error due to noisy channel, error in measurement and quantization of digital information. Image de-noising is a challenging process in digital image processing aiming at the removal or elimination of noise and is still a demanding problem for researchers [Ankita, Archana, 2013]. Image de-noising techniques may lose some dynamic image details these details may be very important specially when dealing

with medial images, so when comparing image de-noising techniques we have to take in consideration the Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index (SSIM) [Zhou et al, 2004].

Filters are categorized into linear (Geometric mean and Harmonic mean filters) and non-linear (midpoint, alpha-trimmed and adaptive local noise reduction filter) techniques. This paper presents applying Gaussian de-noising techniques or algorithms in spatial domain for medical images. Actually, five de-noising techniques are developed on gray scale medical images corrupted by additive Gaussian noise with mean = 0, variance = 1000. In addition, the paper analyzes the de-nosing techniques in terms of MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) for image quality assessment and time complexity for performance assessment. The rest of the paper is organized as follow, section II abstracts related literature work on image de-noising field. Noise signal, sources, types, degradation model definition, deeper details about the Gaussian noise then the inverse operation of image corruption, more precisely the noise removal and a classification of Gaussian elimination techniques are in Section III. Section IV shows experimental results and discussion. Section V ends with conclusion.

Related Work

Many studies have been held to improve the implementation of image de-noising throw many additions either by innovating a new techniques seeking for run time optimization or reach a better results in terms of image quality assessment factors; better PSNR and MSE, or by doing such a comparative study for the currently existing techniques. Below is a sample related work by recent first order.

[Monika, Sukhdev, 2014] presented a comparative study on images de-noising techniques for salt and pepper noise, they applied different spatial filters (Arithmetic, Geometric, Harmonic and Contra-Harmonic mean) for linear filtering and (Min & Max, Alpha trimmed, Midpoint and Median) for order statistics or nonlinear filtering. They compared these filters in terms of PSNR, SNR and MSE. Their showed that the Geometric mean was the best for PSNR and MSE such that it has the maximum PSNR and minimum MSE among all for window size variable range from 3X3 to 13X13.

[Nikola, Milan, 2012] gave an overview on image de-noising techniques by applying more than one type of noises in spatial and transform domain to find the best algorithm per noise type. For example, for spatial nonlinear filtering, the median filter is the most important one to remove random valued impulsive noise. Wiener filter yield most advantageous outcomes for Gaussian corruption model and accuracy criterion is mean square error in the wavelet domain in non-data adaptive transform subcategory under transform domain. [Reza et al, 2013] they found that the recently proposed methods haven't yet attained a desirable level of applicability, So they presented a de-nosing algorithm based on fuzzy cellular automata, The algorithm can effectively eliminate the image noise and keeps edge information without blurring effect, It specially suits the wire bonding images which need high edge detection accuracy. It improves the visual quality of the image and presents higher PSNR compared with the traditional methods.

[Vikas et al, 2013] introduced a modified version of adaptive median filter in the spatial domain as a speckle noise removal technique for ultrasound images. Normal adaptive filter's behavior changes based on statistical characteristics of the image inside the filter region; these adaptive filters are of a greater complexity and analyze

how image characteristics vary from one point to another. The adaptive median filter preserves the details while smoothing impulse noise, but it has a problem that it does not work well for Gaussian and speckle noise. They applied a modification such that they made the use of Euclidian distance as a measure for smoothness of the working window, which is compared to a cut of value. On different test samples, their method achieved very good results.

Noising and De-noising

Noise

Noise is any undesired information that contaminates an image. Noise appears in image from various sources. The digital image acquisition process, which converts an optical image into a continuous electrical signal that is then sampled, is a primary process by which noise appears in digital image. There are several ways through which noise can be introduced into an image, depending on how the image is created [Salem et al, 2010]. Transmission of visual information in form of images is common and major method in image processing field, but during the transmission, images are harmed by a noise [Ravi, Urooz, 2013], Arises due to electronic circuit noise and sensor noise due to poor illumination and/or high temperature [Rafael, Richard, 2008]. There are various types of noise or noise models [Rafael, Richard, 2008] such as Gaussian, Impulsive, Speckle, Shot, White [Ravi, Urooz, 2013], Exponential, Rayleigh, Erlang (Gamme) noise [Rafael, Richard, 2008]. Impulsive noise can be either fixed valued like salt & pepper which is black and white spots on images or random valued which is the noise can have any random value between 0 and 255 hence its removal is very important and difficult [Nikola, Milan, 2012]. These types of noise are additive noise and can be described by a PDF (probability distribution function) [Rafael, Richard, 2008]. And this paper focuses on the Gaussian noise. There is another type of noise, which is called periodic noise it can corrupt the image from electrical or electromechanical interference during acquisition [Rafael, Richard, 2008].

Degradation Model

Degradation model for an image in spatial domain is given by Eq.1 [Rafael, Richard 2008]

$$g(x,y) = h(x,y) \star f(x,y) + \eta(x,y) \quad (1)$$

Such that $g(x,y)$ is the noisy image, $h(x,y)$ is the degradation function, $f(x,y)$ is the original image and $\eta(x,y)$ is the noise. The symbol means a convolution process in spatial domain. In addition, Eq. 2 [Rafael, Richard 2008] gives the corresponding equation in transform/frequency domain with the same meaning as the Eq.1 above [Rafael, Richard 2008].

$$G(u,v) = H(u,v)F(u,v) + N(u,v) \quad (2)$$

Gaussian Noise

Gaussian noise is additive in nature it is independent at each pixel and independent from signal strength. It also called “Normal” noise, and is mathematically tractable in spatial and frequency domain. It arises due to electronic circuit noise and sensor noise due to poor illumination and/or high temperature. It is given by probability destiny function (PDF) Eq.3. [Rafael, Richard, 2008]

$$p(z) = \frac{1}{\sqrt{2\pi}\,\delta} e^{-(z-z`)/2\delta^2} \quad (3)$$

Such that z represents intensity, z` is the mean (average) value of z and δ is its standard deviation, the standard deviation squared is called variance of z, and the Fig.1 is a plot for Eq.3 mathematical representation. When z is described by the equation above approximately 70% of its values will be in range $[(z` - \delta), (z` + \delta)]$ and about 95% of its values will be in range $[(z` - 2\delta), (z` + 2\delta)]$ [Rafael, Richard, 2008]. Figure 2 below shows an example for a Gaussian noisy image and its corresponding histogram representation [R & R Online Lib].

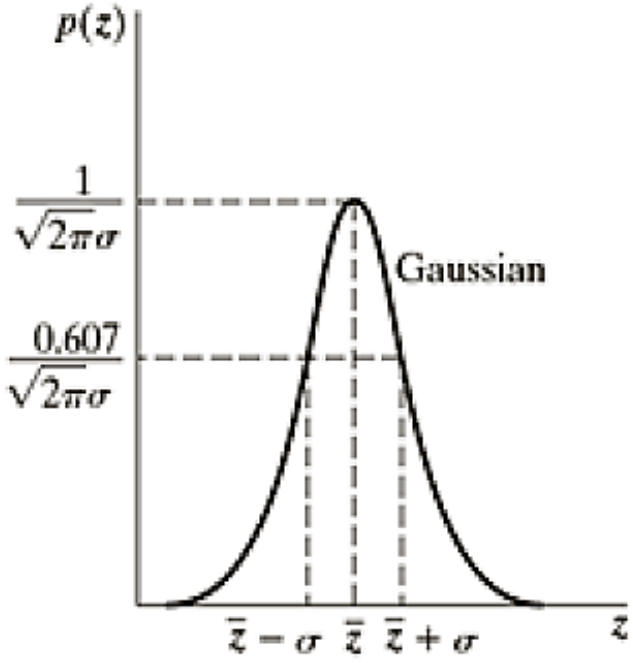


Figure 1. Gaussian Plot

Figure 2. Gaussian Histogram Representation

De-noising

Image de-noising is a challenging process in digital image processing aiming at the removal/elimination of noise and is still a demanding problem for researchers [Ankita, Archana, 2013]. Image de-noising techniques may lose some dynamic image details these details may be very important specially when dealing with medial images, so when comparing image de-noising techniques we have to take into consideration the Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index (SSIM) [Zhou et al, 2004]. Spatial filters suits the additive noise but frequency domain filters suits the periodic noise. In noise elimination, we assume that the degradation function is equal to 1 such that the image was degraded only by noise with no external factors as well as the noise is independent of spatial coordinate and uncorrelated to the image itself [Rafael, Richard, 2008]. The de-noising of the image can be done in two ways: linear filtering and nonlinear filtering. Figure 3 shows the selected Gaussian elimination techniques. There are common mathematical notations used for expressing the filters such as $f`(x,y)$ is the restored image at point x, y, mXn is the size of the neighborhood or subimage window, $g(x,y)$ the noisy image at the same point x, y, $S_{x,y}$ is the set of image point in the subimage window.

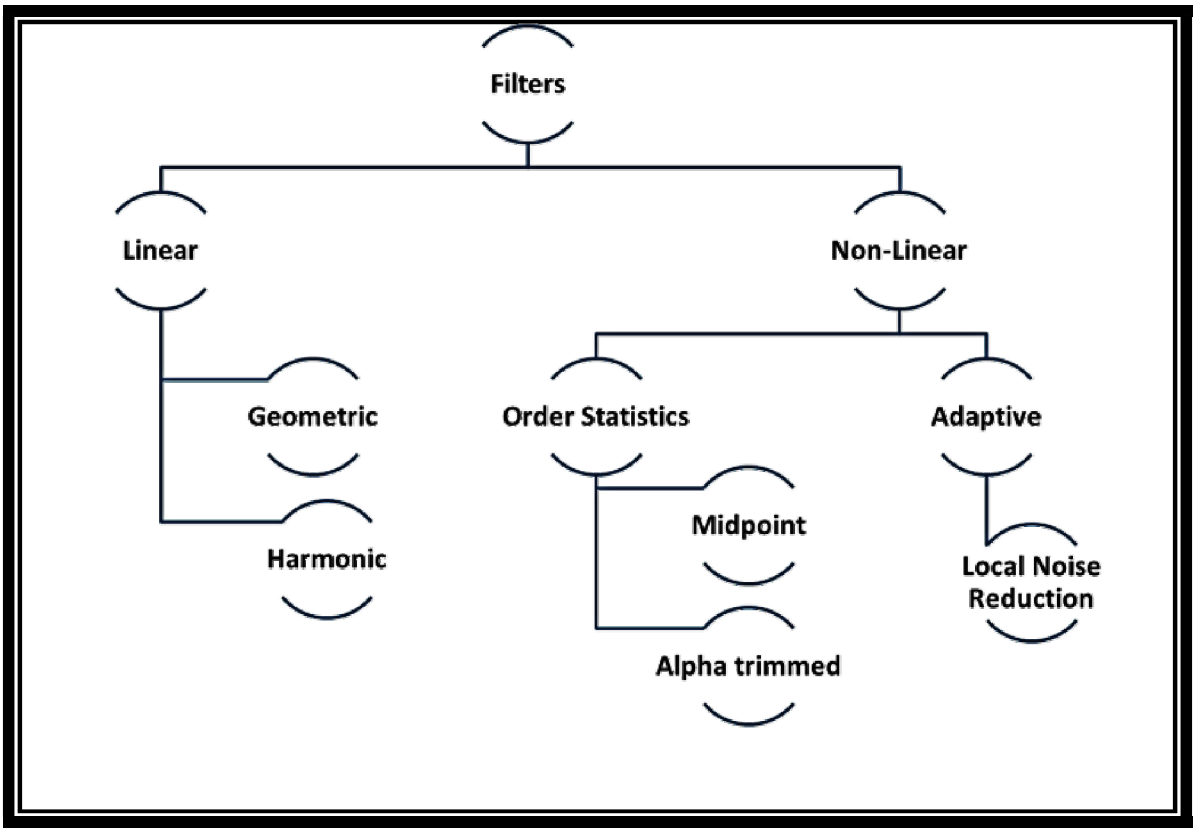


Figure 3. Selected Gaussian Elimination Techniques

Linear filtering

The noise reduction algorithm is applied for all pixels of the image linearly without knowing about noisy pixel and non-noisy pixel. e.g. Geometric and Harmonic filters. Geometric filter is given by Eq. 4 [Rafael, Richard, 2008] and it works as each restored pixel is given by the product of the pixels in the subimage window, raised to the

power $1/mn$ it gives a smoothing effect and tends to lose very little details of the image [Rafael, Richard, 2008]. Eq. 5 [Rafael, Richard, 2008] represents Harmonic filter. It represents the concept of sliding window is used in which a window is considered around pixel to be noised and neighborhood pixel is considered for computation of harmonic mean. The mathematical harmonic mean is calculated based on gray values of neighborhood pixels within the window region [Monika, Sukhdev, 2014].

$$f`(x,y) = [\prod_{(s,t\,\epsilon\, S_{x,y})} g(s,t)]^{\frac{1}{mn}} \tag{4}$$

$$f`(x,y) = \frac{mn}{\sum_{(s,t)\epsilon\, S_{xy}} \frac{1}{g(s,t)}} \tag{5}$$

Nonlinear filtering

Employ a low pass filtering on groups of pixels with an assumption that noise occupies the higher frequency region of the spectrum. Generally, spatial filters eliminate noise to a considerable extent but at the cost of blurring images, which in turn makes the edges in pictures invisible [Vikas et al, 2013]. Order statics filters are spatial filters whose response is based on ordering (ranking) the values of the pixels contained in the image area encompassed by the filter e.g. Midpoint. Adaptive filters whose behavior changes based on statistical characteristics of the image inside the filter region e.g. local noise reduction filter. Midpoint filter is given by Eq. 6 [Rafael, Richard, 2008], which gives each restored pixel the average value between the pixel with maximum value and the pixel with minimum value. Alpha-trimmed mean filter is given by Eq. 7 [Rafael, Richard, 2008], such that d takes a value in range from 0 to mn-1 when d = 0 it won't work as a best for Gaussian such that the filter will be reduced to arithmetic mean filter [Rafael, Richard, 2008]. Local noise reduction filter is given by Eq. 8 [Rafael, Richard, 2008], such that δ_L^2 is the local variance and $\mathfrak{m}_L$ is the local mean of subimage window $S_{x,y}$, δ_η^2 is the noise variance. There is an assumption that the ratio $\frac{\delta_\eta^2}{\delta_L^2} = 1$ because the local variance is a subset of the whole image variance and we seldom know the variance of the noise [Rafael, Richard, 2008]

$$f`(x,y) = \frac{1}{2}[max_{(s,t)\epsilon\, S_{xy}}\{g(s,t)\} + min_{(s,t)\epsilon\, S_{xy}}\{g(s,t)\}] \tag{6}$$

$$f`(x,y) = \frac{1}{mn-d} \sum_{(s,t)\epsilon\, S_{xy}} g(s,t) \tag{7}$$

$$f`(x,y) = g(x,y) - \frac{\delta_\eta^2}{\delta_L^2}[g(x,y) - \mathfrak{m}_L] \tag{8}$$

Quality Assessments Metrics

Objective methods for assessing perceptual image quality traditionally attempted to quantify the visibility of errors (differences) between a distorted image and a reference image (Ground Truth) using a variety of properties. Quality metrics contain four main measurements these measurements are 1) ***MSE*** – (Mean Squared Error) computed by averaging the squared intensity differences of distorted and reference image pixels [Zhou et

al, 2004] and is computed by Eq.9 [Salem et al, 2010]. 2) ***SNR*** – (Signal to Noise Ratio) defined as ratio of average signal power to average noise power for an image of size MxN [Monika, Sukhdev, 2014] *3)* ***PSNR*** – (Peak Signal to Noise Ratio) defined as the ratio of peak signal power to average noise power. PSNR looks at how many pixels in the text image differ from the ground truth image values and find quantity of the pixels. Higher the value of PSNR indicates better result [Monika, Sukhdev, 2014] and is computed by Eq. 10 [Salem et al, 2010]. 4) ***SSIM*** – (Structural Similarity) that compares local patterns of pixel intensities that have been normalized for luminance and contrast [Zhou et al, 2004].

$$\mathrm{MSE} = \frac{1}{MN}\sum_{i}^{M}\sum_{j}^{N}[g(i,j) - f(i,j)]^2 \tag{9}$$

$$PSNR = 10\, log_{10}\left(\frac{255^2}{MSE}\right) \tag{10}$$

Results and Discussions

Experiment was done on four sample medical images corrupted by additive Gaussian noise. De-nosing trials are done in spatial domain filters with subimage/window size range from 3X3 to 9X9

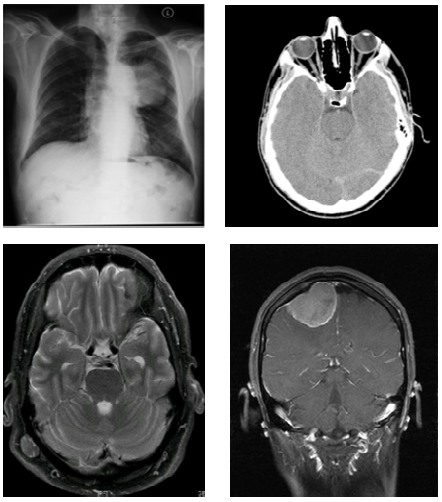


Figure 4. Input Ground Truth Images

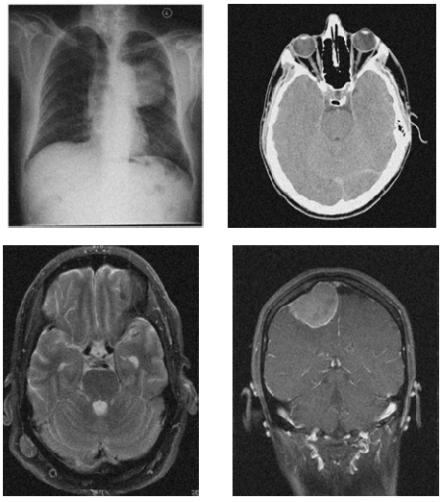
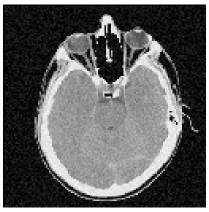
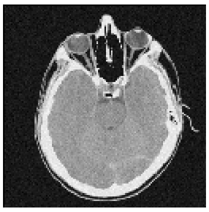
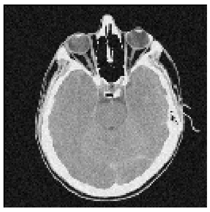
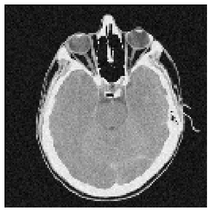
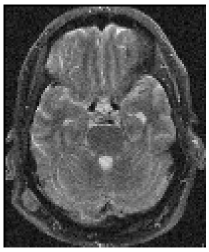
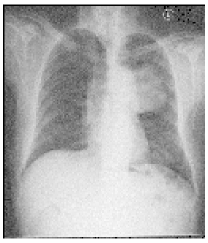
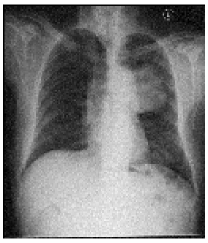
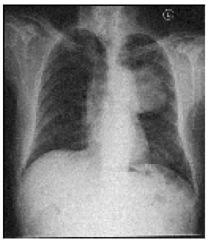
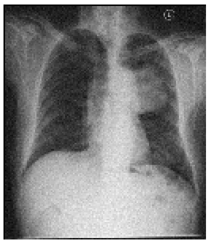
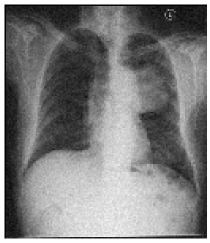
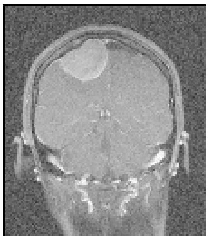
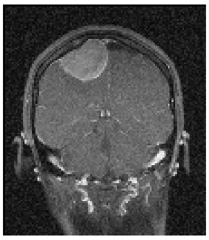
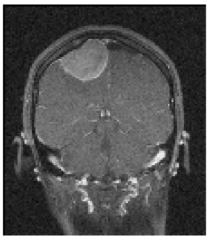
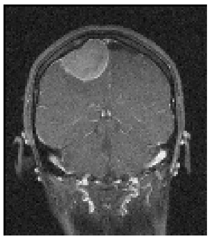
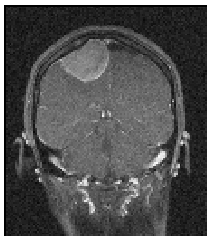


Figure 5. Gaussian Noisy Images

Experimental Settings

Figure 4 shown selected sample of ground truth medical images downloaded from [R & R Online Lib; Open I]. Figure 5 shown the same sample after being corrupted with Gaussian noise with mean = 0 and variance = 1000. In addition to applying post processing technique for contrast starching from 0 – 255.

Table 1. Gaussian Elimination Techniques Output - 3X3 Window Size

Geometric Mean Filter	Harmonic Mean Filter	Mid-Point Filter	Alpha Trimmed Filter	Local Adaptive Noise Reduction
				
				
				
				

Results

The five de-nosing techniques were implemented in visual C#. Table 1 shows the results of the data sample after applying the five de-nosing techniques, where a window filter size 3X3 is used in this illustration. Figures 6, 7, 8, 9 show a graphical representation for the results for different window/filter size 3X3, 5X5, 7X7 and 9X9 consequently. From the figures, it is obvious that harmonic filter de-nosing technique is the best from PSNR prospective and the de-nosing technique Geometric mean filter was the best form time prospective.

De-nosing filters gave the best PSNR when the filter size was 3X3 while they gave the worst results when filter size was 9X9; Geometric filter had the largest time complexity regardless the window or filter size. Midpoint filter is the best filter (gave the largest PSNR) among nonlinear filtering selected techniques while the Harmonic gave the least time complexity regardless the filter size.

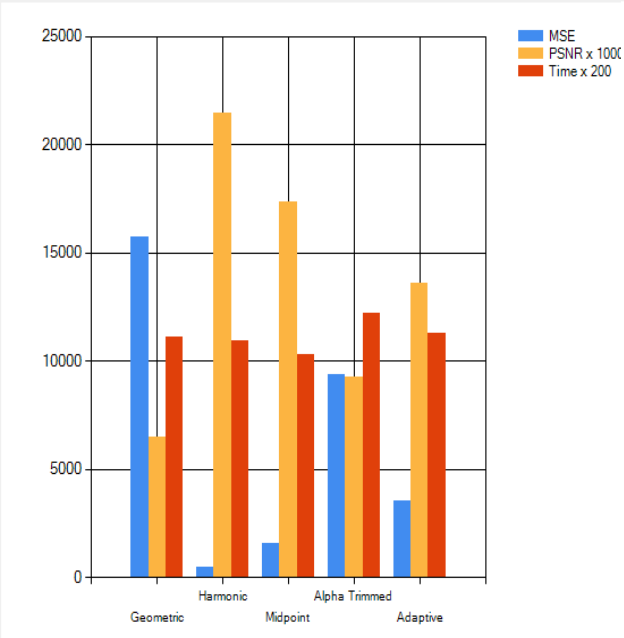


Figure 6. Avg. 3X3 Results

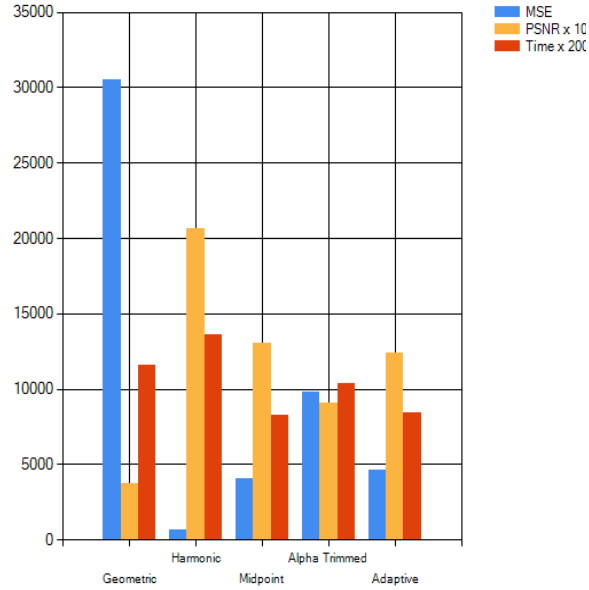


Figure 7. Avg. 5X5 Results

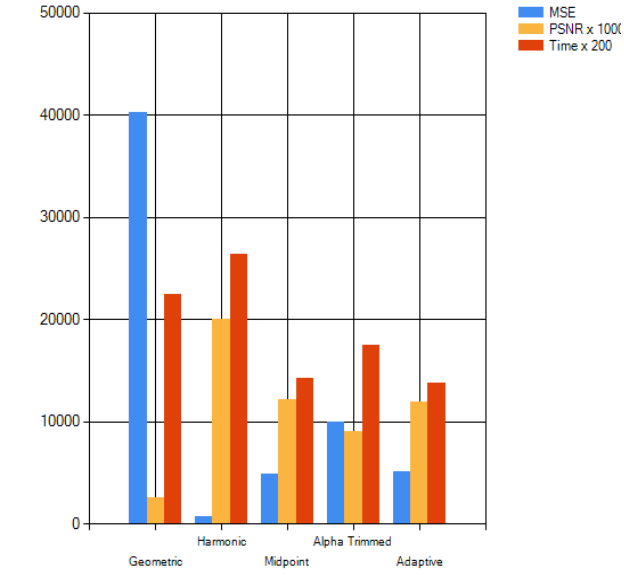


Figure 8. Avg. 7X7 Results

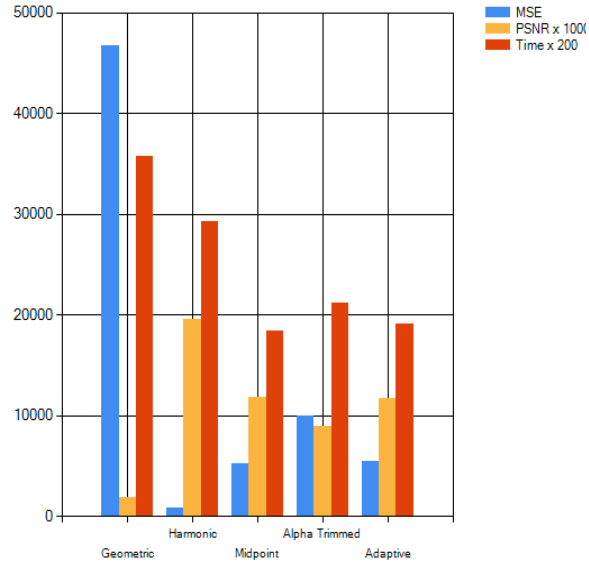


Figure 9. Avg. 9X9 Results

Conclusion

Image de-noising is the elimination of noise from digital images where noise is any undesired information that contaminates an image. De-nosing is achieved through various filtering techniques that not only enhance the image but also keeps all its important details. Filters are categorized into linear (Geometric mean and Harmonic mean filters) and non-linear (midpoint, alpha-trimmed and adaptive local noise reduction filter) techniques. This paper presented applying Gaussian de-noising techniques or algorithms in spatial domain for medical images. Actually, five de-noising techniques are developed on gray scale medical images corrupted by additive Gaussian noise with mean = 0, variance = 1000 in visual C# environment. In addition, the paper analyzed the de-nosing

techniques in terms of MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) for image quality assessment and time complexity for performance assessment. The results showed that the Harmonic filter was the best from PSNR prospective and Geometric mean filter was the best form time prospective.

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