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A WORD OF WELCOME FROM THE EDITORS

We are very glad to welcome readers and researchers to "Central European Researchers Journal (CERES)". Topics of this journal cover different areas and problems of engineering. The main topics of the journal concern modern information technologies, computer systems, critical infrastructures, etc. their modelling, analysis, estimation, performance, reliability. It is first number of the journal that has been formed under project Tempus CERES - Centers of Excellence for young RESearchers (544137-TEMPUS-1-2013-1-SK-TEMPUS-JPHES). This fact causes principal goal and specifics of the journal. The principal goal of this journal is the support of young researchers, their investigation by the proposition of stable platform for publications and presentations with active distribution. Therefore this journal is on-line journal with free access. Publications of PhD students, post-doctoral students and young researchers will be dominantly in the journal. Review articles and methodological presentation of well-known researches and engineers will be presented too.

In order to ensure better recognition of the journal on an international plan, an international editorial council will also be formed, so as to give a new boost to regional and international cooperation. The work on promoting and improving quality and recognisability of the journal in the today's highly competitive environment is the greatest goal of the journal. In order to achieve this objective, it is first of all necessary to have interesting research and professional papers, but also to ensure a successful cooperation between the editorial staff, Editorial Board, reviewers, authors, and readers. The peer review process for journal publication is essentially a quality control procedure. It is a process by which experts evaluate scholarly works, and its objective is to ensure a high quality of published research results. This is certain to attract new readers, particularly through the Internet, because, as already mentioned, all papers in the on-line edition of the journal will.

We wish to extend my thanks in advance to all authors who are going to recognise our journal as a proper medium for spreading and presenting their research results, experience.

With best wishes

Prof. Vyacheslav Kharchenko
DrSc. Elena Zaitseva

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CONTENTS

A Resource-based Approach and Methods of Multiply Effects in Computer World

Julia Drozd, Alex Drozd

***Abstract*—** This paper deals with the features of integration of the artificial world created by human into the natural world. The integration process is to solve the challenges of the natural world including the computer problem. Resource-based approach reveals the appearance of new methods ensuring the multiply effect in improving the basic parameters of solving the problems in development and evaluation of models, methods and means which form targeted resources. The basic parameters of resources are throughput, trustworthiness and a resource consumption or resource-saving. They improve at the same time due to increase of the resource development levels of the multiple effect methods. The examples of the multiple effect methods are considered. Experiment results confirming achievement of the multiply effect are received.

***Keywords*—**computer world integration; model, method and mean; target resource; throughput, trustworthiness, resource saving, multiply effect method

I. INTRODUCTION

The method "Robbing Peter to pay Paul" in which a patch is rearranged from the less significant hole to more significant one is dominant in the mind of human. The traditional questions asked at project presentations are: "What has been lost in exchange for improvements?", "What is the cost of achieved improvements?"

At a certain level of development, this method gives up the place to the multiple effect methods which simultaneously improve a number of parameters without losing the other. For example, personal computers over the past 20 years have increased the clock rate of which can be judged on their throughput from KHz up to GHz. Concurrently they increased the memory size from Mb up to Tb, i.e. basic parameters at once increased a million times. At the same time, a number of other factors including the price are improved without any loss [1, 2].

Development of multiple effect methods can be explained from the perspective of resource-based approach that explores the integration of the artificial world created by human into the natural world [3, 4]. Computer world takes a vanguard position in the development of artificial world, the first showing the features of the development expected in other areas of human activity. It relates to multiple effect methods which start to develop in digital technologies.

The artificial world is not initially adequate to the natural world, causing perturbations in it in the form of *challenge*s, including the problems of the computer world. Artificial world fits into the natural world by solving its challenges.

According to the resource-based approach, a solving the problem is composed of performing *three conditions*: achieving some *throughput* for executing certain amount of work for a limited time period, obtaining *reliable* results and investing target *resources*, which provide the above *throughput* and result trustworthiness. Resources contain all the necessary for problem solving: *models*, *methods* and *means*. The models are human understandings of the natural world and its components. The methods are description of resource transformation or estimation of resources. The means consist of *materials* and *tools*. Both the models and the methods form *information part* of the target resources, and the means belong to *technology* one.

The means are *the material carriers* of informational resources. Models and methods are recorded and kept in *structures* and processes of *functioning* the means. For example, the model of the coming winter is coded in onion structure, and the law of universal gravitation is described like the method of interaction of resources in the process of falling an apple from the

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tree. In order to read these records we are to be prepared on a base of *access to the resources* of certain levels of development.

The target resources can be viewed in terms of their structure or functioning like a system of elements or an element of system respectively. All the resources including their own elements are the elements of the natural world. Therefore they develop structurally and functionally from a simple form to real one by structuring under the features of this world. The most evident features in the computer world are *parallelism* and *fuzziness*. Simple resources are sequential and exact in accordance with the initial understandings and possibilities of a human. Real resources, characterizing the natural world, are parallel and approximate.

The resource development occurring under the influence of both parallelism and fuzziness of the natural world passes a number of levels: replication, diversification and autonomy. In the level hierarchy they occupy the low L, the middle M, and the high H position respectively. Each preceding level serves for following them. At all the levels, the goal of resource development is surviving provided from L to H by different methods: increasing throughput, safety (trustworthiness of results) and independence (self-sufficiency as the availability of resources), respectively [5].

In order to reveal preferred directions for improving the methods of resource development, the resource-based approach proposes to arrange the levels of parallelism in ascending order and refer the matrix and pipelined computing to the levels L and M respectively. The method of prepared results is referred to the level H [6, 7].

The paper is focused on the development of the resource-based approach in an assessment of the integration process of the computer world into the natural one. The subject of research is an appearance of the multiple effect methods which demonstrate new opportunities in improvement of several parameters of solving the problems without loss in others. Parameters of problem solving and the multiple effect methods: substantiation and development are considered in Section 2. Experimental confirmation of the multiple effect achieved in the considered method is represented in Section 3.

II. THE METHODS OF MULTIPLY EFFECT

A. Parameters of solving the problems

Challenges are solved for development and an assessment of target resources. It refers them to the problems of synthesis and the analysis, respectively. In framework of model, the method diversifies the means by dividing of them into tools and materials with the different nature of their interaction for problems of synthesis and the analysis. The problems of synthesis are solved with increasing the impact of tool on the material to improve throughput and trustworthiness of result, and the impact of material on the tool is reduced for the purpose of resource-saving (reduction of tool wear). For the problems of the analysis, the material influence on the tool is enhanced to improve the trustworthiness of the material study and throughput, and the influence of the tool on the material is reduced in order to reduce the instrumental error (to increase trustworthiness).

Thus, the conditions for solving the problem (throughput, trustworthiness and resource investment) define the basic parameters for solving the problem (process and result): throughput, trustworthiness and resource consumption or recourse-saving. The wide set of metrics is used for an assessment of the developed resource or knowledge obtained about the resource, but all of them can be brought together to the specified three basic parameters.

Development of methods can be analyzed with use of relative estimates of the basic parameters of a solution in comparison with the underlying methods possessing the conventional high levels of parameters.

The relative assessment of development of a method in an indicator of throughput is estimated as $K_{TP} = P / P_B$, where P and P_B – throughput of the offered and underlying method, respectively.

As a rule, trustworthiness of result is at the high level exceeding 0.5. Wherefore it is expedient to estimate development of a method in an indicator of trustworthiness with use of complementary values by the formula:

$$K_{TW} = (1 – W_B) / (1 – W),$$

where W_B and W – trustworthiness of result for the underlying and offered method, respectively.

The relative assessment of resource consumption (resource-saving) is determined by the formula: $K_{RC} = C_B / C$, where C_B and C – the cost of the invested resources for the underlying and offered method, respectively.

Development of methods can be estimated with use of the integrated assessment considering all basic parameters of a solution:

$$K_{IA} = K_{TP} \cdot K_{TW} \cdot K_{RC}.$$

The multiple effect methods are characterized by the integrated parameter $K_{IA} > 1$.

As a rule, one parameter improves due degradation of another that reflects the ideology of the method “Robbing Peter to pay Paul”. Multiply effect methods eliminating the traditional opposition of basic parameters have not yet become the rule, and their existence raises questions: "Is it possible?", “Due to what the simultaneous improvement of several parameters is achieved?"

B. Due to what is a multiple effect achieved?

In development of target resources it is necessary to distinguish the price and value. Price of the target resource is made up of its prime cost and profit, the size of which is determined by the difference between the value and the prime cost at the time of pricing. The price remains fixed, as well as prime cost, for the majority of the paid resources.

The value is formed by features of the target resource which are shown in its internal organization and functioning and are evaluated in relation to features of other resources. At the time of pricing, the features for which the resource is created are generally considered. Thus a set of all features of the target resource is not less infinitely, than a lot of other resources surrounding it.

The value of the target resource is increasing with new manifestations of features with respect to the appearing resources. This explains the ever-growing value of art works and other rarities, as well as models and methods in relation to the extending set of other resources.

Conditions for expansion of a sat of the target resources and growth of their value are created by increase of a level of parallelism and fuzziness, i.e. by a natural way of resource development. It explains emergence and development of multiple effect methods at achievement of a certain level of resource development in the computer world as vanguard part of the artificial world. It is possible to expect distribution of the multiple effect methods on other areas of human activity.

C. How to develop methods for the multiple effect?

The basis for development of the multiple effect methods is a natural way to increase the level of parallelism and fuzziness in the formulation and solution of problems.

This can be considered on example of the development of an arithmetic operation. It has reached the approximate level of floating-point format with single accuracy, when the result inherits operand size, providing adequate trustworthiness of result [8]. This allows executing a

truncated operation which at achievement of matrix level of circuit parallelism in simultaneous digital units at the same time almost twice increases throughput and simplifies circuit (improves the parameter of resource-saving) [9, 10]. In this case the parameters accept the following values: $K_{TP} \rightarrow 2$, $K_{TW} = 1$, $K_{RC} \rightarrow 2$, $K_{IA} = \rightarrow 4$, which characterize execution of the truncated arithmetic operation like the multiply effect method.

The operation of multiplication is the key to process approximate data, as is present at the record of a number in floating-point format [11]. That's why all of operations with mantissas include multiplication in one or another form, and the results will inherit the properties of the product. Multiplication generates in the interim results and the product more zero values than the units. This domination of zero increases with improving level of the circuit parallelism and consequently throughput. It leads to the masking of faults like shorts or stuck-at faults and thus improves naturally the trustworthiness of results. At the same time it reduces the amount of switching, which is the maximum for the same number of zeros and units. This leads to lower power consumption of the dynamic component, i.e. it increases the parameter of resource-saving. This example shows the development of the multiple effect methods with unconscious assistance of human.

Ordering of types of parallelism on increase of their level opens possibilities of multiple effect method development by increase of this level, for example, transition from matrix parallelism to the pipeline.

Level of parallelism types can be estimated on extent of overcoming of the dependences limiting calculations in possibilities of parallelization. Dependences by data when operands aren't available to operation performance, and on control in case of yet not calculated condition on which branching of algorithm is carried out belong to such restrictions [12].

Comparing matrix and pipeline overlapping, it is possible to note that matrix parallelism is limited on both dependences (at their existence), and pipeline removes dependence by data: results of the previous operation are used as operands in the following operations. The data processing which is carried out with preparation of results is free from both dependences.

Now computer systems are built in the form of pipelines which sections are single-cycle units with matrix parallelism for data processing in parallel codes [13]. The single-cycle iterative array multiplier in version of the fastest scheme carries out operation for $2n - 2$ delays of full adders, i.e. such quantity is connected consistently [14], and each of almost n^2 of full adders of the scheme is used with coefficient $1 / (2n - 2)$. For $n = 64$ full adders are used only for 0.8%, i.e. 99% of operation time stand idle. Thus parasitic switchings of signals owing to various lengths of their propagation paths in addition increase energy consumption to 30% [15].

For increase of parallelism level it is expedient to pass to the bit-by-bit pipeline organization of calculations, as much as possible reducing matrix parallelism of pipeline sections, i.e. to one operational element processing codes of numbers by one bit. Such parallelization of calculations in a consecutive code can be executed in the form of a multiple-stream data processing.

Thus the matrix parallelism is used at the macrolevel of system, but in its best look – as a set of the independent simultaneously working pipelines, i.e. in absence of dependence by data. It repeatedly raises a ratio of throughput to complexity, i.e. allows at once improving indicators of throughput and resource-saving.

Further development of multiple effect methods demands wide use of the method of prepared results which in the LUT-oriented architecture of FPGA projects significantly increases throughput of arithmetic units with matrix parallelism by the accelerated distribution of carry signal in full adders [16].

III. EXPERIMENTAL RESULTS

Experiments are made with use of the program model developed for carrying out lab classes of the master course "Co-Design and Testing of Safety-Critical Embedded Systems" within the TEMPUS SAFEGUARD project "National Safeware Engineering Network of Centres of Innovative Academia-Industry Handshaking" (158886-TEMPUS-1-2009-1-UK-TEMPUS-JPCR) [17].

The program model is developed for a single-cycle arithmetic shifter of mantissas (AS) to evaluate dependence of the calculated result trustworthiness on the level of circuit parallelism. The AS is widely applied to a denormalization of operands at alignment of exponents in the most widespread operation of floating-point addition [18].

The AS executes right shift with the normalized N-bit mantissa A represented in two's complement code and calculates N-bit mantissa of result with single accuracy. Shift is performed under control of R-bit code of shift size B = 0, ..., N, where $N = 2^R - 1$.

In single-cycle units the operation of arithmetic shift is carried out with use of multiplexers. Each bit of the shifted mantissa is calculated on one multiplexer. Operation can be executed consistently according to separate bits of shift size *B* or sets of its bits.

The program model realizes *R* versions of the AS circuit with various level of circuit parallelism. The first version consists of R consistently connected shifters on one bit of shift size. They carry out shift of a mantissa on 0 or 1, 2..., $2^R - 1$ positions for values 0 or 1 corresponding bits of shift size. Version $I = 2...$, *R* contains $R - I$ consistently connected shifters, first of which copes the set formed of the first *I* bits of shift size. Each of the described shifters contains *N* multiplexers (working in parallel) constructed in two levels of gates AND and OR. Thus, the program model describes the AS with various number of gate levels: 2, 4..., 2*R*.

The program model sets random sequence of values for mantissa and shift size and in each step brings (using the – Fault Insertion Testing – FIT technology [19]) stuck-at faults in randomly the chosen point (inputs and outputs of gates AND and OR) for each version of the AS circuit.

Results of experiments for R = 4 are shown in Table 1.

TABLE I
RESULTS OF EXPERIMENTS

Levels of circuit parallelism	1	2	3	4
Amount of gate levels	8	6	4	2
Trustworthiness of results, %	78.2	79.2	81.6	83.3
Amount of points	615	675	945	1695
K_{IA}	1	1.27	1.54	1.89

Version 1 is considered as underlying. It determines the parameters as $P_B = 1$ for 8 gate levels, $W_B = 1$ for 78.8% of result trustworthiness, $C_B = 1$ for 615 points of the AS circuit (a complexity assessment by W. V. Quine).

Reduction of number of gate levels in versions 2, 3, 4 in proportion increases throughput. Increase of result trustworthiness reduces their complementary values, in inverse proportion to which the K_{TW} parameter increases. Growth of quantity of circuit points in proportion increases circuit complexity and reduces the K_{RC} parameter. Last line of the table contains the integrated K_{IA} parameter which grows due to increase of parallelism level and the accompanying increase of the result trustworthiness.

Thus, the method increasing a level of circuit parallelism for the computing units which reached the level of single accuracy belongs to multiple effect methods.

IV. CONCLUSION

Resource-based approach allows analyzing features of the computer world integration into the natural one. This process consists in the solution of problems, i.e. challenges of the natural world as reactions to development of the artificial world created by the human. The resources necessary for the solution of problems contain models, methods and means. Basic parameters of the problem solution are throughput, trustworthiness and a resources consumption or resource-saving.

The method "Robbing Peter to pay Paul" limiting development of resources only with redistribution of quantitative indices of basic parameters dominates in consciousness of the human. Increase of level of parallelism and fuzziness leads to development of the multiple effect methods improving some basic parameters without loss in others. The made experiments confirm in practice existence of the multiple effect methods and their receiving with development of resources on the way of increasing the levels of parallelism and fuzziness.

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A Self-Checking Logic Cell

Sergey Tyurin, Alex Gorodilov

***Abstract*—** In the article a self-checked logic cell (SCLC) FPGA is proposed. Self-checking is performed by using the second half of the transmitting transistors tree, which verifies the active half. Additional transistors are needed to transmit settings to the active sub tree and to compare the results of calculations. The device is protected by a patent of the Russian Federation.

***Keywords*—** FPGA; Logic Cell; Look Up Table – LUT; Transmitting Transistors Tree.

I. INTRODUCTION

A field-programmable gate array (FPGA) consists of an array of logic blocks (Configurable Logic Block, CLB) [1]-[6], including of a few logical elements or cells (LE, LC). A typical logical cell consists of a 4-input LUT (Look Up Table), which is based on the tree of the transmitting MOS transistors – Fig.1:

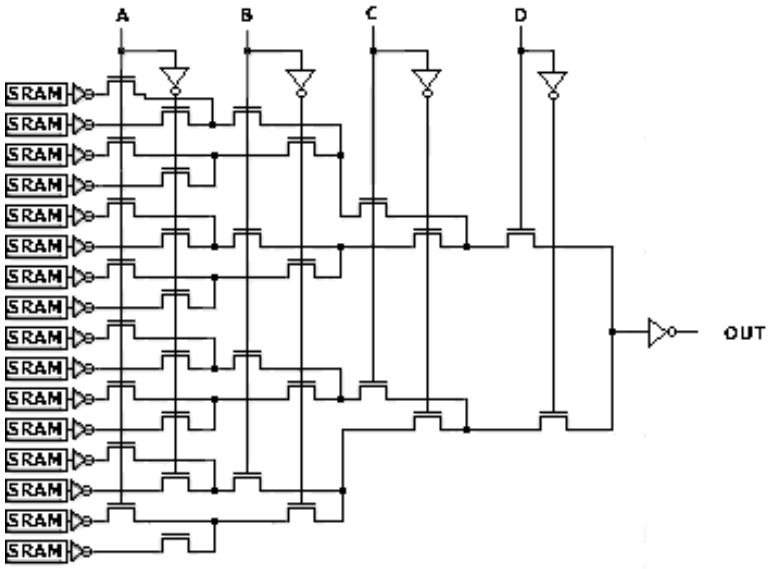

Fig.1 – Logic cell - a 4-input LUT FPGA

The truth table of the required logical function, for example F(ABCD), is loaded in the SRAM cells. They are usually uses LUT on 4,5 variables, they already adapt LUT to 6 and even on 7 variables, containing a large number of transistors. Therefore, validation of their functioning is actual. While calculating of the assigned logical function, one of the 2^n chains from the entrance to the output is activated in the tree of the transmitting transistors LUT. Studies in the region of highly reliable FPGA for the critical applications were activated recently. One of the leading experts in the field of PLD FPGA development Yervant Zorian thinks: "Now the main problem of system on a chip repair is development of embedded technologies and methods of the logic repair that occupies no more than 10% of chip area" [7]. It is most important with Radiation Hardened By Design (RHBD) in military and aerospace applications [4].

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II. A SELF-CHECKING

Self-checking is performed by using the second-half of the transmitting transistors tree, which verifies the active half. The comparison of the results of calculations is produced by element XOR (LUT-2) – Fig.2.

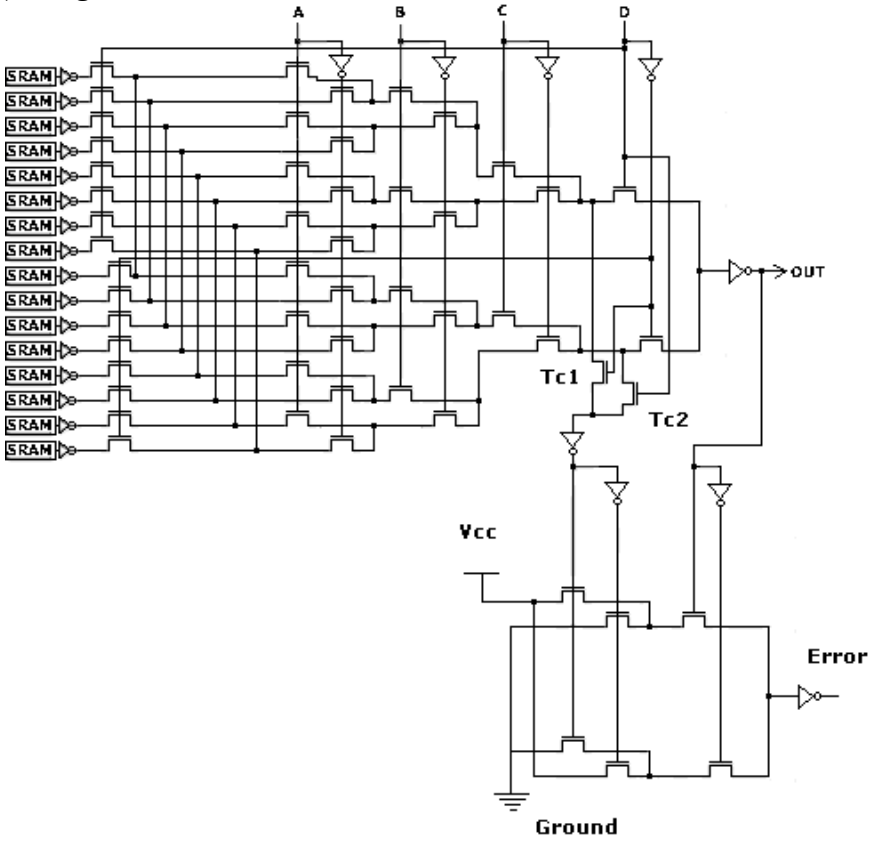

Fig.2 The self-checked logic cell SCLC

The redundancy of the tree of the transmitting transistors of SCLC with respect to LUT is evaluated by the expression:

$$\delta_{\text{C-LUTn}} = \frac{2^{n+1} + 2 \cdot n + 2^n + 16}{2^{n+1} + 2 \cdot n}. \quad (1)$$

We will obtain taking into account the memory of tuning:

$$\delta_{\text{SRAM+C-LUTn}} = \frac{2^{n+1} + 2 \cdot n + 2^n + 16 + 8 \cdot 2^n}{2^{n+1} + 2 \cdot n + 8 \cdot 2^n}. \quad (2)$$

The graph of change (2), constructed in system “MathCAD” is represented in Fig.3.

Thus, with n=4 we obtain the redundancy of order 17%. With an increase in n the redundancy approaches 10%!

The authenticity of the SCLC (P) functioning can be evaluated by the expression:

$$P_{\text{D-C-LUTn}}(t) = e^{-\cdot(2^{n+1}+2n+2^n+16)\lambda \cdot t} + 2 \cdot (1 - e^{-\cdot(\frac{2^{n+1}+2^n}{2})\lambda \cdot t}) e^{-(\frac{2^{n+1}+2^n}{2})\lambda \cdot t} \cdot e^{-(16+2n)\lambda \cdot t}. \quad (3)$$

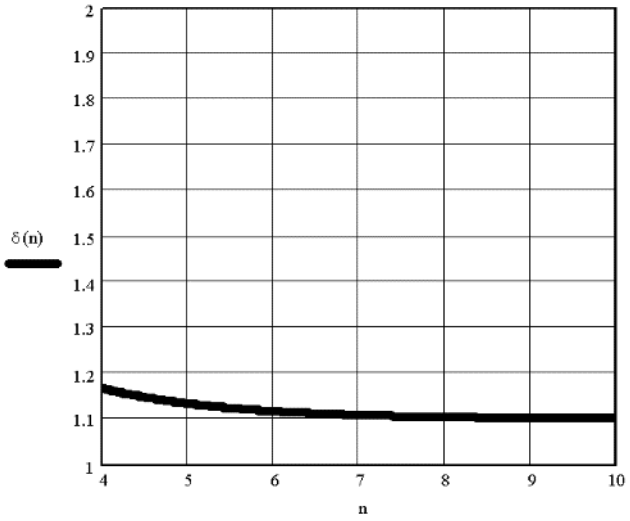

Fig.3.The graph of the redundancy change

The authenticity of the functioning of the tree LUT:

$$P_{1\text{-}LUTn}(t) = e^{-(2^{n+1}+2n)\lambda \cdot t} \quad (4)$$

Comparison of the authenticity of the functioning of the tree LUT (4) and SCLC (3) for $\lambda=10^{-8}$ are described in Fig.4.

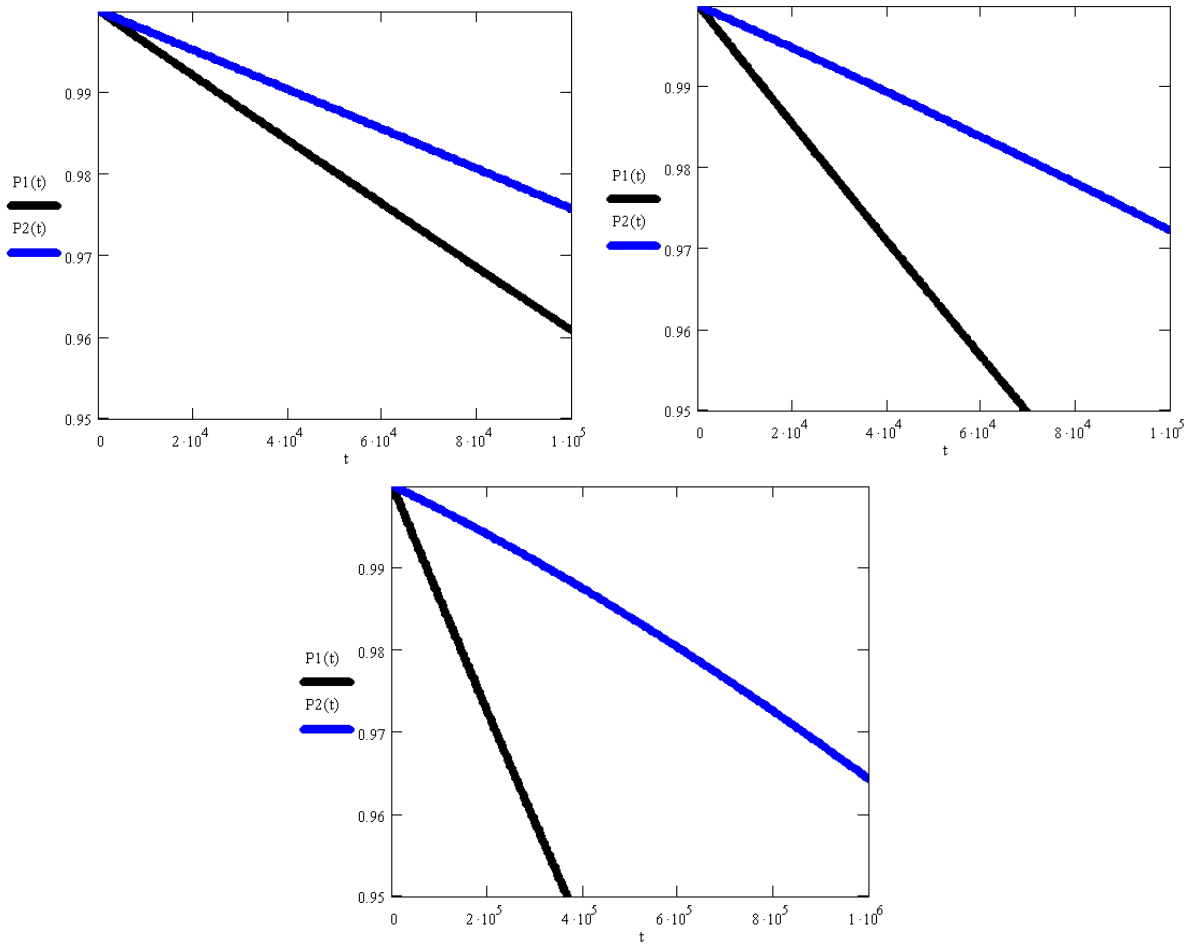

Fig.4 Comparison of the authenticity of the functioning of the tree LUT and SCLC for n=4, n=5 and n=6.

Thus, we obtain significant gain in the authenticity of the functioning.

III. SIMULATION OF THE SCLC

Simulation was carried out in the system NI Multisim 10 by National Instruments Electronics Workbench Group [8]. Model of the SCLC-2 is presented in Fig. 5.

Implementing XOR element based on LUT-2 is presented in Fig. 6:

The modeling disconnection d0-d2 transmission 1 to d2. At the output of XOR observe the error signal (Fig. 7). In case of transfer of 0 to d2-error signal is not generated (Fig. 7)

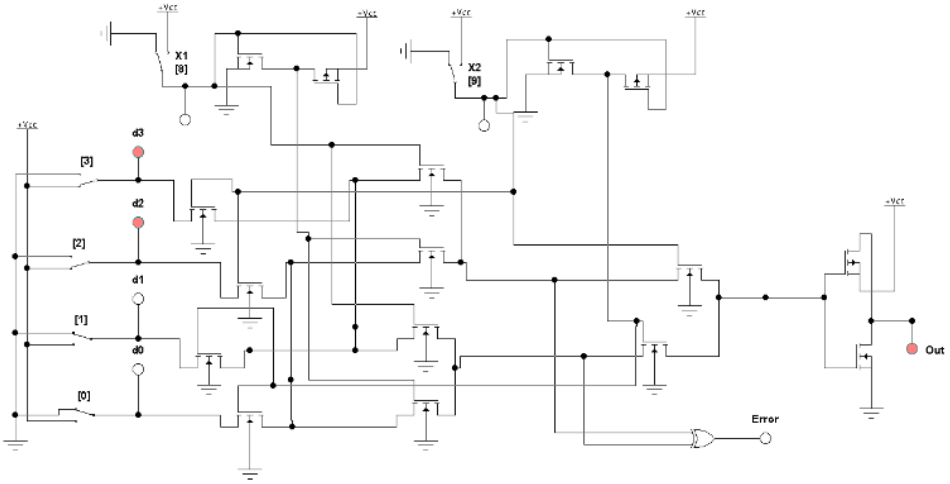

Fig. 5. Model of the SCLC-2 in the system NI Multisim 10. Transfer with zero input 0.

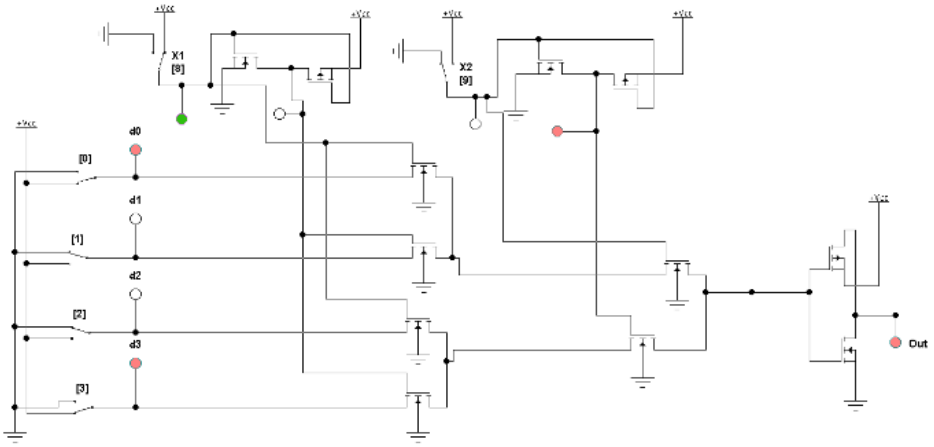

Fig. 6. Implementing XOR element based on LUT-2(x1=1, x2=0).

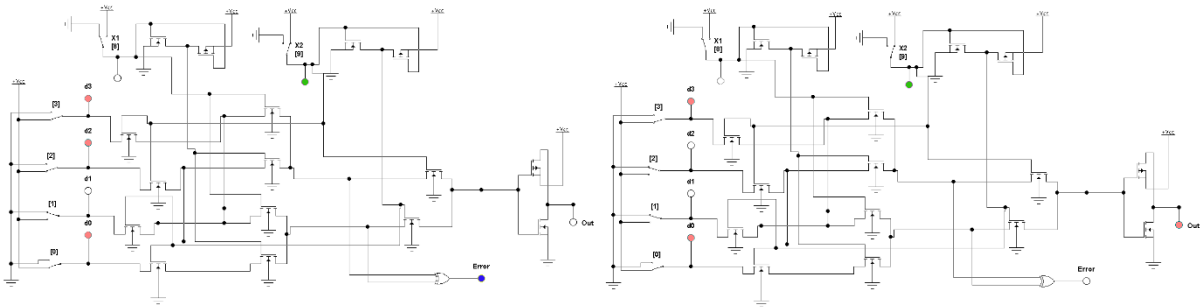

Fig. 7. The modeling disconnection d0-d2 transmission 1 to d2 and 0 to d2.

So break will be fixed only by transferring 1. Accordingly, the circuit connection to the bus «Ground» or permanently closed transistor is detected during transmission 1.

IV. CONCLUSION

The proposed self-test logic cell can detect the problem and accelerates the recovery of FPGA logic. Analysis shows that the authenticity of checking tree LUT in a number of cases proposed can exceed the authenticity of duplicating. The simulation SCLC in the system NI Multisim 10 confirms the performance of the proposed scheme. To ensure reliable setup (SRAM) and inverter input variables, such as the use of methods [9], [10]. Further studies taking into account proposed in the article approaches are expedient. The device is protected by a patent of the Russian Federation [11].

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Quality in use expert assessment system for critical software

Anastasia Orekhova, Anna Tilinska and T. Albo Baqer Karrar

***Abstract* —** A system for quality in use expert metric assessment of critical system software is proposed. Existing quality models are analyzed and their extension is proposed based on the modern standards. A tool software for expert assessment process support is developed. Practical results of critical system software quality assessment using the proposed methodology are provided.

Keywords — quality model, quality-in-use, characteristic, attribute, factor, criterion, metric, systems of critical use

I. INTRODUCTION

Software quality evaluation is revision of suitability of a product to its requirements. There are a number of quality models in software engineering literature, each one of these quality models consists of a number of quality characteristics (or factors, as called in some models). These quality characteristics could be used to evaluate the quality of the software product from the view of that characteristic. Selecting which one of the quality models to use is a real challenge. Complex quality-in-use model QUIM (Quality in Use Integrated Measurement) [1-3] was based on aggregation of existing standardized and non- standardized software quality models, including the ISO 9126 standardized model [4]. In the QUIM model the main attention is paid to such property of a software product as usability [5-7]. This fact allows studying software quality from a user's point of view. The development of standardized software models led to the development of ISO 25010 [8] model. In the new standard the model's structure is changed and some new software quality characteristics are added. Special attention is paid to evaluation of software flexibility and it's compatibility with an end user. For systems of critical application [9,10] it is necessary to take into consideration the requirements tosuch classof systems . The regulation document NUREG-0700 [11] contains set of such requirements, and this document describes the order of formation of human-machine interfaces (HMI) critical systems. In [12-13] information technology quality assessment and functional safety I&C systems HMI based on Safety Case methodology and method of a comprehensive assessment of the whole life cycle of HMI were proposed. Also the structure and main steps of utilizing the technology were described. Besides that examples of innovative design technology HMI monitoring and control of technological equipment were considered. In [14] expert evaluation technology for the quality of green human-machine interfaces were proposed.

A purpose of this paper is to improve completeness and feasibility of quality in use assessment of critical system software due to improvement of the quality model and tool software development. In section 2 modern quality models applicable to critical system software requirements are described. An expert metric assessment methodology is provided in Section 3. Section 4 contains description of the software tool. Section 5 contains a study case of assessment of HMI elements of industrial post-accident monitoring system (PAMS) for a VVER-1000 nuclear power plant. Section 6 presents the conclusions.

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II. QULITY-IN-USE MODEL

A. Quality-in-use QUIM model

QUIM model is a multilevel hierarchical model which contains 4 main levels. Level one contains factors that represent quality's characteristics, such as usefulness, productivity or user's satisfaction. Level two contains criteria that appear as subcharacteristics of factors. Criteria are identified on expert-language, that's why they are rather hard to understand. Examples are failure-resiliency, consistency, accountability and confidentiality. Criterion is determined by the set of metrics. Level three contains metrics that are functions that allow getting numeric value of quality characteristic. The lowest model's level is data, which is used for metrics calculation.

There are two types of data: quantitative (such as the number of elements on the screen, the number of colors used in the interface) and qualitative , which can take linguistic values (for example, user's satisfaction of the help window may take values "bad", "satisfactorily" or "good").

The conception of "artifact" is defined in the model – that means "information sources, consisting data". Examples are related documentation, paper or computer prototypes, reports of requirement analysis, sets of test cases, product guide and the software itself.

This model has a universal evaluation scale of each metric. Expert chooses minimal or maximum metric value by him/her self and gives its interpretation (for example: the more, the better). Calculation of criteria's value is based on metric value aggregation and factor value is based on criteria value aggregation with the use of additive convolution method.

QUIM model consists of 10 factors, 25 criteria and 129 metrics.

1. Safety–safety evaluation of operator which works with the software and its informational recourses and environment preservation.
2. Possibility of studying - user interface simplicity evaluation, evaluation of quality of help system and informational content level.
3. Confidence – evaluation of "transparency" of software's work, its controllability, reliability, fault tolerance and maintainability.
4. Availability – evaluation of difficulty level of actions made by user and software's possibility to adjust to its needs.
5. Usefulness - evaluation of accordance of results with user's expectations.
6. Productivity- evaluation of time showings of software and its efficiency.
7. Satisfaction – software attractiveness evaluation.
8. Versatility – evaluation of possibility of work with the software by users who have various knowledge levels and in various exploitation conditions.
9. Economy - evaluation of the use of hardware resources.
10. Effectiveness - evaluation of the availability and completeness of the ongoing requirement.

B. ISO 25010 Model

The family of standards ISO 25000 describes the evaluation process and product quality requirements. ISO 25010 standard details computer systems and program products quality model and describes practical guide about the use of this model.

The standard examines quality of system as a combination of quality of its elements and quality of their cooperation. The parameters of software quality are separated into eight characteristics (functional suitability, reliability, efficiency of productivity, availability, security, compatibility, maintainability and the ability to move) which are separated into subcharacteristics measured by inside or outside quality attributes. Quality in use is reviewed as a degree in which product satisfies some users by matching their requirements for

achievement of specific purposes. Characteristics of efficiency, flexibility, safety and satisfaction in use are described in this document.

C. NUREG-0700 Guide

At the moment there is no uniform quality model of critical use, but a lot of documents were created that describe development principals of such system. One of the topical normative documents is NUREG-0700, which describes an order of the HMI building for critical systems.

It contains the guiding principles of constructing new HMI elements: management, information display and cooperation.

Those elements are used as building blocks for interfaces of information and control systems development. The guide reviews principles for signalization system, safety functions and parameters of system monitoring, systems of displaying group views, systems of soft management, systems of computer procedures and principles for computerized operator support and communication system. Special attention should be paid to design principles and general HMI characteristics on the top level, which can be used in a form of hierarchy for HMI quality evaluation. The document offers the set of structured requirements and it is a good basis for the formalization of these requirements and for adding them into the QUIM quality model. It allows using this model for systems of critical use.

D. The extension of model

As it's been said earlier, the ISO 25010 standard is the extension of ISO 9126 standard. The quality model hierarchy described by the standard remained the same, consisting of characteristics, subcharacteristics and attributes. The data structure has been modified: some characteristics' titles were changed, the new ones were added and the existing ones were extended. For extension of the QUIM model a number of changes was made. Some factors' names have been changed (for example, efficiency has been renamed into efficiency of use). Some factors are extended with new criteria. For example, the availability factor is extended by such criteria as the conformity context in use, the extensibility context in use and the special possibilities of use, and technical availability.

The basic structure similar to the QUIM model based on NUREG-0700 is allocated. It describes the systems of critical use HMI quality characteristics and is presented in a form of factors and criteria. Requirements that characterize principles of HMI development are allocated. Metrics have been formed and functions for getting numerical metric specifications have been developed, both based on requirements. Metrics are added into the structure. There were changes made in the extended QUIM model for adding critical systems HMI quality characteristics (table 2):

1. The safety factor was extended; the primary and the secondary loads were added.

2. The criterion of compatibility is presented a factor and extended by the following criteria: cognitive compatibility (convenience, overlay, cursor keys location), physiological compatibility (sensitivity, speed, activation control), consistency (display of only available options, alternative key names), the target compatibility (suitability, functionality, usability).

3. For the availability factor design simplicity criterion (readable conditions, visibility, readability of the encoded information) and flexibility criterion (display, variable length of the data areas, and the number of ways to accomplish tasks) were added.

4. The user manual criterion was supplemented by such metrics as aid frequency, trainability, appropriate wording of commands in the user guide, the operating frequency of the use of help by user.

The Fig.1 shows the extension of quality in use model:

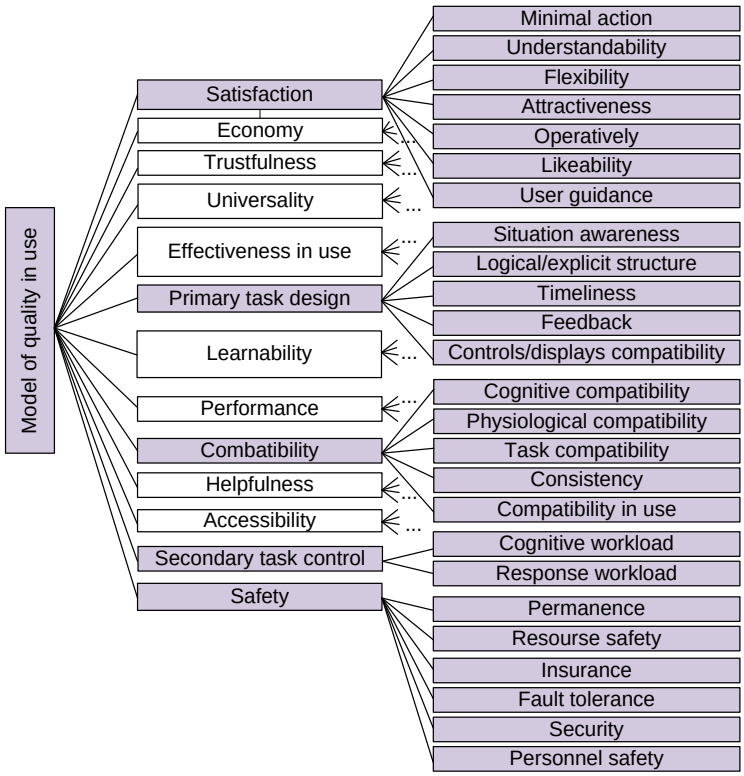


Fig. 1 The extension of quality in use model

III. The Technique Of Assessment

A. Metric expert evaluation method

Software quality in use evaluation technique is based on expert information and quality model. Quality indicators are assigned at hierarchy levels depending on how they are formed. Values of the indicators are formed at each level basing on the indicators of the previous level. The indicators influence the interface quality differently, that is why their weights have to be taken into account when assessing the quality. This information can be incomplete and cover only some indicators. To form the quality profile the quality model is used.

At first stage, the indicators and evaluation scales are studied, significance, preference and weights of indicators are discussed, experts are selected.

The idea of expert direct measurement is determining of quantities or quality indicators directly in specified measure units. Such measurement is carried out both on ratio scale and on ordinal scale. Expert direct measurement is the most complicated method and it specifies high requirements to the experts.

Ranging is placing of assessed objects or indicators according to their preference, importance or weight. The resulting position is called range. The higher the range is, the more preference, weight and importance is given to the indicator. Expert evaluation to characterize the indicators' preference is added to the quality model after the impact of various sets of ordinal and interval data on the integral quality indicator has been studied.

Results analysis is a process of forming the evaluation report on the software product quality. Presentation of results using the integral assessment does not provide a broad picture and does not identify the problems. That is why, evaluation results are given in tables, graphs and functions.

To give a visual representation of the results, radial metric diagrams are used. Values of metrics, criteria and factors are displayed on the axes in per cents. In this way, problems are identified in easy and illustrative way. The report also includes the results of prototypes' comparison and the checklists.

To spot the software quality problems, the report is analyzed and the list of recommendations to improve the quality of the system is formed.

B. Checklist method

Use of checklists is an effective and efficient way to improve the quality of software products. As applied to the interface, checklists do not involve high-cost testing procedures. There is a great number of checklists for interfaces. Obviously, there's a need to develop a special checklist in any particular case, since it has to take into account the features of the developed software product.

Using of checklists does not require special training. Still, any checklist cannot ensure the high quality of the interface. At the most, the checklist contributes to eliminating of gross errors.

IV. THE TOOL

As said above, software quality assessment is a difficult task performed mostly by software quality experts, who need to estimate number of metrics and turn their estimates into an integral quality estimate to make it comparable with similar estimates made for other similar software products.

To compose an integral estimate, every estimate made for every specific metric should be normalized to put it on a generic scale to be taken into account with a specific weight factor. Then all metric estimates should be collected together to form an integral quality estimate. Such routine operations should be performed by designated tool software designed to be used by a team of expert for software quality evaluation.

This problem is not new, so some software for similar purposes was developed before. But none of them got wide spread and used systematically; expert quality evaluation for software product is not widely performed yet by software developers either.

So, it is necessary to develop tool software based on modern quality in use approach to perform the following functions:

- Program class – Decision support software
- Program target users – software quality experts
- Main functions:
    - Implementing of quality models as an hierarchy of quality factors, criteria and metrics (FCM)
    - Keep and allow modification of the quality model (FCM composition)
    - Support profiling of the model for a specific area of application (by choosing appropriate subset of FCM, assigning weights and scales of the metrics)
    - Support quality assessment report preparation by providing interface to an expert for metric estimation, collecting and processing data
    - Generate and present quality assessment reports

Primary requirements to the software are the following:

- Keep and display linked lists of Factors, Criteria and Metrics with ability to edit their composition, relations and properties of the items, including a selected adding, updating and deleting of a selected item.

- Keep and display list of profiles and mapping of FCM items to a profile. A profile can be added, changed or deleted.
- Keep and display list of reports and a single report based on predefined report templates. A report is mapped to a profile. Metric values entered by an expert are stored within a report. A report can be added, changed or deleted.
- To allow multiple users to work with the tool same time, client-server architecture should be used for tool implementation to allow all the data stored at server to be available to all users.
- When a user enters metric values, the total progress should be displayed based on number of completed metrics against their total number; total numeric normalized quality estimate should be displayed to a user.

The following picture (Fig. 2) displays the software tool architecture of the program.

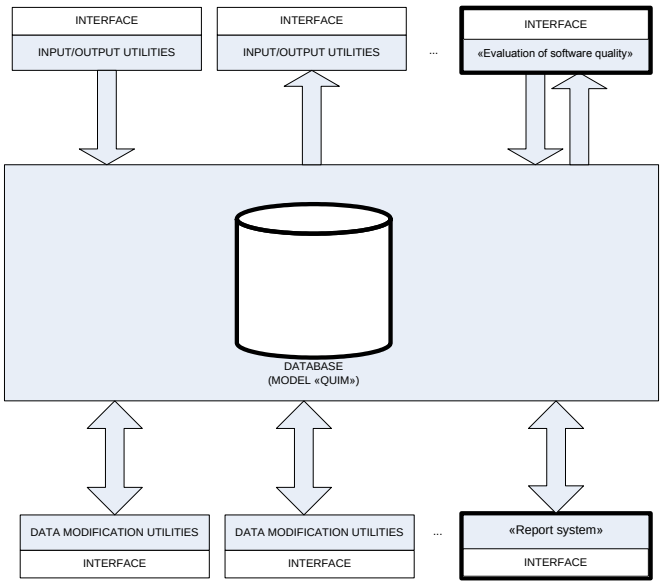


Fig. 2 The software tool architecture

Two following pictures display interfaces of the utilities: “Evaluation of software quality” interface on Fig. 3, and the “Repot system” interface on Fig.4.

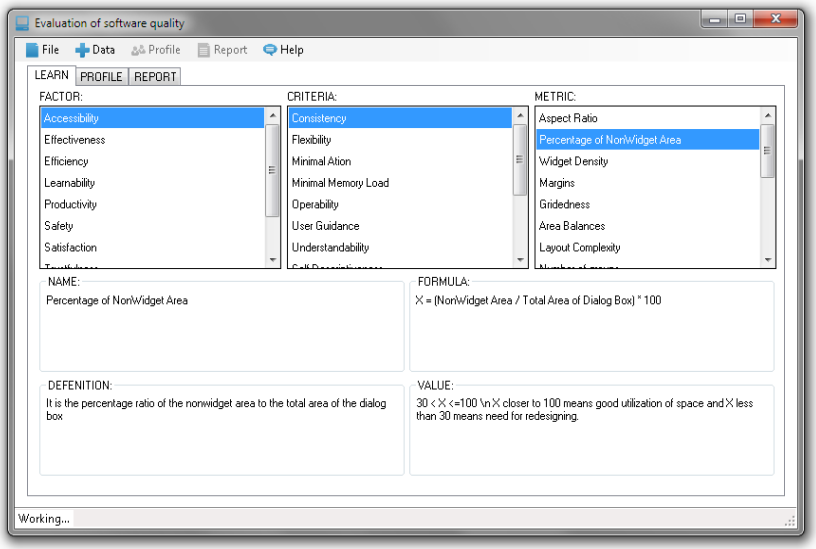


Fig.3 “Evaluation of software quality”

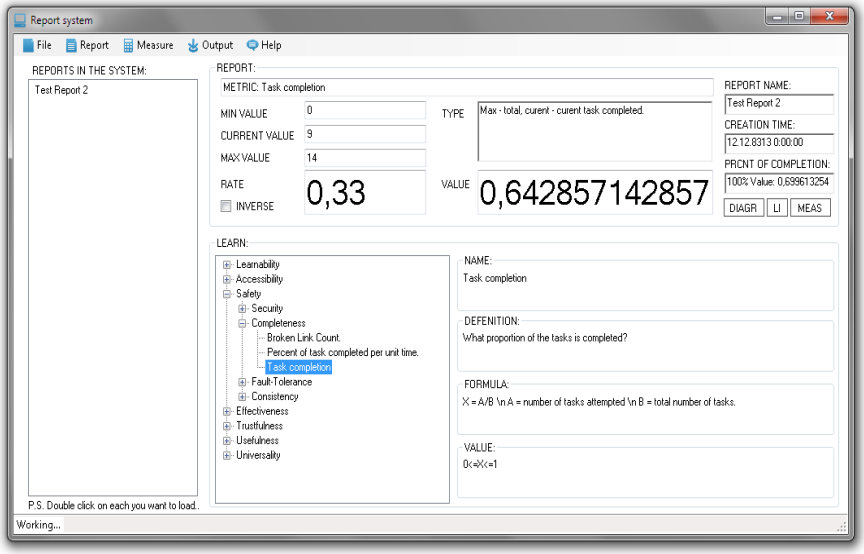


Fig.4 "Repot system"

«Evaluation of software quality» is utility that allows user to get information about all model elements from database.

«Report system» is utility that allows user to realize more detailed report management and to get complex assessment of the project.

The functions written above could be split between two utilities. «Evaluation of software quality» should specialize in configuration of the quality model at the hierarchy of factors, criteria and metrics, and «Report system» is pointed to performing quality assessment report based on expert's inputs.

V. CASE STUDY

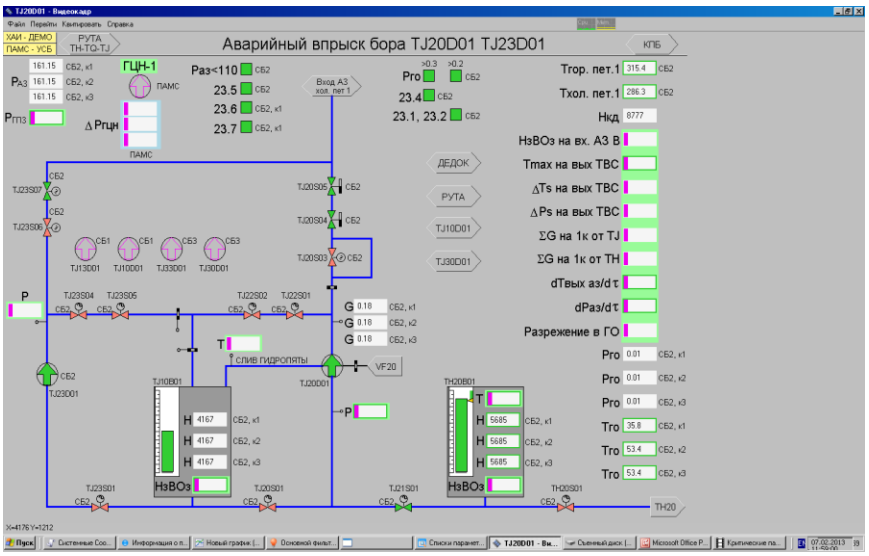
Today ICSs of nuclear power stations (NPS) are the complexes of distributed data processing with HSI implemented on workstations. The main purpose of HSI is providing the personnel with the information about the status of NPS units and the interface to control the actuator. The data is displayed on the monitors of the control room and on workstations. Except for the monitors, the hardware component of HSI may include the standard keyboard with a trackball and the function keyboard.

The purpose of ICS software is receiving and processing of the information, generating of control inputs, displaying, registration and issuing of the data about the current status of the technological process to the external systems as well as ensuring of the interaction between the operator and the system. The software works on controllers and on PC.

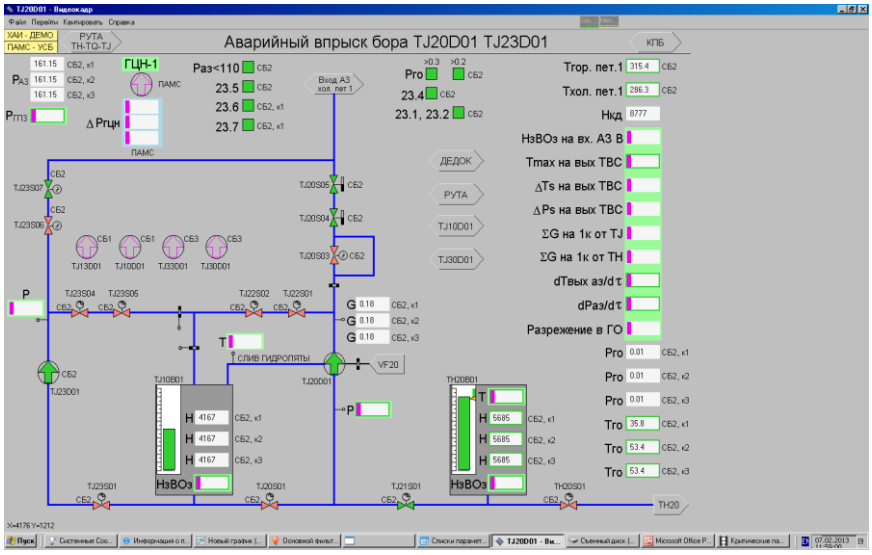
The main component of displaying the details about information and control systems is video frames (VF) organized as a number of systems with multilevel hierarchy and capability to transfer both from one level of hierarchy to another, inside the levels and between the systems. In addition, video frames can be called from the menu or from the function keyboard.

VF provide the operator with the technological information in real time in form of mnemonic diagrams (animated fragments of technological schemes or images of technological equipment), diagrams, histograms, tables, charts and so on.

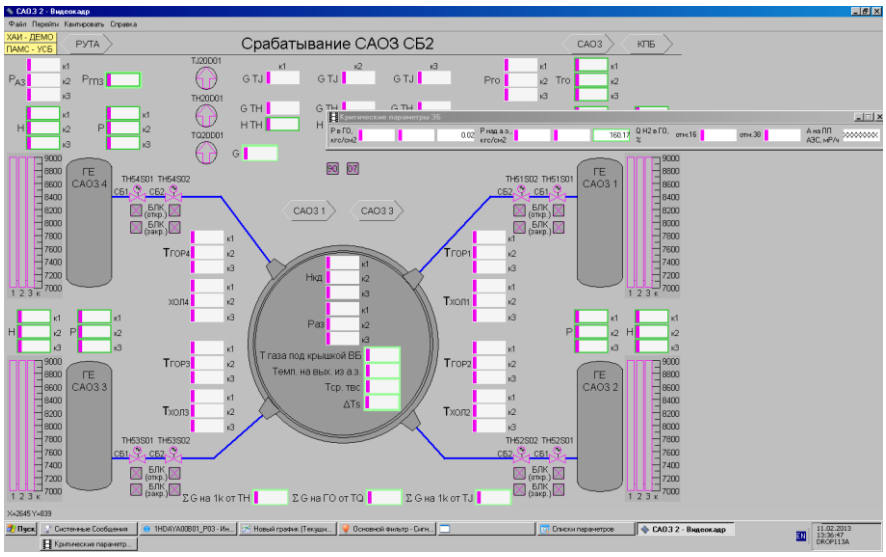
As an object for the case study the three process displays for VVER NPP post-accident monitoring system were chosen. The process displays are shown in fig. 5.



A)



B)



C)

Fig. 5 Video frames (A - TJ30D01- TJ33D01, B - CA03SB2 , C - RUTA)

The quality profile is shown given in fig. 6. The quality characteristics at the top level (Productivity, Satisfaction in use, Safety and Effectiveness in use) are Factors. The lower level items are a basis for criteria composition.

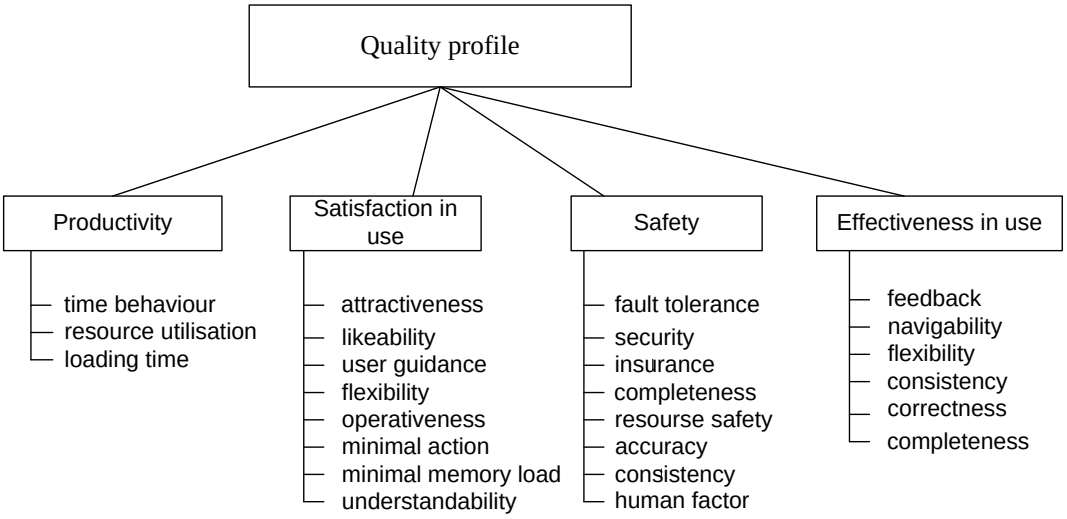


Fig. 6 Quality profile

Some criteria are not applicable to the study case or cannot be estimated in any measurable way. After excluding such criteria the final list of the criteria is the following: Consistency, Correctness, Human factor, Time behavior, Loading time, Flexibility, Resource utilization, Fault tolerance, Feedback, Completeness.

Metrics composition for the model composed of binary (yes/no options) and numeric items. The binary items compose a check list. Some of the checklist items are provided in the table 1.

TABLE I
CHECKLIST OF QUESTIONS

№	**Questions**	+/-
1	Does the design reduce the potential injuries among personnel to a minimum?	+
2	Does the design reduce the exposure to harmful materials to a minimum?	+
3	Do operator's functions include the object-oriented and important tasks?	+
4	Does the interface allow the personnel to be always aware of the current status of the object?	+
5	Does the interface provide the high load level?	-
6	Does the interface decrease the operator's productivity?	-
7	Does the interface provide the sufficient vigilance?	+
8	Is the interface design appropriate in terms of human auditory perception?	+
9	Is the interface design appropriate in terms of human visual perception?	+
10	Is the interface design appropriate in terms of human biomechanics?	+
11	Is the interface design appropriate in terms of human motor control and anthropometry?	+
12	Does the interface have a simple design?	+

Some numeric metrics are listed Table 2. Some of the values are directly entered by an expert, while other are calculated with a formula and expert to enter formula arguments.

Every expert proceeds with checklist and metric value until the whole list of questions is answered.

While using the checklist, it has been found out that some requirements are not implemented, for example, on-line assistance. Since the assistance is provided in form of the user guidance, the content of it is displayed on call for assistance but there are no screen tips. Most of experts give a negative answer to the question: «Does the system has informative, easy in use and

relevant recommendations on-line?». Moreover, they answer negatively about quick, easy and correct understanding of the information, since the design is specific enough.

TABLE II
NUMERIC METRICS

Metrics	Parameters	Description
Incorrect operation avoidance	A	Number of avoided critical and serious failures occurrences
	B	Number of functions available to user
	X=	A/B
Error-undo ability	A	Number of error-undo functions
	B	Total number of functions available on the interface
	X=	A/B
Task completion	A	Number of tasks attempted
	B	Total number of tasks
	X=	A/B
Broken Link Count	X	Number of links that lead to missing destination. It should be 0
Percent of task completed per unit time	X	The more is the better
Widget Density	X	Widget Density greater than 100 means a comparatively large number of widgets is present in a small area
Number of groups	X	It is the number of groups of items on the screen
Number of units of measurement per specific item	X	It should be 1 and should not change from page to page or screen
Number of font types used	X	Use of the same font type on all the screens is recommended to get a highly consistent interface
Number of distinct foreground colors	X	Use of one distinct foreground color throughout all the screens of the software product enhances color consistency
Number of distinct background colors	X	Similar interpretations can be made for the background color

The resulting data are processed by the software tool.

While assessing the system, the worst answers out of the possible have been selected for the uncertain questions. This allowed eliminating the possibility of getting the overvaluation of the quality.

The tool normalizes entered data and performs convolution of the results to form integral quality estimates. Integral quality estimates per a criterion for every of the three process displays are provided in Table 3. The estimates per a factor are provided in Table 4.

TABLE III
NUMERIC METRICS

Criteria	TJ30D01-TJ33D01	CA03SB2	RUTA
Consistency	0,561	0,564	0,564
Correctness	0,5	0,5	0,5
Human factor	0,684	0,65	0,715
Time behavior	0,133	0,266	0,266
Loading time	0,459	0,354	0,354
Flexibility	0,332	0,332	0,332
Resource utilization	0,584	0,762	0,761
Fault tolerance	0,3	0,435	0,435
Feedback	0,625	0,625	0,625
Completeness	0,612	0,612	0,612

TABLE IV
NORMALIZED VALUES OF FACTORS

Factors	TJ30D01-TJ33D01	CA03SB2	RUTA
Effectiveness	0,524	0,575	0,575
Safety	0,6394	0,552	0,565
Satisfaction	0,332	0,332	0,332
Productivity	0,391	0,46	0,46

Such representation helps to identify weakness in software design and plan actions for its improvement. Also such data could be visualized using different kinds of diagram (Fig.7, Fig. 8, Fig. 9).

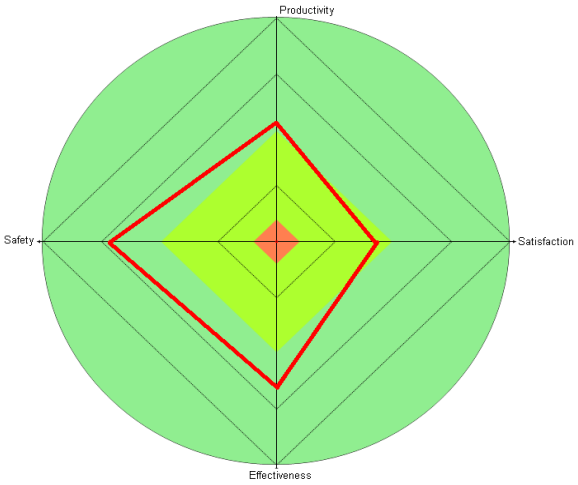


Fig. 7 Kiviat diagram (factors)

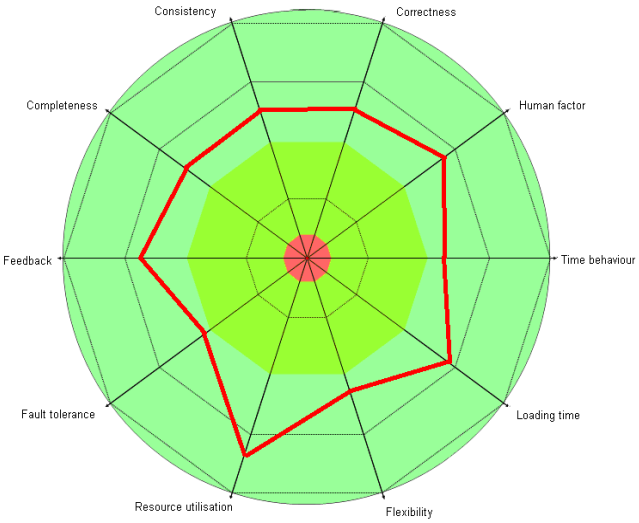


Fig. 8 Kiviat diagram (criteria)

Finally an integral quality assessment value for the whole set of the three process displays is estimated as 0.7836112.

The study proves that the system complies with the requirements to human-machine interfaces of critical systems. 63 out of 67 requirements are met. The system has minimal exposure to the risk of emergencies related to operator's errors. This could be explained by the fact that the control is delegated to the operator limitedly in a critical situation, and the system only provides him with the high-quality information as necessary. It is recommended that the oversized display elements should be used for windows filled less than at 70%. The system

provides the operator with audio. The system of assistance is not flexible enough. However, it is balanced by the preparatory training of the personnel.

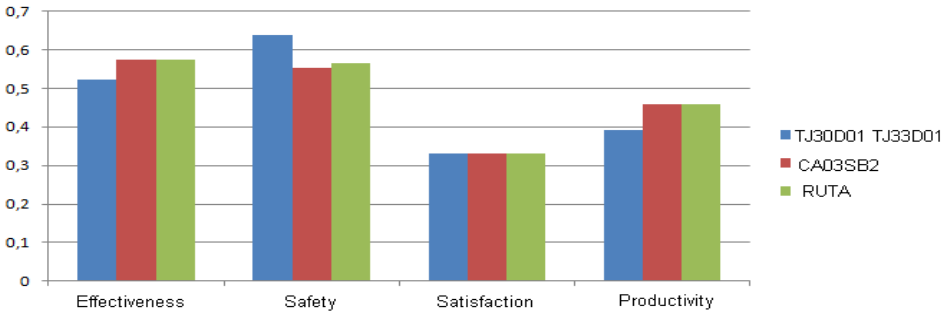


Fig. 9 Process display quality characteristics chart

V. CONCLUSIONS

In this article a system for quality in use expert metric assessment of critical system software was introduced. A software quality models analysis was held. Results of the analysis allowed performing extension of the models to include new features that meet the requirements of modern standards. Software tool for assessment process automation is developed. The results of practical use for the evaluation of software HMI system post-accident monitoring in the nuclear industry are listed. The use of the system allowed increasing completeness and reliability of evaluation results.

A further area of research is the development of the model through the development of new metrics for numeric quality in use evaluation.

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Handwriting recognition method in real-time mode based on distributed neural networks

Yuri Vetroff, Dmitry Adzinets

***Abstract*—** During the last 10 years, use of portable devices like smartphones and tabled PCs for educational, bisuness and entertaining purposes has increased dramatically. In this case, the most difficult aspect is the organization of the data entry. AI-methods like artificial neural networks helps to understand user input. The method proposes the recognizer based on neural networks and uses the parallel computing technologies.

***Keywords*—**neural networks, atrificial intelligence, pattern recognition, distributed systems.

I. Introduction

High prospects of the development of patterns recognition systems are obvious. No device or application processing the data from the outer world are unable to operate without the components that would ensure the correct and timely analysis of the received information presenting it in a structured way and in the right format. The most popular pattern recognition systems are the systems interacting with images: the automatic facial recognition on photos, the selection of moving objects in the video, auto focus in digital photography, handwriting recognition, and so on.

Handwriting systems are highly demanded in smartphones and tablets, which do not have a physical keyboard. Using a virtual keyboard is connected with a number of inconveniences, such as the small size of the keys. Currently there is a sufficient amount of applications and devices using handwriting recognition based on neural networks, but they all have a number of common problems. Firstly, when the application functions in an offline mode retraining neural network to a new set of characters may take quite a long time. Second, the neural networks are not always able to provide the necessary recognition accuracy, conflicts between similar symbols outlines are possible.

The paper offers a method for effective solving of the problem of handwriting recognition input into the computer in a real-time mode based on the distributed neural networks.

II. Problem Statement

The proposed method is based on the principle of general neural networks separation. A number of experimental studies shows that the greatest defect density is observed for recognition of similar characters, such as letters I and J. If you divide these characters, placing them in different groups, you can achieve elimination of such mistakes. Let`s consider the following alphabet: A, B, C, D, E, F, G, H, I, J, K, L. The alphabet contains 12 patterns-letters.

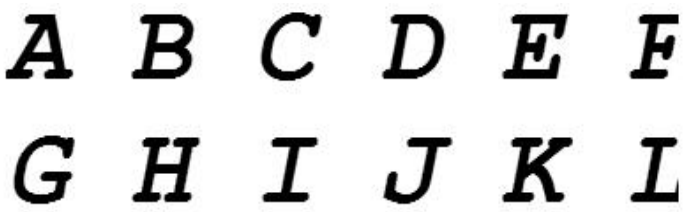

Fig. 1 Outline of the letters.

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If we analyze the features of the outline of each of them (Fig. 1), we can draw the following conclusion. There is a similarity between the characters I, J, L, symbols B, E, F and the characters A, H, K. Let`s divide the alphabet so that similar characters are in different groups. As a result, we have the following clusters:

1) A, E, I
2) B, C, J
3) F, H, L
4) D, G, K

The proposed method provides for the generation of neural networks corresponding to original character set, training of each of them only characters contained in each particular group. This will enable to avoid conflicts like the IJ or EF. Along with this, the processes of training and recognition will be accelerated in the number proportional to the number of groups.

III. DESCRIPTION

Let`s consider a handwriting recognition method based on distributed neural networks in a real time mode. The functioning of the distributed neural network can be formally divided into two stages: training and recognition.

At the stage of training standard sample is formed containing each character that can be entered to the input of recognizer. A collection of standard characters is delimited to clusters according to degree of similarity, then each cluster is supplied with classifier to be taught. Classifier is a multilayer perceptron with one hidden layer neurons which satisfies the following:

$$n_{input} \geq 2n_{hidden} > 2n_{output}$$

where n is the number of neurons in the respective layer.

Perceptrons training is produced by means of a backpropagation error algorithm. The mathematical formulation of the expression of weights adjustment in the training process is the following:

$$\Delta w_{i,j} = \alpha \Delta w_{i,j} + (1 - \alpha)\eta \delta_j o_{j.}$$

Hyperparameter η which determines the speed of training changes in training process in the following way:

$$\eta = \eta + \frac{d_{n-2}}{d_n}$$

This approach enables to accelerate the sloping area of the training, where the change of output layer mistake decreases uniformly, and to slow down increasing accuracy - in areas where hitting the local minimum is possible.

On completing the training each of neural networks will possess its own repertoire of knowledge corresponding to a certain cluster of characters.

At the stage of recognition the pattern entered by the user is decoded into a binary format and is supplied to the input by each neural network in the recognizer. Neural networks pass the pattern through and on completing the proccess store the result in the corresponding collection.

The format of results is a couple of "key-value", where key is the encoding of the obtained pattern and the value is the degree of "confidence" of the network in its response. The pattern of the network that has the maximal degree of confidence is accepted as final result.

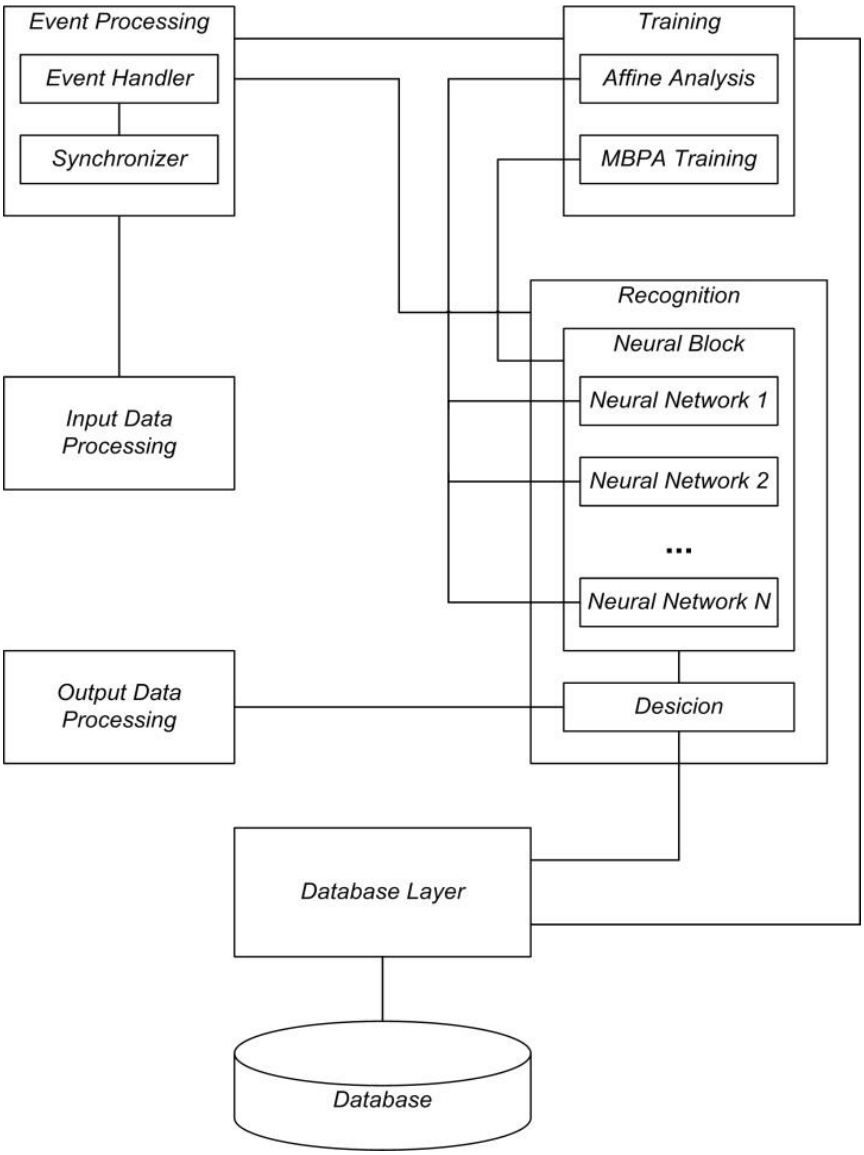

Fig. 2 Schematic diagram.

The specificationof the method is the parallelization of data processing both in the training process and at the stage of recognition. Independence of neural networks from each other allows us to solve a number of problems, such as a significant increase in learning rate due to the impact only on a specific network with a little number of patterns, simple and safe parallelization of calculations using popular technologies (CUDA, MPI), increasing the accuracy of recognition by eliminating conflicts. Individual neural networks training processes and pattern recognition are accelerated in several times due to significant reduction of the working sample.

Handwriting recognition system based on the proposed method consists of the following components (Fig. 2):

1)Event Processing, that provides multitasking and synchronous event processing. The events include: character recognition, structural analysis of the mathematical expression, removing characters, neural network training.

2)Training, that includes a module Affine Analysis (affinity analysis), that analyzes the similarity of images from the training sample and splits it into clusters, and the module MBPA Training, implementing a modified backpropagation error algorithm of neural network training.

3)Recognition, that includes Neural Block module, keeping a collection of neural networks, and Decision module, taking decision about the result.

Database Layer module provides interaction with the database system. The database stores parameters of multilayer perceptrons trained with a modified backpropagation error algorithm that are necessary to the stage of handwriting recognition. Dictionaries defining a set of patterns for each multi-layer perceptron are also stored in the database.

Characters recognition result being corrected by user, corresponding neural network will continue being trained updating the parameters of the classifier in the database. Thus the proposed solution makes it possible to personalize handwriting recognition system, increase its efficiency and to adjust the system to user's handwriting.

IV. Experimental Researches and Test Results

To test the effectiveness of the proposed method experimental researches were conducted that enable to assess the quality of handwriting recognition. For neural network training a sample of 36 patterns and 360 handwritten characters was used (5 different outlines of each pattern). The sample was passed through affine analyzer, which has singled out separate clusters, dividing 36 patterns in 6 groups of 6 patterns. 6 multilayer perceptrons were initialized, a modified backpropagation error algorithm was run for each of them. Thus we found the values of weighting coefficients that are required to initialize the neural network.

Testing was conducted by handwriting characters in a real-time mode into a tablet with a stylus. The total sample for the test is 200 handwritten characters. The average time of recognition of each character is 80 milliseconds (less than one-tenth of a second) for a computer with the following specifications: CPU Intel Core 2 Quad 2.4 GHz, RAM 4 GB.

Overall recognition accuracy: 91.37%.

Accuracy of selecting the "correct" neural network when using a recognizer with parallel neural networks: 96.29%.

Fig. 3 represents the diagram showing each of 6 neural networks "confidence" during the testing.

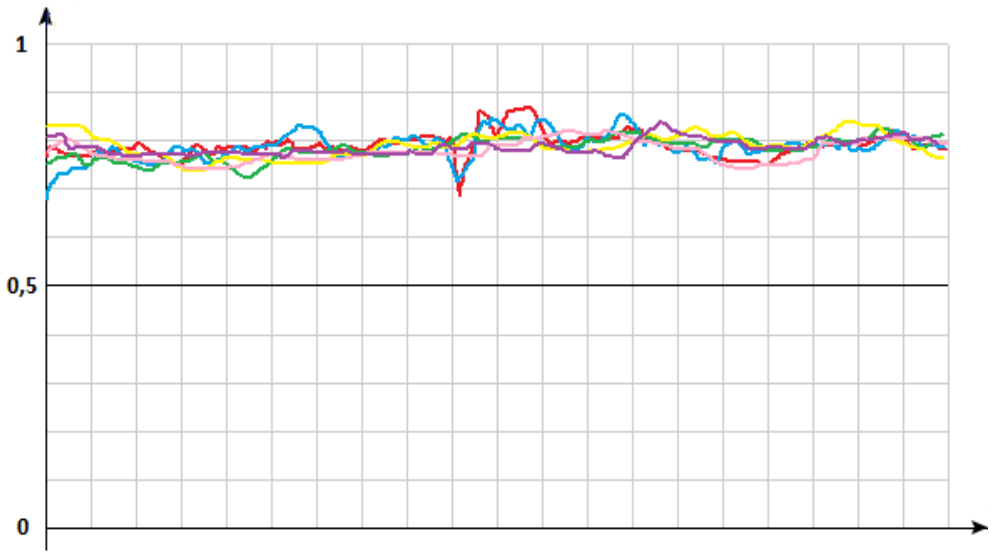

Fig. 3 Recognition diagram.

Accuracy of selecting the right perceptron is higher than the overall accuracy because of the possible classification mistakes in perceptrons. However extremely little difference in overall accuracy and selection accuracy (less than 5%) shows that virtually in all experiments the decision was made in favor of release of the network which showed the correct result. The average recognition time of each character was is 80 milliseconds, which meets the requirements for using the system in a real time mode. Recognition accuracy is 91.37%, the structural analysis accuracy is 71.29%.

V. Conclusion

The article describes a method of handwritten characters recognition input into the computer in a real time mode, which is based on suggested approaches of handwritten characters recognition, interconnected with the idea of parallel data processing. The experimental studies of the proposed method which show a positive result of its operation are described.

Implementation of method corresponds to all the following requirements:

1. Flexibility and capacity for further development.
2. Safety.
3. The minimum response time to the request.
4. Ability to adapt to different handwritings.
5. Convenience and simplicity of the interface.
6. Efficiency.

Acknowledgment

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Technical vision system designed to analyze seeds quality

Svetlana Ostroukhova, Mikhail Tatur

***Abstract*— The possibilities of the use of technical vision systems (TVS) in agriculture for seeds quality analysis are presented. The paper contains the analysis of the requirements for the system and its design. The idea of static TVS is given.**

***Keywords*— technical vision system, seeds quality analysis, optical sorters, static technical vision system.**

I. INTRODUCTION

Technical vision systems (TVS) play a significant role among modern technologies. TVS overcome the limitations of human vision, expand the range of possibilities for the analysis of different images. TVS can be used in conditions unsuitable for humans, especially when the worker's life or health can be damaged.

II. THE PROBLEMS SOLVED BY TVS FOR SEEDS QUALITY ANALYSIS

A. Seeds infection and illnesses detection

Nowadays, specialists identify an illness visually. Small spots on the seeds may be unrecognized or unnoticed. In the brewing industry seeds are germinated (soaked in a warm humid environment) for malting for several days. If some seeds are infected the infection will spread rapidly. As a result, the whole portion becomes unusable.

B. Seeds mixture analysis

Sometimes seeds in a mixture can be rather small with length up to 5-7 mm). It'll take a specialist about the whole day to analyze 12g of a mixture that consists of fescue, ryegrass, bentgrass and Kentucky bluegrass. At the end probability of a human error rises, incomplete seed can be skipped a culture can be detected incorrectly and so on.

In the baking industry TVS helps to determine impurities, such as seeds of another kind of culture. In canning, green vegetable pea shouldn't be mixed with brown fodder pea.

C. Seeds viability determining

Seeds curvature, hollowness shall, fullness and color can be determined visually. The luminescent method helps to determine seeds infections, to recognize viable and unviable seeds. Removing the unviable seeds from a mixture makes the using of the crop areas more effective and help to avoid empty spaces where weeds can appear.

For the purposes of sorting and cleaning of seeds from impurities optical sorters are used. Each seed or a piece of seed is checked. If it doesn't meet appropriate standards it'll be sent to special tray for waste, as a rule, by a sharp concentrated exhaust of compressed air.

There is Voronezhselmash that is the manufacturer of the optical sorters in the CIS. Its equipment sorts the seeds by color, shape and size [1]. The cost of such equipment is about rather high.

Bühler (Switzerland) is another manufacturer of the optical sorters, that analyze such seeds properties as color, shape and size. It has a number of modern technologies (special cameras

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with high resolution, additional cameras InGaAs for invisible properties analysis, PROfile technology for defects detection, extractors) [2].

III. DETERMINATION OF REQUIEREMENTS

TVS should classify seeds, determine the impurities, determine seeds quality (find collapsed, shriveled, incomplete), identify seeds infections. So the system should meet the next requirements.

Mandatory requirements for the system are the next.

- A presence of high-resolution color camera (for getting images of seeds and subsequent analysis of their color, shape and other characteristics).
- Providing high speed analysis.
- Use materials that meet industry standards (e.g. for the food industry).
- Availability of preprocessing module (for brightness characteristics improving, filtering).
- Image processing module (objects detection, properties calculation).
- Classifier module.

If there is a problem of physical separating of seeds, the system as a rule should have high speed of seeds transporting, wear resistant coating along the transporting path that doesn't injure seeds, mechanism for impurities extracting.

Additional requirements for the system are vibrator for better seeds distribution on a surface, special (infrared, ultraviolet, visible range, X-rays, or a combination of them) and reporting module.

IV. TVS STRUCTURAL SCHEME

The most interesting TVS is the one that can classify and then separate seeds. Existing equipment uses small channels for separating seeds. Seeds follow along the channel one by one, video camera gets image, the system classify every seed and then a seed should get either to the main tray or to the waste tray. Better performance is achieved by increasing the number of channels. It causes size and cost increasing.

On the other hand, the analysis can be done without channels. An example of the system is in fig. 1.

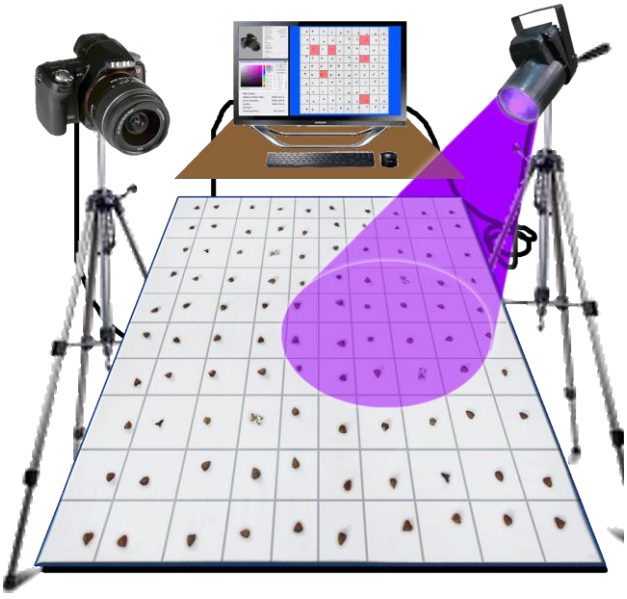

Fig. 1. Example of TVS for seeds analysis.

The seeds are distributed at the surface. The data from camera get to the processing module. The objects (seeds and waste) are identified in the image and classified. We need a database with the information about cultures and seeds properties that will be used by the system to classify objects. After the analysis the system should calculate a sequence to extract some kinds of objects. Then the objects can be extracted in different ways. For example, the surface consists of special cells. After the analysis cells with the same kind of objects are opened, so the objects get to a container. Then the other cells are opened and so on until all the seeds are classified.

The next step is a report creation. A specialist can add some data to the report, and the system should make a conclusion about seeds quality. Also we need a database with standards. A structural scheme is shown in fig. 2. Let's discuss each module with more details.

Images preprocessing module increases the analysis quality. At this module brightness, contrast and sharpness can be corrected, some noise can be removed. We can use filters for better visual difference between objects and the background surface.

Properties calculation module calculates objects properties for the classifying. The seeds can be classified by its color, size, shape and weight. Sometimes its light can be analyzed. For each case some of the parameters are more informative than others.

Color is an important property when we need to classify plant species of the same culture and when we need to detect infections. In some cases the most noticeable difference between the seeds is their form.

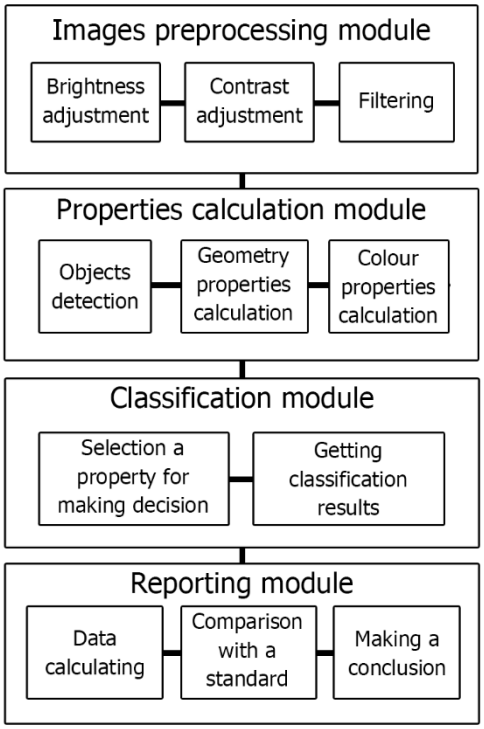

Figure 2. A structural scheme.

The size of seeds can be important too. Fig. 3 shows a mixture of lawn grasses. There are relatively big seeds of ryegrass and fescue and small seeds of Kentucky bluegrass. It's rather difficult to compare its shape. But we can detect a culture by its size. The size of ryegrass and fescue is about 5-7 mm and the size of Kentucky bluegrass seeds doesn't exceed 3.5 mm.

We can get additional information when use luminescence analysis. The method helps to detect seeds infections, determine viability of a seed. The main idea of the method is that after processing with special liquids or in some lighting spectrum the seed begin to glow in a specific way or don't change the color.

Full and empty seeds have different weight. But it's difficult to use the property. Existing sorters don't use it. E.g. if the weight of 1000 seeds is less than 2g, we should use super accurate scales and we need to analyze each seed separately. It causes speed reduction and the system will be more expensive.

Fig. 3. An example of lawn grasses mixture with waste.

In a classification module a decision about object is made. Depending on its size, shape and color it can be a seed of some culture or waste. The main property should be selected, because properties importance varies in different cases. Then each object is classified.

When the analysis is finished, a report should be composed. The system has all the information about mixture and seeds.

V. CONCLUSION

TVS is rather useful in seeds analysis. It can solve a number of problems: counting the number of each component in a mixture, determine its quality, identify seeds defects and impurities, the detect infections. TVS advantages are high processing speed, accuracy, efficiency. The most important advantage is that system can't be tired, the analysis is always impersonal and specialists can save their health (vision).

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Approach of writing NPE-safe code in java applications

Vladislav Matelsky and Natalia Lapitskaya

***Abstract*— Null pointers and dealing with them. Automated code checks by compiler. Usage of Maybe to reduce amount of null pointer exceptions.**

***Keywords*— Software quality, programming technologies, Maybe, compiler-checks, human factor.**

I. Introduction

Complexity of developed systems is growing as well as complexity of goals they are intended to achieve. One of factors that make systems more complex is that the same development tools are used for their creation. Abstraction level of problems to be solved is growing faster than the abstractions that programming languages provide. This difference makes coding process more vulnerable to human factor related mistakes. Therefore the better development tools or modification of development methods are needed.

In some spheres the importance of error may cost the earth. The error may lead to deaths of people or to crashing of highly expensive scientific machines. For example the catastrophe Ariane 5, that happened June 4 1996. According to the prof. Jacques-Louis Lions [1], the reason of the catastrophe was a mistake in software that occurred at boundary values.

To minimize the probability of errors checking of software reliability should be performed for all stages of system creation. If human performs verification, the chance of human-factor related mistake still exists. Instead of humans it's possible to rely on automated tools that check different aspects of systems under development.

This article provides a way to prevent NPE using set of simple rules and agreements during development process.

II. Reasons of NPE

At first definition of NPE has to be provided. NPE is an abbreviation of "null pointer exception". Where pointers are links to memory that application uses to store own data. These links are commonly known as variables. The variables point to application memory or to a "null area". If a variable points to the "null area" it means that this variable specifies no data application can use. Since this variables contains no data attempts to obtain data from them are exceptions.

If application tries accessing objects by null pointer NPE occurs and this cases may be threated as breach of interaction contract: the null pointer occurs in a place where null pointer shouldn't be. Such contract e.g. is a set of input and output parameter. In programming languages it's a set of typed input/output values. Passing null pointer in function that don't expect it is a breach of interaction contract. Let's take a look at the following function:

```
Complex sum(Complex a, Complex b) {
        return a.add(b);
}
```

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The goal of that function is to sum two complex numbers. Thereby, the function takes two complex values. But it's also possible to pass null pointers instead of certain parameters. It's not contrary to java specification, but it imposes an implicit restriction on the implementation. The implementation must take into account the fact that any of the parameters can be null pointer.

On the other hand the function is responsible for addition of two complex values while NULL is not a complex value, therefore passing it is the breach of interaction contract.

To be sure that NPE is impossible it's needed to analyze the whole code to check whether the variables are initialized correctly and none of computations produces null. And places where null pointers are possible are the places of potential NPE. Lots of condition checks make difficult looking through the code to understand it and to find other mistakes. Furthermore, as it was described above, java compiler allows passing nulls instead of objects everywhere. Such assumption can leads to a situation when changed code produces null pointer and pass it to other one that crash the application with NPE. Compiler says nothing about it despite the fact that it's breach of interaction contract. In other word modules may lose consistency silently. And because NPEs are produced in some use cases only, the investigation of them become more difficult.

III. WAY OF NPE MINIMIZATION

As it was described above NPEs occur when the interaction contracts are breached. Compiler does not detect situations of that kind, therefore there is not warranty that contracts in the whole system are consistent. To prove that additional analysis works are needed. The most logical way is to check consistence during the build process. And if such error is found the build process should be stopped.

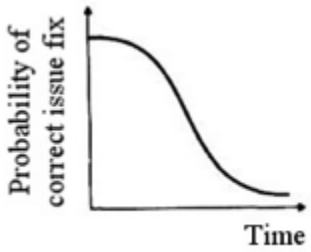

Fig. 1. Dependency of issue fixing cost from the time when the issue is detected

Detection of contract beach during the build step doesn't allow forward movement of product until issues are not fixed.

Which means that this kind of issues will be fixed during testing process, because testing process goes afterwards. Therefore tests will be performed on consistent modules.

Such way allows detecting issue earlier, and the earlier issue is detected the less money fix costs. This relationship is shown in fig. 1.

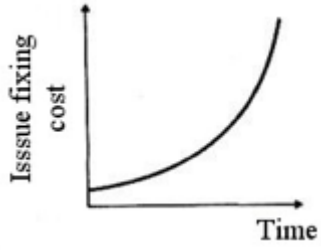

Fig. 2. Probability of applying correct issue fix during the application lifetime

Additional checks of contract consistency allows to detect issue earlier, therefore fixing of it will cost less money. And from the right graph follows that the probability of detection becomes higher.

The most reliable way of preventing issue is to prevent the possibility of occurring issues of that kind. For instance, there are some languages like Haskell where null pointers absent as a class. Instead of nulls programmers use special type called Maybe. Maybe can take one of two states: Nothing of “Just Value”. Nothing is an equivalent for null.

```
data Maybe a = Just a | Nothing deriving (Eq, Ord)
```

Variable of Maybe type clearly specifies that it may obtain no value. So, to get a value programmer have to check whether variable have it. It's semantic approach that helps to differ whether it’s value or maybe it's value. In the second case the check follows from the type.

One by one other languages implements similar solution. For instance, Scala has Option. Or Kotlin's compiler allows to assign null to variable only if “?” is followed after the type of variable. Let's take a look at example:

```
var a: Int;  // assigning null is forbidden
var b: Int? //  possible to assign null
```

These types are not equals therefore compiler checks all assignment operations between them:

```
b = a; // correct assignment
a = b; // type mismatch
```

Such way of defining type of variables allows reducing count of NPEs mostly because of types semantic: the type presupposes that value may be absent and it force programmer to think whether null-available type is needed in certain case. In additional such code is friendlier for verification: it's possible to detect where value-containing check is missing. Because if value-check is not needed it means that type should be strict and doesn't allow to assign nulls.

IV. Implementing type Maybe for Java

Common java library doesn't support semantic difference between null-possible and null-safe types, therefore NPEs occurs. There are several languages that successfully prevents from this kind of issue, so it may be useful to implement similar approach on java. One of the possible implementations is shown in the listing 1.

Listing 1. Implementation of NPE-safe class on Java

```
public abstract class Maybe<T> {

    public static <T> Maybe<T> just(T value) {
        return new JustValue<T>(value);
    }

    public static <T> Maybe<T> nothing() {
        return new Nothing<>();
    }

    static <T> Maybe<T> nullIsNothing(T value) {
        if (value == null) {
            return nothing();
        } else {
            return just(value);
```

```
            }
        }

    public abstract boolean isValue();
    public abstract T value();
    public abstract T or(T defaultValue);

    public static class JustValue<T> extends Maybe<T> {
        private final T value;

        public JustValue(T value) {
            this.value = value;
        }

        @Override
        public boolean isValue() {
            return true;
        }

        @Override
        public T value() {
            return value;
        }

        @Override
        public T or(T defaultValue) {
            return value;
        }
    }

    private static class Nothing<T> extends Maybe<T> {

        @Override
        public boolean isValue() {
            return false;
        }

        @Override
        public T value() {
            throw new RuntimeException("Trying to obtain value from nothing");
        }

        @Override
        public T or(T defaultValue) {
            return defaultValue;
        }
    }
}
```

Class Maybe<T> encapsulates null check in a way to make variable creation code linear. The example is provided in listing 2.

Listing 2. Example of usage of Maybe<T>

```
String defaultString = "Default string";
Maybe<String> withValue = Maybe.nullIsNothing("String with value");
Maybe<String> nothing = Maybe.nothing();
System.out.printf("with value \"%s\"\n", withValue.value());
// System.out.printf("with value \"%s\"\n", nothing.value()); // throws an
exception if uncomment
System.out.printf("or()    for    string    with    value    \"%s\"\n",
withValue.or(defaultString));
System.out.printf("or() for nothing. Should return default string: \"%s\"",
```

```
nothing.or(defaultString));
```

As it's shown in listing creation code is linear, and if it's needed to get value if it exists or default value otherwise it's possible to use method or(). And to obtain certain value programmer have to check whether value exists using method isValue().

V. COMPARISON WITH ALTERNATIVES

Java provides different ways of handling null variables. For example Listing 3 provides comparison with null implementation and listing 4 shows how to handle NPE using try\catch.

Listing 3. Using comparison with null to check if variable is null

```
void printIfValue(String str) {
  if (str != null) {
    System.out.printf("value: %s\n", str);
  } else {
    System.out.printf("no value defined\n");
  }
}
Listing 4. Using try\catch to handle NPE if variable is null
void printIfValue(String str) {
  try {
    System.out.printf("value: %s\n", str.toString());
  } catch(NullPointerException) {
    System.out.printf("no value defined\n");
  }
}
```

The main feature of comparison with null is that programmers have to remember that variable may be null everywhere they are trying to access it. These approaches don't separate null-possible and variable cannot be null, therefore they presuppose accessing each variable after null check. So, programmers prefer the following compromise: use null check only if variable may be null. But it's necessary to remember that code is changing, therefore variable may become null after some time and nobody will warns about possible NPEs in this case.

There is one more approach based on using annotations [3]. The approach is provided in listing 5.

Listing 5. Using annotations to specify that function expects not null parameter

```
void printIfValue(@NotNull String str) {
    System.out.printf("value: %s\n", str.toString());
}
```

If anybody passes null to such function compiler will generate warning. Such solution is suitable if team is looking through warnings list and fixing them. It allows to pass null as parameter, compile code and perform it.

The example of function that process Maybe variable is shown in listing 6.

Code described in Listing 6 provides following output:

– value: String with value

– no value defined

During code review places where Maybe variable is not checked is clearly visible that allows

to detect possible error earlier.

Listing 6. Example of processing Maybe-parameter in function

```
printIfValue(withValue);
printIfValue(nothing);

public static void printIfValue(Maybe<String> maybeString) {
        if (maybeString.isValue()) {
            System.out.printf("value: %s\n", maybeString.value());
        } else {
            System.out.printf("no value defined\n");
        }
    }
```

Moreover if the whole team follows the rule “use no nulls in own code”, approach with Maybe introduces compiler check on passing wring parameter. For example, if function expects to get Maybe, programmer can pass Nothing in function. On the other hand if function expects certain type and passing null is forbidden, programmer should change the signature of the function. Changing of signature produce a set of compiler errors that indicates breach of interaction contract that should be fixed as well to restore consistency.

VI. Conclusion

This article describes the reason why NPE occurs and a way to struggle against it in different programming languages.

For instance, some programming languages don't use null pointers at all. Other languages require direct specifying that null can be assigned to variable. For other languages like java was introduced similar way of preventing NPE.

The approach that was described in current article had helped to reduce count of NPE close to 0% during development process one of business applications.

Ought to remember that java still allows assigning null pointer to variable of Maybe type, but it should be treated as incorrect usage of development methods. Particularly Maybe is intended to change null pointers inside application code under development, therefore null pointers should be changed with Maybe.nothing() as quickly as possible in places of obtaining data places that are out of developer's control like remote sources.

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CERES

Automating the creation of OLAP-cubes on the base of MS SQL AS for optimization of the infrastructure of Informational analytical system of the enterprise

Dzmitry Karzhounik, Natalia Lapitskaya

***Abstract*—** Automating the creation of OLAP-cubes on the base of MS SQL AS in purpose to get around data access delays of regional informational analytical system caused by extension of raw data.

***Keywords*—** analytical pyramid, informational system, Data Warehouse, Data mart, OLAP, OLAP cube, MS SQL, .NET

I. INTRODUCTION

In our days government facilities usually exploit information systems (IS) with architecture based on outdated technologies. Regional analytical information system (RAIS) was created in 2006 to provide reports exchange and collection of various statistical indicators from organizations in different areas. Such kind of data can be hierarchically organized but after long period of exploitation the growth of raw data in a data warehouse (DW) based on relational database (DB) model leads to noticeable delays in query execution. Existing client applications of the system are strongly connected to current DB model. To resolve that problem cost-effectively such situation creates a need to change already existing infrastructure to make use of that data without warehouse remodeling.

To update the infrastructure of informational exchange of the system new functionality must be added according to modern standards. Such standards can be shortly described by the concept of the "Analytical pyramid" (Figure 1).

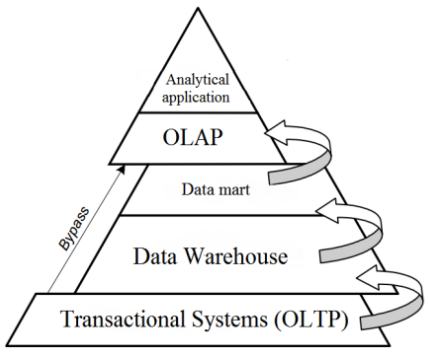

Figure 1. Analytical pyramid

II. ANALYTICAL SYSTEMS

RAIS provides information to the users by integrating data from different data sources. Though to view that data in a convenient way it should be processed and aggregated in a form of summary reports.

RAIS development to the next level means its update to OLAP-system. But the main goal is to create in the system means for enterprise resource planning or business process management.

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Such tasks are related to the area of Business intelligence (BI), so the software should be based on data marts using the technology of multidimensional OLAP-cubes. It's integration into the system will provide the required application performance in terms of growing volumes of data [1].

III. PRACTICAL RESULTS

At the moment RAIAS level according to analytical pyramid is DW and applications generate direct requests to it. If we add a level which includes Data marts and technology to ensure the functionality of OLAP-systems we will get the following schema of information interaction in the terms of Microsoft SQL server technology, which was selected cause it supports local cubes. (Figure 2).

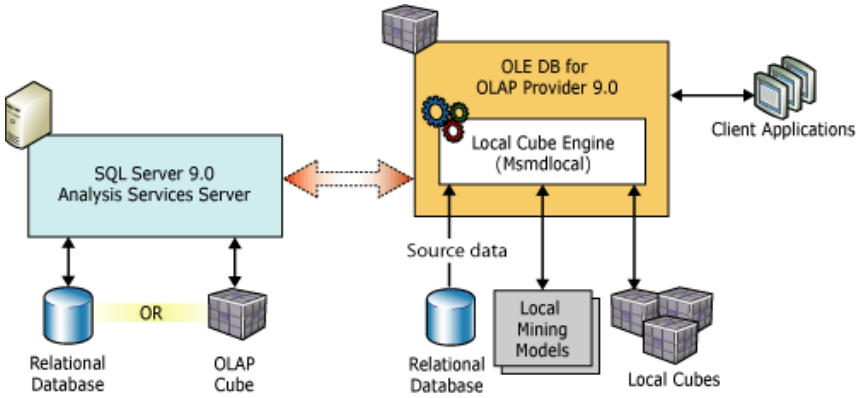

Figure 2. OLAP-systems interaction schema

Short explanation for Figure 2.The system collects reports with different, periodically varying statistical indicators from different branches of the organization in the region:

1. DW - Data Warehouse DBMS Oracle.
2. SI - statistical information, indicators of accounting, financial, etc. accounting
3. EDPS –local data bases of collected SI
4. IA - Interface array, the model describes how the lists are in SI DW.
5. SP IA SI – IA SI training system, designed to collect data from EDPS, convert them to a format IA and transfer the array to be loaded into DW.

BI-solution module in this case means a software that automates the construction of server OLAP-cubes as data marts and OLAP-local cubes as a report file with the extension * .cub. [8][5]

Based on the requirements of the domain user module must obtain a three-dimensional structure of a cube star - model, cube will contain following aggregated information: timing, area and accountable organization, depending on enterprise filial, organizations, and relevant lists of indicators, which reduces amount of excess aggregated data in the reports and data marts.

The resulting solution involves the use of tools and programming language support software to generate local and server cubes based on the data from the repository, as well as provide a complete API for working with data in the cubes and allow the standard to test the correctness of their selection for automatic generation. Comparative analysis showed that for model creation and implementation of the described functionality suitable technology stack from Microsoft to use the .Net platform and C# [3].

Microsoft Analysis Services has OLAP server model supports for local cubes, and integrates with database MS SQL Server, which will provide connection to the DW as the data source. In general with the use of following technologies (Figure 3) helped us to develop required software module with advanced functionality and even provide means of testing the output data [9].

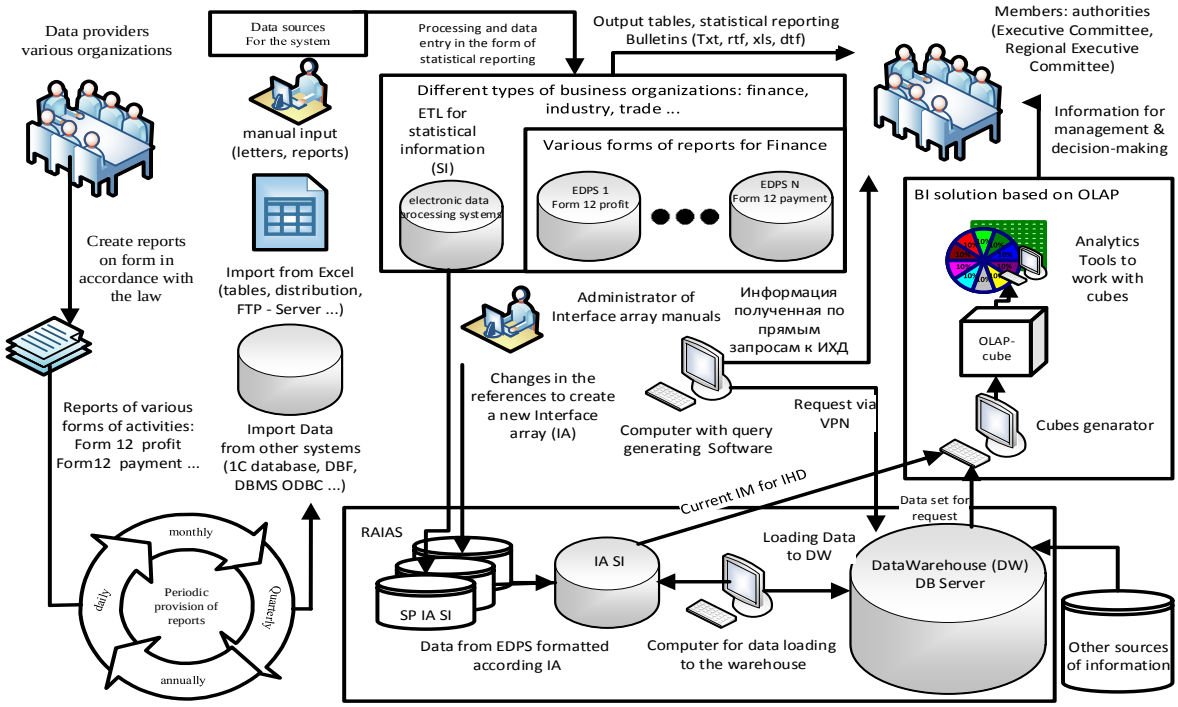

Figure 3. Infrastructure of information exchange system

NET Framework and C# gives following benefits [7]:

1. Modern data storage modes: xOLAP and Local cubes
2. C# + LINQ + Visual Studio + MS SQL Server. Good tool and means for software development
3. OLEDB (for Oracle DW) Connection to different data sources
4. AMO (Analysis Management Objects) for OLAP. Is used to automate the process of creating a cube, we need to do this programmatically [4]
5. ADOMD.NET provides API to work with cube data
6. MDX (Multidimensional Expressions) For testing aggregated data from the DW to cube
7. XML (standard form of data representation) For implementing special functionality
8. XML (standard form of data representation)

OLAP Server cube generation is divided into 7 steps:

1) Connect to the Analysis Services: Create a connection of Analysis Services server.
2) Create a Database: Create a database in Analysis Services server and save it.
3) Create a Data Source: Add a data source (our DW) to the database and set its connection string.
4) Create a Data Source View:
   a) Create a Data Set.
   b) Add Fact tables in Data Set.
   c) Add Dimension tables in Dataset and Relation between them.
   d) Create a Data Source View based on the created Data Set.
5) Create the Dimension, Attribute, Hierarchy, and Member Property Objects:
   a) Add Dimension to the Database.
   b) Add Dimension Attributes.
   c) Set Attribute usage and source
6) Create the Cube, Measure Group, Measure, and Partition Objects:
   a) Add Cube to the Database and set Cube source to the Data Source View.
   b) Add Measure Group to the Cube.
   c) Add Measure to Group and set Measure source.

7) Generate Cube:
a) Add Dimension to the Cube.
b) Use Regular Relationship Between Dimension and Fact Table Measure Group.
c) Link Table Key in Dimension Table with Table Key in Fact Table Measure Group.
d) Save Cube and all objects to the Analysis Services

After creating the cube, it can be processed manually from Microsoft Analysis Services [6], or programmatically so that logic could be included into business logic layer of the software added into the system infrastructure.

IV. Conclusion

It has been found that the OLAP-based solution can be implemented in several steps. First AMO is used to create multi-dimensional structures on the basis of MS SQL analytics server service. On the second step a client application can be developed to provide remote access to the data stored and implement any specific functionality required by the users. On the third step the software module based on ActiveX Data Objects Multi-Dimensional (ADO MD) can be used to create other software application integrated with .NET Framework, which would enhance system infrastructure.

The following tasks were completed in the project:

1) A software method of constructing a multidimensional data model, OLAP-cube, in order to optimize data storage and increase the speed of processing user requests, also increasing the flexibility of the system by excluding redundant data in local marts.

2) Implementation of a software module with the support of AMO.NET ADOMD.NET technologies that allow to connect to the server relational and analytical databases, ensuring the creation of these databases on the server, and provide an ability for automate testing correct data structures.

3) Feature of creating local cubes of data, those can be used as summary reports, gives a convenient way to work with the data from the repository without a need to connect to the database server, just using MS Excel instead.

Members of analytics team have reduced time spent on reporting, due to the developed software module that uses data marts of OLAP cubes, and as a result requests for information are faster. The analysis and reporting procedures has become much easier due to use of local files in custom tools such as Pivot Table.

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Researching of Thermophysical Processes in Acheson Furnace to Develop Automatic Process Control System

Oleksandr Zhadanos, Ihor Derevyanko

Abstract **-** Thermo-physical model of silicon carbide production process in Acheson furnace is worked out. Dynamics of thermal state of reaction zone in the furnace is computed by finite difference method with the use of PC. The dimensions of zones of products of silica carbon thermal recovery due to heat generated when passing electric current through the furnace core are determined according to modeling results. Temperature front of reducing reactions is indicated.

Keywords **-** Silicon carbide, Acheson furnace, thermophysical model, temperature zones, automatic process control system

I. INTRODUCTION

Silicon carbide is one of major artificial inorganic materials widely applied for manufacture of abrasive tools, high-temperature radiators, refractory ceramic as well as in metallurgy. The most part of silicon carbide in the world industry is produced by method suggested by Acheson in the end of 19th century [1]. The method consists in carbon-thermal reduction of silicon due to Joule heat generated when electric current passing through the furnace core. The principal scheme of self-moving resistance furnace is presented in Figure 1.

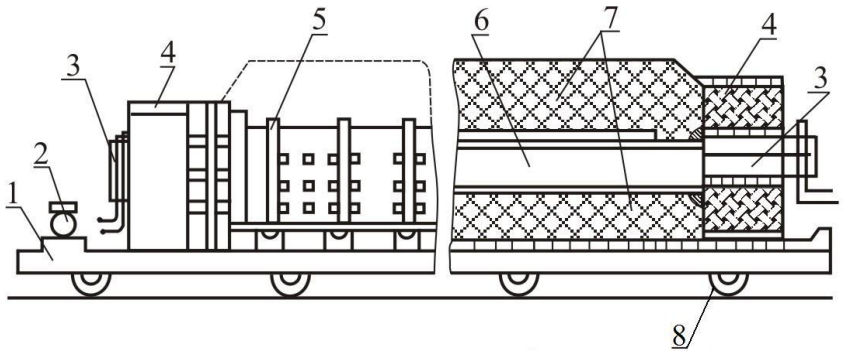

Fig 1. - Self-moving electric resistance furnace for production of silicon carbide: 1 - carriage; 2 – furnace movement mechanism; 3 - electro contact nodes; 4 - fire brick face walls; 5 - side shields; 6 - working electrical resistance (core); 7 - burden; 8 - wheel pair [2]

SiC production process is very labor-consuming and requires significant power consumption 7300-7600 kW·h/t. According to [2], amount of electric energy in the structure of cost price of silicon carbide of abrasive quality is 50-60 %, at burden distribution 60-70 t, commercial yield is 10.5-11.5 tons (15-19%). Therefore, maintenance of maximum product yield at the rational charge of electric energy is an important industrial problem.

The most precise methods of SiC production process control are based on direct measurements of reaction zone temperature. However, high temperature and corrosive environment make it almost impossible to apply direct methods of temperature control with the use of thermocouples or pyrometers. Indirect methods based on measurement of electrical resistance or acoustic emission signals are not used because of errors. Therefore, the process is

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controlled by empirically determined diagrams of dynamics of lead-in power [2].

In this case, the key criterion of power regime control is charge material capability and type of produced silicon carbide. Information about processes of furnace thermal field formation and parameters of chemical reactions initiated by this field is required for development of rational technological regimes of SiC production by Acheson`s method. Therefore it is reasonable to use mathematical modeling in order to receive information about these processes.

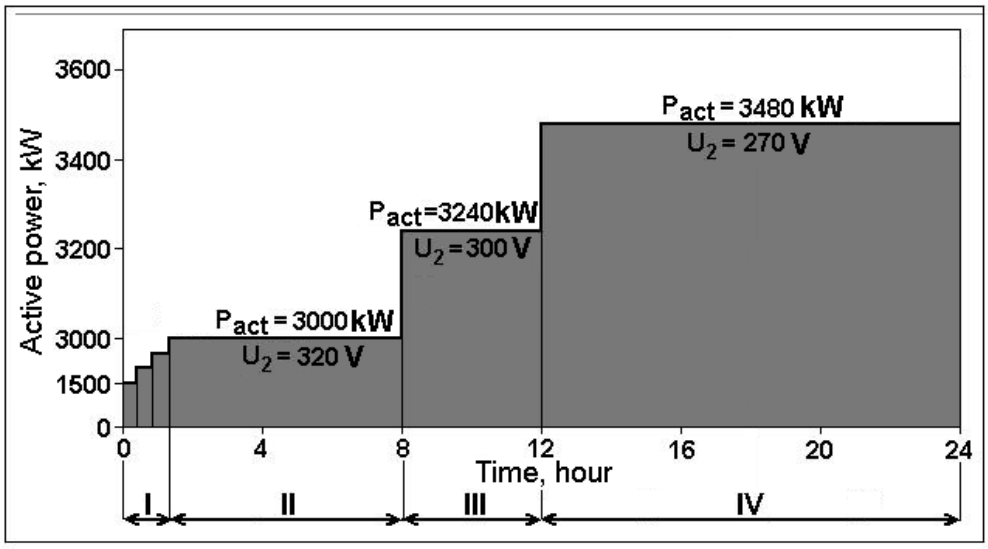


Fig 2. - Dynamics of lead-in power during the process of silicon carbide production: I (0-1.5 h) - power 1500-3000 kW; II (1.5-8 h) - power 3000 kW; III (8-12 h) - power 3240 kW; IV (12-24 h) - power 3480 kW [2]

II. RETROSPECTIVE OF RESEARCHES AND PUBLICATIONS

A number of publications, for example [3, 4], are devoted to investigation of heat and power processes in Acheson furnace. These works present methodology of construction of mathematical models of this process. The current level of mathematical modeling and development of personal computer enables to remove the specified restrictions. The task of present research is working out of computer model of thermal condition of Acheson furnace reaction zone which will enable to develop further technological recommendations concerning conduct of silicon carbide production process.

III. THERMO-PHYSICAL MODEL OF THE PROCESS

Acheson furnace is a complicated power-technological and thermo-physical unit in view of mathematical modeling. The main heat source is electric energy during silicon carbide production process. Electric power of furnace is supplied from monophase transformer (Figure 3).

Heat current formed in the center is distributed from internal zones of the furnace towards external zones. Due to warming-up of reaction burden, the process of carbide formation starts in the center and then is distributed in the contiguous zones. Total reaction of carbon-thermal process of high-silica sand interaction with carbon is as follows:

$$SiO_2+3C = SiC+2CO;\ \Delta G=555615-322{,}11\cdot T,\ kJ/mole \quad (1)$$

There are four temperature zones in the resistance furnace [3, 5, 6].

1. $T < 1452°C$. At these temperatures there is no interaction of components – composition of initial and end products is almost the same.

2. 1452 °C < T < 2609°C. The main siliceous product is silicon carbide in reaction products at excess of carbon, and at deficiency of carbon - SiO2 recovery takes place only until the formation of gaseous monosilicon oxide.
3. 2609 °C < T < 2927°C. In this temperature interval silicon is the basic reduction product.
4. T > 2927°C. In this area of temperatures all siliceous products of reactions at any relationship of initial components can be only in gaseous state.

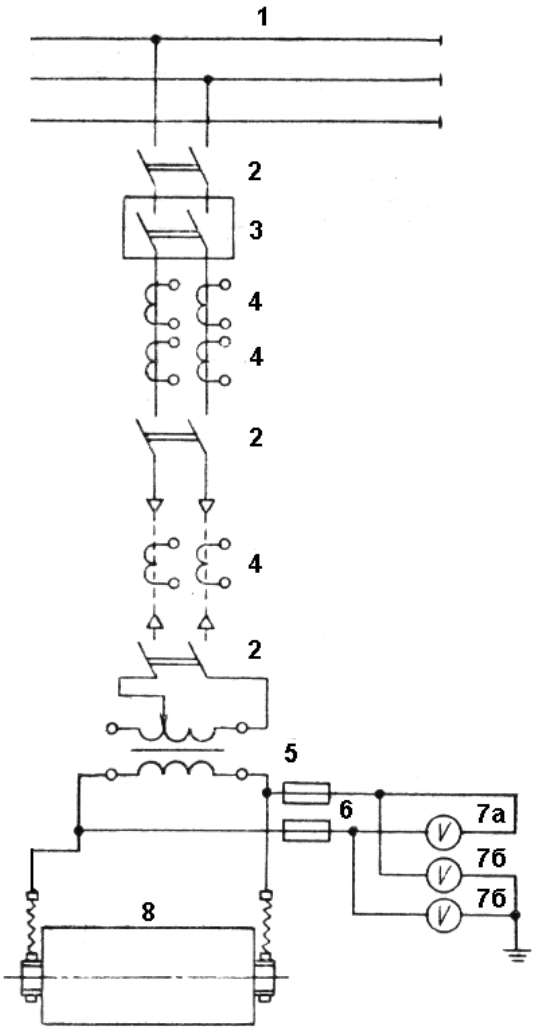


Fig 3. - Schematic circuit diagram of turning resistance furnace on for silicon carbide production with power 4000 kV·A: 1 - high voltage bus (10 kV); 2 - air-break disconnections (type РВФ-10/600); 3 - oil circuit breaker (type ВМГ-10, 10/600); 4 - measuring current transformer (type ТПЛ-10-0.5/Р-400); 5 - furnace transformer; 6 - thermal links; 7 - voltmeter gauges (type Э-378) for linear (a) and phase (b) voltage; 8 - resistance furnace

The furnace operates in unsteady thermal regime therefore heat losses increase in due course. Temperature conditions of the furnace define the process of silicon carbide formation. Thus, the following factors have effect on dynamics of thermal condition of furnace: energy generated in the center of furnace, energy consumption due to endothermic reactions, significant amount of off gases, heat transfer in the environment. Taking into account lay-out of furnace center along the whole length of the furnace we assume uniform energy generation from a core surface. When estimating dynamics of thermal condition of furnace lining we consider that heat currents are directed only in axial direction. Therefore in this paper we consider a two-dimensional model of heat transfer in the furnace volume and one-dimensional model of heat transfer in

fireclay lining through the bottom and side walls. Then differential equations of heat conduction for furnace laboratory (2) and linings will be as follows (3) [3]:

$$C_s(T_s)\cdot\rho_s\frac{\partial T_s}{\partial\tau}=\left(\frac{\partial}{\partial x}\left[\lambda_s(T_s)\frac{\partial T_s}{\partial x}\right]+\frac{\partial}{\partial y}\left[\lambda_s(T_s)\frac{\partial T_s}{\partial y}\right]-C_{gas}\cdot\rho_{gas}\cdot\upsilon_f(\tau)\cdot T_{gas}\right)-\frac{\rho^0}{\nu\cdot\mu}\cdot Q_{SiC}\frac{d\eta}{d\tau}, \quad (2)$$

$$\begin{aligned} C_l(T_l)\cdot\rho_l\cdot\frac{\partial T_l}{\partial\tau}&=\frac{\partial}{\partial x}\left(\lambda_l(T_l)\frac{\partial T_l}{\partial x}\right)\ \text{for furnace walls}\\ C_l(T_l)\cdot\rho_l\cdot\frac{\partial T_l}{\partial\tau}&=\frac{\partial}{\partial y}\left(\lambda_l(T_l)\frac{\partial T_l}{\partial y}\right)\ \text{for furnace bottom}\end{aligned}, \quad (3)$$

where: Cs(Ts), $C_l(T_l)$, C_{gas} - specific heating capacities of charge materials, lining and waste gas;

ρ_C, ρ_l, ρ_{gas} - densities;
$\lambda s(Ts)$, $\lambda_l(T_l)$ - coefficients of thermal conductivity of charge materials and lining;
$v_f(\tau)$ - rate of gas filtration;
Tgas - gas temperature;
ρ_0 – initial concentration of charge materials;
v, μ - stoichiometric coefficient and molecular weight of initial charge materials;
Q_{SiC} – thermal effect of reaction of SiC formation;
η - depth of transformation of initial materials.

IV. INITIAL AND BOUNDARY CONDITIONS

There are next boundary conditions when we solving this task [7]:

- the 2nd rate for interface furnace center - furnace laboratory (as we know power generated on a core)

$$-\lambda_s(T_s)\cdot\left(\frac{\partial T}{\partial x}+\frac{\partial T}{\partial y}\right)=q_s(\tau), \quad (4)$$

where $q_s(\tau)$ - unit power generated on a core (figure 2).

- the 4th rate on the interface of furnace work zone and lining

$$\left.\begin{aligned} T_{c.external}&=T_{1.internal}\\ \lambda_s(T_s)\cdot\left(\frac{\partial T_s}{\partial n}\right)_{n_{s.external}}&=\lambda_l(T_l)\cdot\left(\frac{\partial T_l}{\partial n}\right)_{n_{l.internal}}\end{aligned}\right\}, \quad (5)$$

where: $T_{c.external}$ - temperature of external surface of the charge,

$T_{l.internal}$ - temperature of internal surface of lining.

- the 3rd rate on the interface of furnace work zone and environment (as the furnace top is open and gas is removed from the surface as a reaction product)

$$-\lambda_s(T_s)\frac{\partial T}{\partial y}=(\alpha_{env1}+c_{gas}\cdot\rho_{gas}\cdot\upsilon_1(\tau))\cdot(T_{c.external}-T_{env}) \quad (6)$$

where: $\alpha_{env\ 1}$ - coefficient of heat-to-environment transfer from furnace surface,

T_{env} - environment temperature.

- the 3rd rate for interface lining – environment.

$$-\lambda_l \cdot \left(\frac{\partial T_l}{\partial n}\right)_{n_{l.external}} = \alpha_{env2} \cdot (T_{l.external} - T_{env}) \quad (7)$$

where: $\alpha_{env\,2}$ - coefficient of heat-to-environment transfer from furnace bottom and walls.

We assume that in the initial moment of time the temperature inside furnace and lining and environment temperature are equal.

V. MODELING AND ANALYSIS RESULTS

Dynamics of thermal condition of furnace reaction zone was computed by finite difference method with the use of PC. Results of modeling are illustrated in Figure 4 and 5 [7]. Zone development of reduction processes causes the formation of intermediate products of reduction reactions except for silicon carbide.

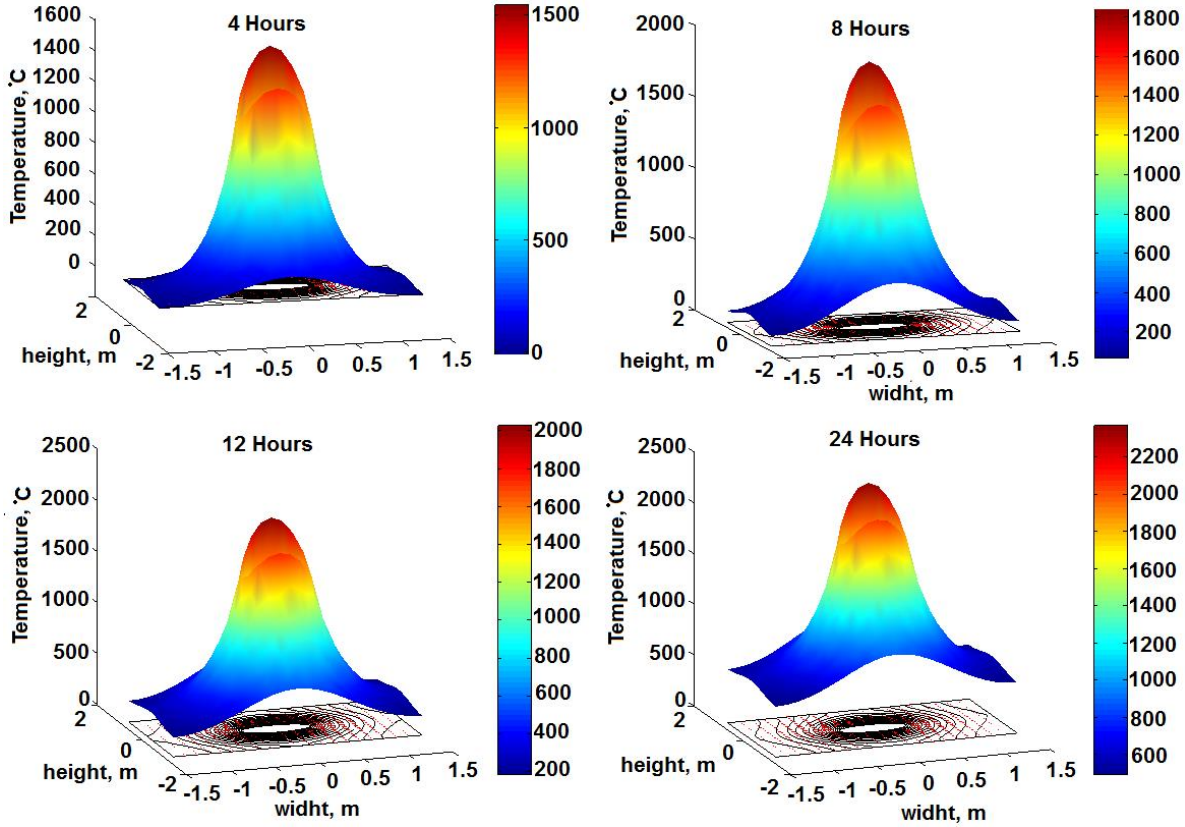


Fig 4. - The distribution of the temperature field in the cross section of Acheson furnace after 4, 8, 12 and 24 hours of heating

Zone development of reduction processes causes the formation of intermediate products of reduction reactions except for silicon carbide.

1. Zone I - area of formation of intermediate products of silica reduction by carbon. Presented by siloxicon and aggregates containing 40-60 % SiC.[7]
2. Zone II - amorphous area presented by crystals β - SiC (70-85 % SiC).
3. Zone III – macro-crystalline abrasive α - SiC (92-98 % SiC).

Dimensions of zones of formed products of carbon-thermal silica reduction due to heat are defined according to modeling results, the temperature front of reducing reactions is marked out. It is determined that zone of siloxicon and aggregates (I) is 60 mm thick in the bottom and side parts and 190 mm in the top. Sizes of amorphous zone (II) presented by crystals β – SiC

are 250 mm and 340 mm. The area of coarse silicon carbide (III) in the bottom and side part is 120 mm thick and 300 mm thick in the top. Asymmetry of zones is caused by upward currents of hot gases [8].

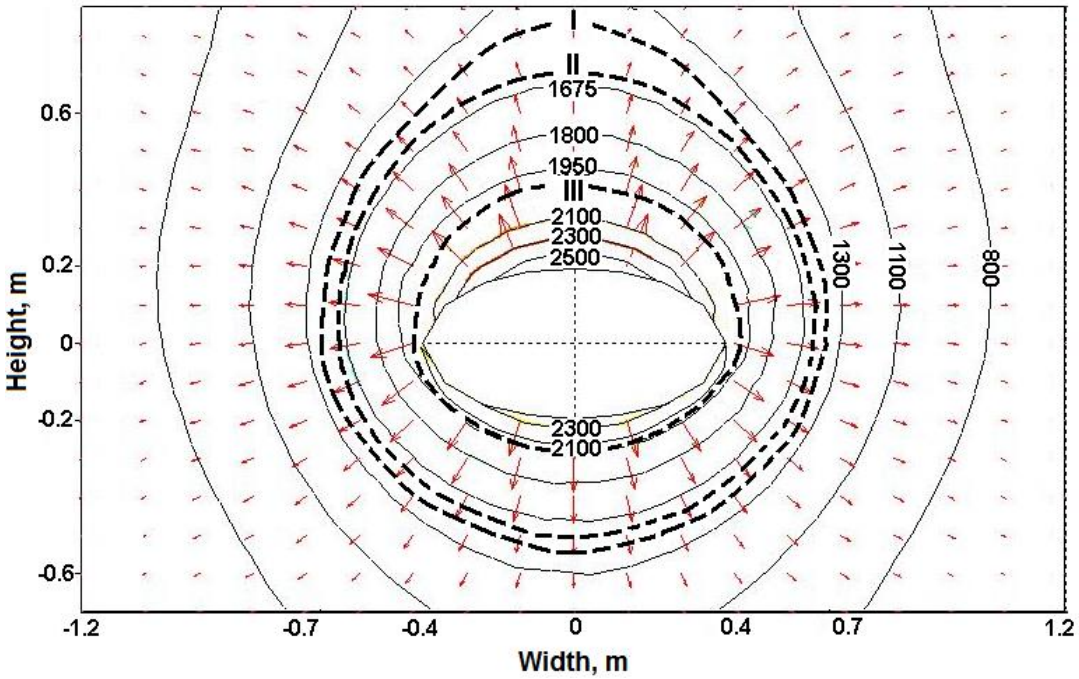


Fig 5. - Temperature pattern distribution across the section of reaction zone of Acheson furnace after heating during 24 hours

VI. THE STRUCTURE OF AUTOMATIC PROCESS CONTROL SYSTEM

The structure of automatic process control system is developed (fig. 6). The system can opportunity to setting of thermophysical model parameters. And we offer commensurability-integral regulator in this system.

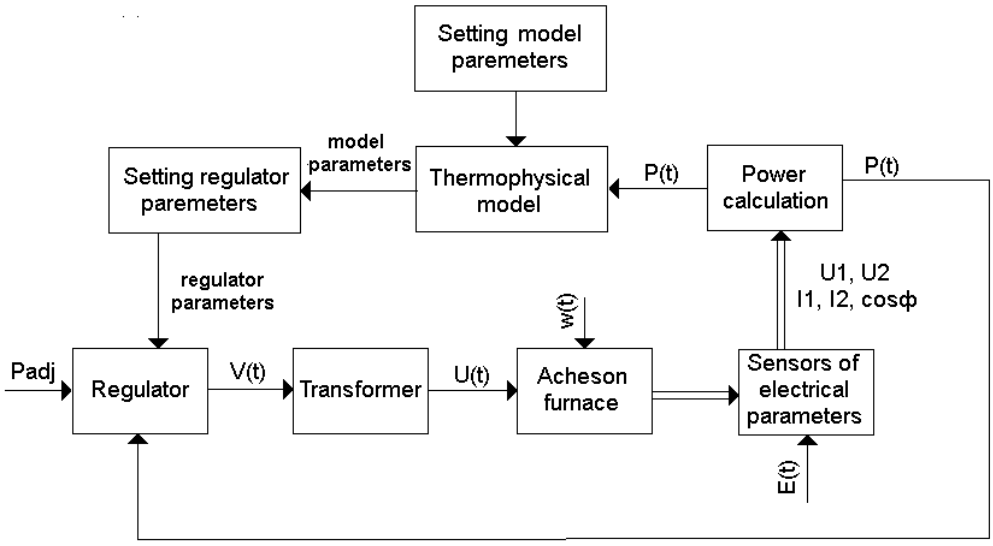
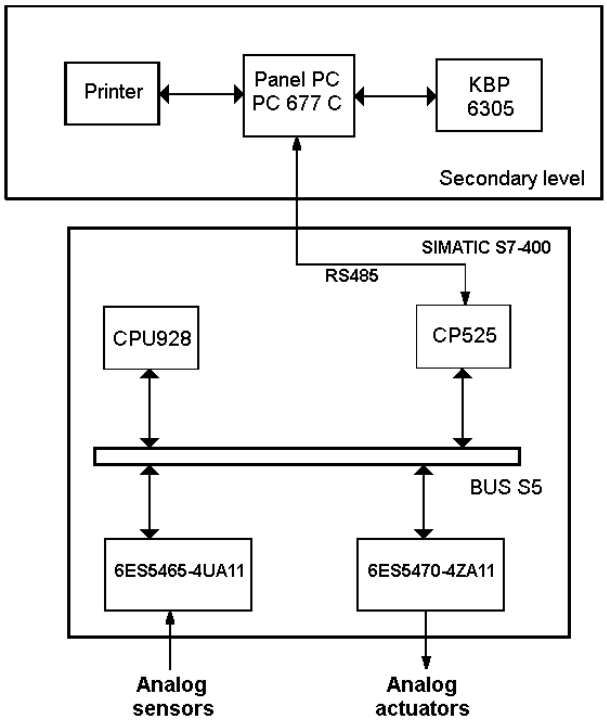


Fig 6. - The structure of automatic process control system:

P_{adj} - adjusted electrical power; V(t) – control effect of regulator, U(t) - secondary voltage, w(t) – disturbance, E(t) – vector sensor error, U1, U2, I1, I2, cosφ – electrical parameters, P(t) – electrical power

Possible structure of control computer system can be based by Siemens industry computers and controllers (fig. 7).



Pos. design	Title
Panel PC PC 677 C	Industry computer
CP 525	Communication processor
S5	Internal data bus
CPU 928	Central processor
6ES5470-4ZA11	Analog output module
6ES5465-4UA11	Analog input module
KBP 6305	Keyboard

Fig 7. - Possible structure of the control computer system

VII. CONCLUSIONS

1. Thermo-physical model of silicon carbide production process in Acheson furnace is developed. Dynamics of thermal condition of furnace reaction zone is computed by finite difference method with application of PC.

2. Zones of existence of products of carbothermic reduction of silica are sized up by results of modeling.

3. It is reasonable to estimate effect of input power dynamics on sizes of zones of reduction products by means of developed model in order to obtain analytical dependences of change of thermal condition of furnace reaction zone which will enable to work out technological recommendations on conduct of silicon carbide production process and to develop Automatic Process Control System of furnace.

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Modelling of the Tendering Process

Tetiana Kolpakova

***Abstract*—**The model of electronic tendering process was developed. The suggested model allows splitting tendering process into several stages from preparing of tender documentation to selection of a winner, which helps to specify input and output data of each stage and optimize all stages separately, namely maximize the effectiveness of their results and minimize the time spent on their accomplishing.

***Keywords*—**e-procurement, tendering, group decision making.

I. Introduction

A tender is one of the most effective and fair ways to enter into a sales contract. It often helps to solve a problem of choosing the best solution in conditions of limited resources. In this case the validity of final decision determines the direction of further development of the project. Almost all progressive countries have already made significant steps toward the transition to electronic tenders [1]-[4] and in some countries online systems for electronic tendering are supported and developed at the state level [5].

An indisputable advantage of a tender as a way to find the project executor is that it can be applied to an almost any contract, selling both goods and services and signed between two businesses (B2B) or a business and an individual customer (B2C) and even a business and a government (B2G). Though these types of tenders have their own specific features, a basic workflow of the process is common for all of them.

Usually the tendering process refers directly to the stage of working with the participants of a tender [6]-[8]. However, in practice this stage is preceded by significant organizational work which consists of the selection of experts and arranging of customer's requirements, including the transformation of verbal descriptions of requirements in the formal readable form.

If the company which organizes the tender solves these tasks on a regular basis, it probably already has a list of experts with verified skills and an efficient mechanism of the organization of tenders. However, for companies conducting the tender for the first time or working in a variety of areas requiring the involvement of experts of various specialties, the organizational part of the tendering process can be quite complicated.

The purpose of this paper is to expand a workflow of the tendering process, split it into stages and represent it as a mathematical model for further optimization.

II. Stages of the Tendering Process and Their Key Features

The suggested process extends a common used scheme of a tender adding to it some extra steps.

A tender stage list may vary depending on the subject area or the country. Nevertheless, any tendering process must include following stages: pre-qualification, invitation to participate in tender, submission, evaluation of proposals, selection of the winner, archiving. In this paper it is suggested to add to this list two more stages: organization of tender committee and preparing of tender documentation.

A. Organization of tender committee

A tender committee can be created on a temporary basis or on permanent basis if tenders are

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conducted regularly. This organization should include experts and representatives of the customer. The decision maker may also be a part of the tender committee but in the development of solutions his voice has no significant advantages over the others. In this case after finishing of evaluation stage he should take into account all recommendations provided by the committee and make a decision on who should be selected as the executor of the project.

B. Preparing of tender documentation

In tender documentation members of the tender committee should list all requirements to the object of the contract (products or services). This document will allow potential contractors to prepare more detailed information about their proposals.

Tender documentation usually contains a detailed description of all project requirements, contract terms and tender parameters, such as the time of tender ending, its format and evaluation system. Main requirements to tender documentation are a clear structure and a list of key parameters, based on which the participant will be able to make a proposal.

C. Selection of potential contractors

After customer's approval, the tender documentation is published and can be accessed by everyone. In addition the committee may send it to some pre-selected potential contractors personally inviting them to participate in the tender.

Pre-selection is optional but desirable stage for complex projects such as building and engineering design. This stage demands from participants to provide a set of supporting documents. Organizer performs audit, assessing reputation, financial position, capabilities and professional qualification of each participant. According to audit results, participants are divided into different groups according to their abilities or are arranged into rating.

Thus, if the company organizes several projects which are common by area but different by complexity, it can associate lists of potential participants to the complexity of each project. For more complex or critical projects more qualified participants are invited, and for simple ones – less qualified, but less expensive participants.

D. Proposal submission

After getting acquainted with the tender documentation all participants prepare their proposals and send them to the tender committee. Potential participants must prepare their proposals in accordance with the requirements specified in tender documentation. Each proposal can be processed either manually or automatically. For example, e-tendering system can automatically reject applications submitted after the specified tender ending time.

In practice, this step can be a weak point in the system, especially if the system is public and each participant can see the proposals of other participants. In this case, the later the participant comes with his proposal, the more chances he has to understate prices and terms, so that his application will be noticed before others. Even if system is not public, in case of manual processing of incoming applications an unfair participant may try to find an insider, who can provide him with the desired information about competitors. Obviously, there are two ways to avoid it: either proposals should be sent in "envelopes" and all "envelopes" should be opened after closing of the tender, or the system should be made invulnerable to the influence of the human factor by implementing of automatic proposal processing.

E. Evaluation and winner selection

After tender is closed the tender committee should perform an evaluation of proposals and make a final decision on the choice of executor the project. Evaluation can be performed in different ways, but they must be based on honesty. This means that the evaluation should be performed in the way when the decision maker is not able to implicitly or explicitly give preference to the desired party.

In general evaluation stage includes:

- preparation of data, including survey of experts, obtaining experts evaluations using ranking and the analytic hierarchy process, processing and formalization of survey results;
- calculation of experts competence during a survey using coefficient of confidence in expert opinion;
- aggregation of evaluations using the modified method of ranks summarizing which takes into account the competence of experts.

F. Archiving

After finishing of the tender all documents related to it should be archived. It is necessary for future analysis of tender results, when with a help of this archive it will be possible to evaluate the effectiveness and real qualifications of the winner in the long term. It also can be used in similar tenders allowing to omit the pre-selection stage and send invitations to participate in the new tender to verified companies.

The results of each stage have a significant impact on subsequent phases and, accordingly, on the final decision [9].

III. MATHEMATICAL MODEL OF THE TENDERING PROCESS

Tendering process is characterized by a certain set of data [10]. There are sets of data that define statement of the problem: M – a set of criteria for evaluation of participants, N – a set of alternatives, that are proposals from potential contractors, S – a set of experts invited to evaluate participants in the tender.

The results of the tender are represented by following sets of data: GW – a set of vectors of ratings obtained as a result of experts survey, v – a vector of coefficients of confidence in expert opinion, D – a vector, which includes the final rating of participants.

Thus, the tendering process P can be represented by the following tuple:

$$P = <M, N, S, GW, v, D> \tag{1}$$

where

$$M = \{M_i \mid i = 1..m\} \tag{2}$$

$$N = \{N_i \mid i = 1..n\} \tag{3}$$

$$S = \{S_i \mid i = 1..s\} \tag{4}$$

$$GW = \{GW_i \mid i = 1..s\} \tag{5}$$

$$v = \{v_i \mid 0 \le v_i \le 1, i = 1..s\} \tag{6}$$

$$D = \{D_i \mid \sum_{i=1}^{n} D_i = 1, i = 1..n\} \tag{7}$$

where M – a set of criteria for the participants evaluation;
m – a number of criteria used in the tender;
N – a set of proposals from potential contractors;
n – a number of participants;
S – a set of experts invited to the tender committee;
s – a number of experts;
GW – a set of vectors of ratings obtained as a result of experts survey;
v – a vector of coefficients of confidence in expert opinion;
D – a vector, which is the final rating of participants.

On the preparatory phase all input data and parameters of the problem are formalized. At the initial stage of the tender during the organization of the tender committee, a set *S* of experts whose opinions will be taken into account when making a decision is determined. Then, the preparation of tender documentation is made. It includes selection of a set of project criteria *M* from a set of all possible criteria of evaluation. The process of pre-selection of potential contractors includes determining of a set *N*.

Proposals analysis based on obtaining evaluations by experts, as well as evaluating of competence of the experts themselves are the most important and difficult stages of the tendering process, and they require using of mathematical methods for their performing. The problem of a decision making P_{DS} itself can be represented as a set of data:

$$P_{DS} = <T, N, M, X, F, G, GW, v, D> \tag{8}$$

where *T* – a statement of the problem (to select a better alternative, or to organize the entire set);

X – a set of methods for measuring preferences;

F – a mapping of valid alternatives to a variety of criteria evaluations;

G – a system of expert preferences;

D – a decisive rule that reflects a system of preferences.

In this problem the mapping F of sets *N* and *M* is uncertain.

A set *X* can be represented in both absolute and relative scales of measuring of experts preferences.

System of preferences *G* is formed by a group of experts.

The result of this stage is a set of ratings of alternatives *GW*, developed by experts, and a vector of coefficients of confidence in expert opinion *v*.

A vector *D* (rating of participants) is calculated based on results of the evaluation stage.

Thus, the main purpose of the tendering process is to provide a following mapping:

$$f : N \to D \tag{9}$$

where mapping rule is the procedure of rating determining based on experts evaluations.

IV. Experimental Application of the Suggested Model

The developed model formed the basis of the new information system architecture. Each stage is represented by a separate module for better flexibility of entire system. Each module contains a set of methods performing data processing.

The efficiency of the information system was investigated. For experimental investigation information about tenders which took place in past was used. It was provided by building and engineering design companies.

As experimental data related to finished tenders, it was possible to compare real results of tenders with recommendations of the system and evaluate successfulness of real results in the long term. During experimental investigation some potentially weak solutions were discovered and unsuccessful tender results were predicted.

V. Conclusion

The developed model of the tendering process provides consistent partitioning of this process into several stages from setting the problem to making final decision. Decomposition of the complex process helps to get clearly defined sets of input and output data used on each stage

and to optimize each of them independently.

Using of this model as a basis of an information system allows creating a flexible, modular architecture consisting of independent components. Such architecture increases the efficiency of its use in a variety of subject areas.

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Complex eco-biological systems modeling

Timofey Burak, Marina Lukashevich

***Abstract*—**In this paper presented algorithm and methodology for computer modeling of complex eco-biological models, based on system approach of J. Forrester. Also specialties of modeling in ecology and biology are considered.

***Keywords*—**computer modeling, system approach, biophysics, ecology.

I. Introduction

Computer modeling, as a field of science and engineering activity, connected to theory and practice of computing experiment. Complicated dynamic systems are special kind of mathematical models, and computer modeling – is a modern form of mathematical modeling, new technology of obtaining knowledge about objects.

Modeling is widely used in biology. Application examples are [1]: populations and biogeocenoses, researches in biological society theory, ecological modeling. Biological systems, like reserves ecosystems and populations of different species, have a complex structure and processes inside them are difficult to describe using mathematics.

Developing a universal algorithm of modeling ecological and biological systems will simplify process of describing complex dynamic systems and provide engine for performing modeling.

II. Mathematical Schemas for Modeling

Computer modeling, as a field of science and engineering activity, connected to theory and practice of computing experiment. Complicated dynamic systems are special kind of mathematical models, and computer modeling – is a modern form of mathematical modeling, new technology of obtaining knowledge about objects.

Main tasks of mathematical modeling are:

- to find such mathematical representation of a object (such object also called mathematical model), so it will be equivalent to a real object;
- to research this mathematical model and determine main characteristics of model and real object.

Type of mathematical model depends on the nature of real object, research goals and desirable accuracy. Every mathematical model describe corresponding object with finite approximation level [2].

In analytical modeling processes inside models described using functions and logical expressions. The most complete research of system functionality can be achieved if exact dependencies between system characteristics, start parameters and variables are known. However, those dependencies could be determined only for relatively simple models. As model complication level increases, analytical method faces problems, sometimes unsolvable.

In imitational modeling implemented algorithm reproduces how real object behave in time. Basic processes in objects are imitated, saving their logical structure and sequence in time. This approach allows determining system state in particular moments of time and estimating system characteristics.

There is a combined approach, which integrates advantages of analytical and imitational methods. In combined models the main operating process of an object divides to several sub-

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processes. For every sub-process then represented as model: analytical model if possible, imitational otherwise. This combined approach allows covering new types of systems, which cannot be researched using just analytical method or just imitational method separately [3].

Classification of basic mathematical modeling schemas includes following approaches:

A. Deterministic-continuous models

Deterministic-continuous models are described as one or several differential equations. If system is distributed, then functions describing processes inside system depend on several variables. In this case partial differential equations are used.

B. Deterministic-discrete models

Deterministic-discrete models are the subject of automata theory. According this theory, models represented as automaton, which processes discrete portion of information and changes its state in discrete moments of time. Sub-state machine is separate subclass of automaton with finite number of states.

C. Stochastic-discrete models

Stochastic-discrete models are also separate subclass of automaton – nondeterministic automata. The main difference is that nondeterministic automaton transition function has stochastic component and value of this function is basically a probability distribution function for transition.

D. Stochastic-continuous models

Stochastic-continuous models, or queuing models, are the object of queuing theory. In queuing theory a model is constructed so that queue lengths and waiting time can be predicted [4].

III. Modeling in Biophysics and Ecology

Biophysics is an interdisciplinary study about fundamental basics of structure, functioning and development of living systems. Biophysics use experiments along with mathematical modeling to describe processes in living systems with different levels of organization. Unlike physical processes, processes in biological systems are hard to describe using mathematical equations [5]. Therefore in modeling of biological processes they are mathematically simplified and abstracted. In most cases difficulties in describing biological models exclude the possibility of using analytical modeling methods.

According to [6], modeling process of ecological and biological systems has following features:

- All biological systems are complex, spatially structured systems consisting of many components. Two approaches could be used in modeling such systems. The first is to distinguish key characteristics of system as a whole and determine how these characteristics change in time. Second approach is to consider in detail every component of system and determine the way they interact with each other.
- One of the most important features of biological systems is their ability to autoreproduct. It means that equations in biological models should have autocatalytic elements, which determine population stability and its ability to grow.
- Biological systems are open. They always pass through themselves energy and matter flows. In practice it means that biological and ecological systems are not in state of thermodynamic and energetic equilibrium.
- Biological objects have complex multilevel system of self-regulating. It means that biological components are connected to each other using positive and negative feedback loops. In models feedback loops described using nonlinear equations, which determine the

occurrence of complex kinetic modes, including oscillation mode.

Book [7] analyzes different modeling approaches in history of theoretical ecology. The conclusion is that majority of mathematical models in ecology and biology are either inadequate and shouldn't be used in practice, or trivial and useless in practical experiments. However system approach in modeling gives more accurate results due to using expert functions.

IV. MODELING METHODOLOGY

Basic mathematical modeling schemas are simple and clear, but they have small application area. Most practical problems require working with complex dynamic systems. In this case basic modeling schemas cannot be used. One of the approaches for modeling complex dynamic systems introduced in the papers of J. Forrester, the founder of system dynamics [8]. This approach combines features of basic schemas and can be used as a simple and flexible tool in modeling of complex dynamic systems.

The main idea of system approach is that model represented as a set of main characteristics. Changes of model characteristics are driven by feedback loops [9]. *Feedback loop* is the closed chain of interaction between parameters. Such self-regulating mechanism better describes processes in dynamic systems.

System with feedback loops described using two kinds of variables: *stocks* and *flows*. Stock L is a numerical value of significant model characteristic at a certain moment of time. Flow D_L describes how value of stock changes during interval Δt. Equation (1) shows how value of stock L could be determined:

$$L(t_{i+1}) = L(t_i) + \Delta t \cdot \sum_j D_{Lj} \quad (1)$$

where Δt is time interval between moments t_{i+1} and t_i; D_{Lj} are flows for stock L.

Assume $t_0, \dots, t_i, t_{i+1}, \dots, t_n$ are discreet moments of time, which corresponded to modeling iterations (index i is a serial number of iteration), and $ti - ti + 1 = \Delta t \; \forall \; i \in [1, n]$. If Δt will be sufficiently small, equation (1) transforms to following equation (2):

$$\frac{L(t_{i+1}) - L(t_i)}{\Delta t} = \frac{\Delta L}{\Delta t} = L' = \sum_j D_{Lj} \quad (2)$$

Thereby model is represented as deterministic-continuous model using system of differential equations.

Depending on whether or not stochastic variables are used in equations, system approach of J. Forrester could be used to describe deterministic and stochastic models.

Stock L is described by its value at the initial moment of time $L(t_0)$ and the set of flows D_{Lj}, which determines how value of stock L will change during modeling. Stocks with empty set of flows are constants.

To simplify the way of describing formulas for flows temporary variables are used. Temporary variables are basically intermediate calculations for flows and other temporary variables. Also, temporary variables could be used as additional source of information about model behavior during modeling. In model temporary variables set as functions of model stocks and other temporary variables (eq. 3):

$$Tmp(t_i) = f(IL(t_i), IT(t_i)) \quad (3)$$

where $IL = \{L_0, \dots, L_m\}$ – certain set of system stocks, which temporary variable Tmp depends on; $IT = \{Tmp_0, \dots, Tmp_k\}$ – certain set of temporary variables, which temporary

variable Tmp depends on.

Eco-biological systems are complex and consist of many interacting components, so it is necessary to provide ability to divide complex system into smaller sub-systems. Division will simplify process of describing model and provide its hierarchical structure. Lets define object Obj as structural unit of model, structural equivalent of system component. Every object is a sub-model, which interacts with other objects. Decomposition of complex systems into separate components makes process of describing model easier. Hierarchical structure of a model illustrated in figure 1.

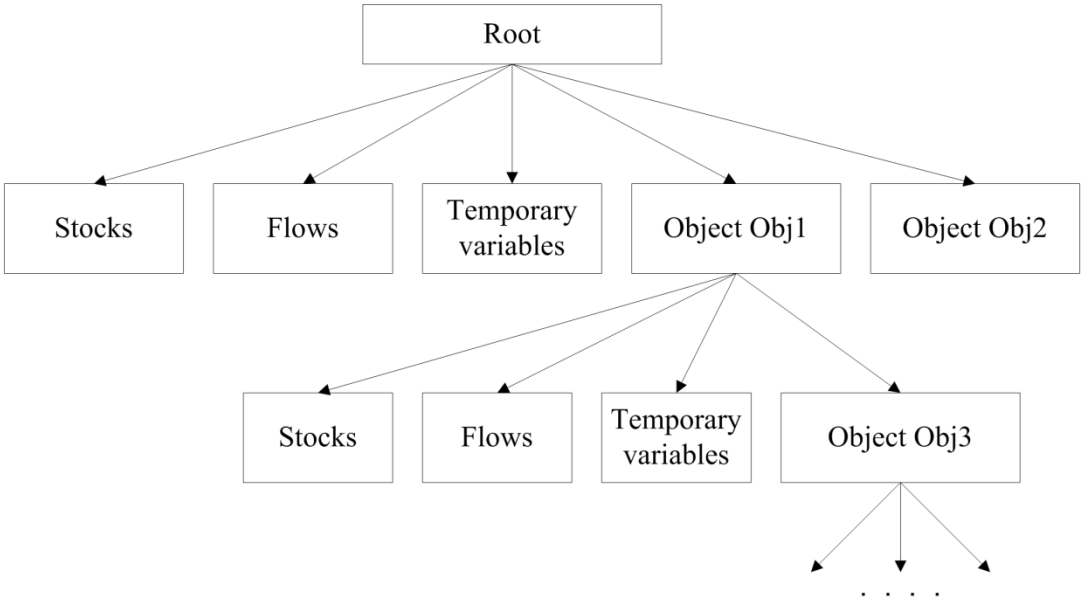

Fig. 1 Model structure

Modeling process for complex eco-biological models can be divided into three steps: model describing, model tuning and performing experiments on the model. Following sequence of actions could be useful for model describing:

- Complex system should be divided into components, i.e. system decomposition should be performed. Obtained components specify the set of model objects. If components themselves are complex systems, process of decomposition should be repeated for them. Thus, the hierarchical structure of model will be obtained.
- It is necessary to determine main parameters of model and each component, which will determine system state in certain moments of time and show system dynamics in time. These parameters specify the set of model stocks.
- For every stock we should determine factors, which influence its value. Factors should be analyzed to determine dependency function between factors and variation of stock value. This dependency formula specifies a flow for certain stock.
- Finally, to simplify calculations and model describing, we could introduce temporary variables into model structure.

As a result of actions listed above we will get model of complex eco-biological system with hierarchical structure. Before using this model for experiments and researches it is necessary to check if model is valid. To do this we should perform a testing modeling on time period, where precise state of model is known. Results of testing modeling we compare to actual data about system and make conclusion: is this model accurate enough or not.

If modeling results are not accurate enough – it should be tuned. Methods for tuning model include: correction of model constants and coefficients, correction of dependency formulas for

flows and change of model structure.

Model tuning can be performed in several iterations, until needed accuracy of model will be achieved. After model is described and tuned it is ready for using in experiments and researches.

V. PROGRAM IMPLEMENTATION

Program modeling is a process of getting sequence of model states in time. Let's define S_M as model state in certain moment. S_M is a set of values of all model stocks L_i and temporary variables Tmp_j as shown in equation (4):

$$S_M(t_i) = \{L_0(t_i), \dots, L_N(t_i), Tmp_0(t_i), \dots, Tmp(t_i)\} \quad (4)$$

where N – amount of model stocks; K – amount of temporary variables.

Modeling process is shown in figure 2. At the beginning program performs model initialization: set start values for stocks and calculate values of temporary variables (step A). After that, program saves current model state $S_M(t_i)$ (step B). Using values of stocks and temporary variables from $S_M(t_i)$ new model state $S_M(t_{i+1})$ is calculated (step C). It means that using values of stocks and temporary variables from previous iteration we calculate values of stocks and temporary variables for next iteration. Steps B and C are the one modeling iteration. Finally, iteration counter check if program completed required amount of iterations, and return program flow to step B if not.

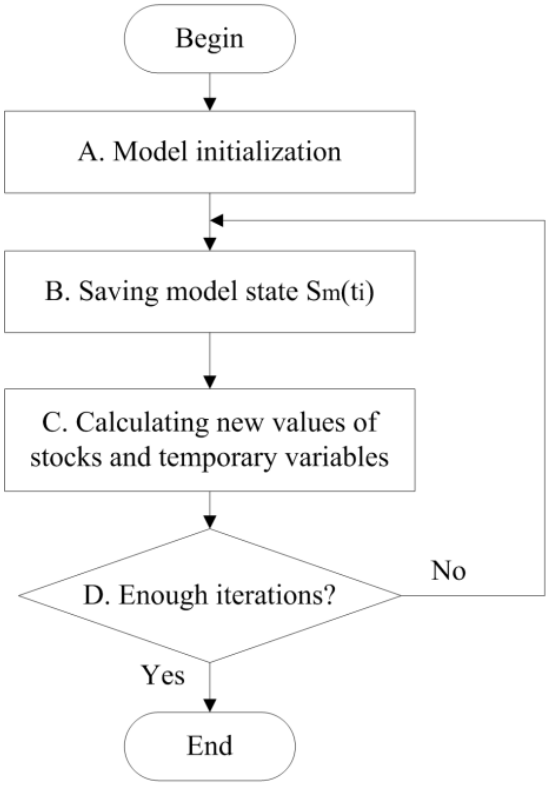

Fig. 2 Modeling process

Right now graphical user interface for modeling software is under development. Graphical interface will use "visual programming" technology, which minimize programming skills requirements for using this software.

VI. Modeling Results

Modeling methodology described in this paper was used in modeling of lemmings population. Used model "vegetation – lemmings - arctic foxes" described in work [10]. Modeling results shown in figures 3-5.

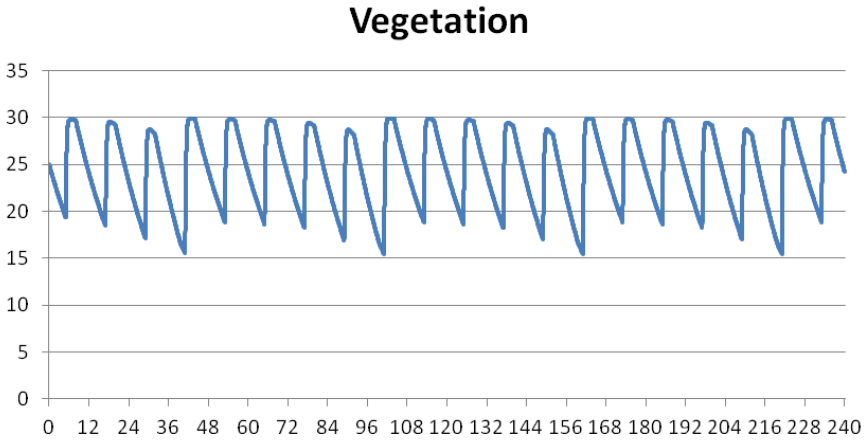

Fig. 3 Vegetation level, quintals per hectare

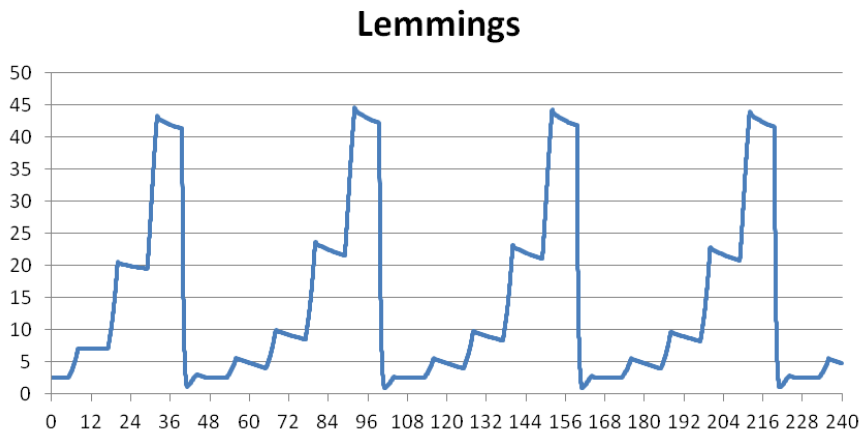

Fig. 4 Lemmings population, specimens per hectare

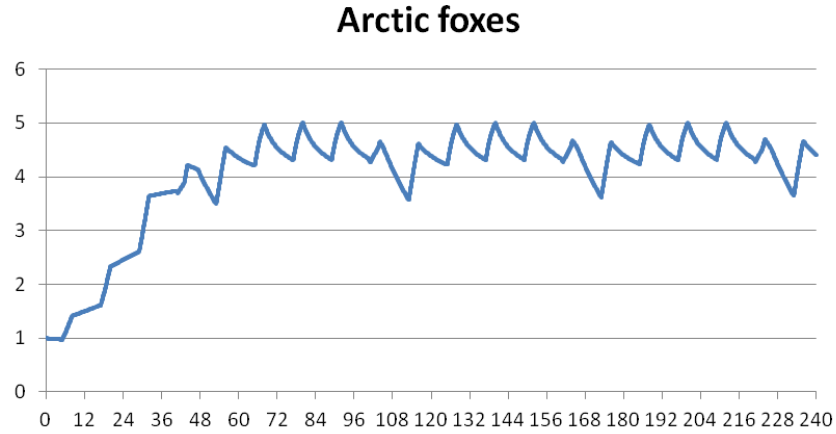

Fig. 5 Arctic foxes population, specimens per hectare

VII. CONCLUSION

Developed algorithm of describing models is universal for complex ecological and biological systems. Modeling algorithm considers specialties of eco-biological systems and shows adequate and accurate results in practice.

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Using appearance for improving facial expression recognition

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Abstract—Traditionally, recognition of a facial expression is performed by extracting and analyzing specific set of landmarks (collectively often referred to as a "shape"). Here we take alternative approach, based not on shapes, but instead on appearance – pixel values within region of interest. We construct classifier based on these data and compare its performance to a shape-based one. We also propose combined method using both sets of features.

Keywords—active appearance models, classification, facial expression recognition, shape and appearance.

I. INTRODUCTION

Understanding emotional state of a person plays key role in such areas as social and psychological research, marketing, gaming industry and many others. In most cases this information is transmitted between people via non-verbal channels. According to [1], about 55% of this information is generated by person's facial expression. Thus, creation of efficient algorithms for expression recognition is mandatory for advanced human-computer interaction.

Existing methods of facial expression recognition vary a lot. Some of them rely on static data (e.g. static images of a face), others - on dynamic ones (e.g. video), some represent input as optical flow, others - as connected vibrations or set of key points. And, of course, algorithms themselves differ a lot. Good overview of different approaches may be found in [2]. In this paper we will concentrate on analysis of static images of a face.

Almost all methods for analyzing static images consist of two steps: feature extraction and recognition itself. Contents of these steps vary a lot, though. For example, on the first step there are 2 main groups of features: general and specific to faces. First group includes all features popular in computer vision. For instance, in [3] Gabor filters are used, while [4] utilizes local binary patterns. Such techniques are easy to implement, but very often resulting features give low accuracy during recognition. Features, specific to faces, include, in particular, action units from FACS coding system [5] and sets of key points, describing shapes of main elements of a face. One method for obtaining key points, known as *active appearance models (AAM)* [6][7][8], gained a lot of attention in the area of facial analysis.

With AAM, recognition is normally performed by extracting coordinates of key points and training classification algorithms on them. Such methods have pretty high accuracy, are intuitive and easily interpretable from psychological point of view. At the same time, this approach ignores information stored in *appearance* - pixel intensities within region of interest. In this paper, we evaluate relative importance of this information and propose combined method that uses both - location of key points and intensity of pixels in the region.

II. SHAPE-BASED METHOD

In order to evaluate importance of appearance for facial expression recognition first of all we need to set up baseline to compare with. In this paper we use a variant of classic algorithm based on position of key points as such baseline.

Essentially, this algorithm consists of 2 steps: obtaining coordinates of key points and classification. Classification of objects by their feature vectors (coordinates of points in this

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case) is a standard task of supervised learning and is of no interest in the context. We only need to mention, that in this paper we used support vector machines for this task, since it demonstrated good results on similar problems.

On other hand, obtaining key points is much more difficult task. According to recent publications (e.g. [2]), it seems like the most popular algorithm for this is active appearance models. Here we describe in short essential steps of this algorithm.

AAM takes a set of images and corresponding sets of key points describing shape of main elements of a face (e.g. see Fig. 1). Using these data algorithm builds 2 statistical models:

- *shape model* - parametric linear model describing possible variations of coordinates of key points. In this context, term "shape" denotes a vector of coordinates of key points: $s = (x_1, y_1, x_2, y_2, \dots, x_n, y_n)$;
- *appearance model* - similar model, but describing possible variations of pixel intensities in the area of interest. Also, unlike shape model, term "appearance" here denotes not a vector, but an image $A(x)$ defined over all pixels $x \in s$.

Fig. 1 Set of key points describing main elements of a face

Note, that here we borrow somewhat inexact, but convenient notation from [7] and write $x \in s$ to refer to all pixels inside shape and not to shape elements themselves.

Since different images may contain different number of pixels inside shape, all images are first aligned to some mean shape. Normally, piecewise affine transformation is used for this: first, set of key points is triangulated, and then every triangle is warped to new coordinates via regular affine transformation (see Fig. 2). Piecewise affine transformation is essential to this work, since it will be also used in appearance-based and (implicitly) in combined methods.

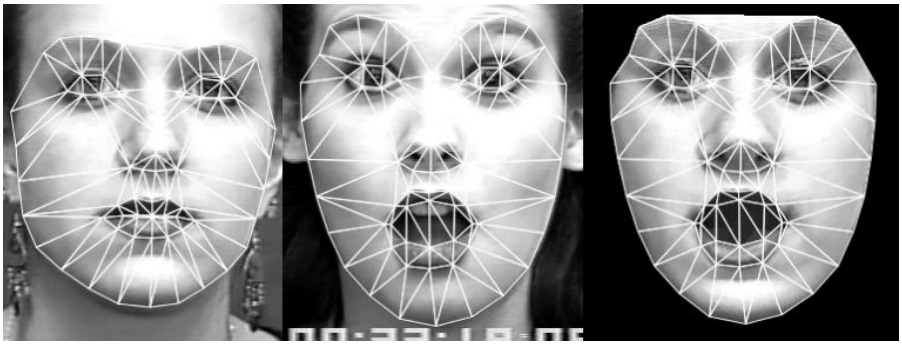

Fig. 2 Example of piecewise affine transformation. On the left: original image and corresponding triangulation. In the middle: target image. On the right: original image warped to the shape of the target one

When applying to new images, algorithm first finds position of a face and applies approximate shape to it. Then, shape and appearance models are iteratively fitted to an image to find exact location of key points. Detailed description of active appearance models can be found in [6] and [7].

Putting it all together we get the following 2 stage algorithm.

Algorithm 1. Shape-based classifier (training)

```
Train AAM: AAM ← aamtrain([x_i for every i])
for each image I_i(x) in dataset do
    Get shape by applying AAM: s_i ←
aamfit(I_i(x))
end
Train classifier: C ← svmtrain([a_i for every
i])
```

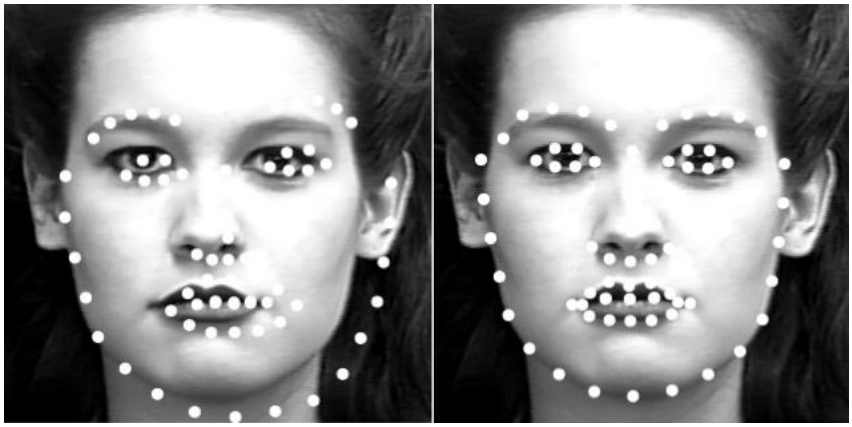

Fig. 3 AAM fitting. On the left: initial guess for a shape. On the right: fitted shape

First, we train AAM on a dataset to use it on later steps. We don't dive deeper into details of AAM training and fitting here because it's not the main topic of this paper, but instead simply state existence of functions *aamtrain* and *aamfit*. Also it's important to note that, though in our experiments we used the same dataset everywhere, dataset for training AAMs should not necessarily be the same as for training main classifier. In fact, it's totally valid to have pre-trained AAM model or even dataset with precomputed coordinates of key points. In our case we obtain these coordinates by fitting trained AAM to every image in the dataset.

Finally, we pass these coordinates to SVM training procedure to get instance of the classifier.

Algorithm 2. Shape-based classifier (predicting)

```
Get new image: I(x) ← new image
Get face shape from it: s ← aamfit(AAM,
I(x))
Apply SVM to get prediction: P ←
svmpredict(C, a)
```

Predicting expression for new image is straightforward: first we obtain that image, then fit AAM to find coordinates of key points and then simply apply trained SVM to get prediction.

Note, that in this method appearance is used purely for obtaining coordinates of key points, but it isn't used on classification step. On the contrary, in next section we will describe method that primarily uses appearance data.

III. APPEARANCE-BASED METHOD

Possibility to learn facial expression from a shape is well known and described in a number of papers. But at the same time this possibility with regard to appearance got from little to no interest in computer vision community. So first of all we need some evidence that appearance holds at least some information about encoded facial expression.

To prove it we propose following informal experiment. We take several images of faces and transform them to the mean shape computed previously using AAMs. We use same piecewise affine transformation which gives us pretty smooth deformation. Result of this transformation is depicted at Fig. 4.

From pictures it's clear that all key points for eyes, eyebrows, nose and mouth have identical coordinates between all images, i.e. all transformed faces have *exactly the same shape*. But it's also noticeable that original facial expressions are still easily guessable. This provides us with evidence that appearance really contains information that encodes human facial expression, and possibly quite a lot of it.

To compare amount of information stored in appearance with one stored in shape, we build another classifier, this time based on pixel intensities.

Algorithm 3. Appearance-based classifier (training)

```
Train AAM: AAM ← aamtrain([x_i for every i])
for each image I_i(x) in dataset do
    Get shape by applying AAM: s_i ← aamfit(I_i(x))
    Warp image to the mean shape: A_i(x) ← W(I_i(x))
    Flatten appearance: a_i ← fl(A_i)
end
Train classifier: C ← svmtrain([a_i for every i])
```

First we preprocess all images in a dataset: fit pre-trained AAM to each of them to obtain shape of a face and then use this shape to warp image to AAM's mean shape. This way all images get same shape (and thus same number of pixels inside), but keep most information about appearance. Then we flatten images, i.e. rearrange pixels inside shape into a single vector of a fixed size. Mathematically, fl denotes a mapping from matrix $A \in R^{m \times n}$ to a vector $a \in R^k$. Finally, we use these flattened appearance vectors to train SVM classifier.

Algorithm 4. Appearance-based classifier (predicting)

```
Get new image: I(x) ← new image
Get face shape from it: s ← aamfit(AAM, I(x))
Warp new image to the mean shape: A(x) ← W(I(x))
Flatten appearance: a ← fl(A)
Apply SVM to get prediction: P ← svmpredict(C, a)
```

During application of classifier to a new image, we follow same steps as during training. First, we apply AAM to obtain shape of a face on the image. Then, using this shape, we warp new image to the mean shape, making it usable for classifier. Finally, we apply trained SVM model to pixels of the transformed image to get prediction.

Before moving further, let's briefly recall common and different parts of two algorithms. Both of them are split into 2 stages - training and predicting. Both require preprocessing to obtain features. First algorithm uses coordinates of key points as its features, while second is based on pixel intensities. In both cases SVM is used as a final classifier.

We should also note, that in this specific work we use AAM for aligning image to the mean shape, though, it's not mandatory precondition. For example, in [9] face is located using several predefined landmarks and then 3D-modeled to obtain possible transformations.

Fig. 4 Transforming images to the mean shape. On the left: images of emotional faces. On the right: same faces transformed to the mean shape. Though shape is the same, facial expressions are still easily distinguishable

IV. COMBINED METHOD

Having 2 similar methods with different sets of features it's natural to combine them in a single algorithm: we can merge information about key point coordinates and pixel intensities into a single vector and use it for classification. Since all essential parts have already been discussed in previous sections, here we will simply list steps of combined algorithm.

Algorithm 5. Combined classifier (training)

```
Train AAM: AAM ← aamtrain([x_i for every i])
for each image I_i(x) in dataset do
    Get shape by applying AAM: s_i ← aamfit(I_i(x))
    Warp image to the mean shape: A_i(x) ← W(I_i(x))
    Flatten appearance: a_i ← fl(A_i)
    Combine vectors: x_i ← [s_i; a_i]
end
Train classifier: C ← svmtrain([a_i for every i])
```

Algorithm is very similar to previous 2 except for the last step in a loop where we combine 2 kinds of features, i.e. simply concatenate their vectors (operator [;] here has signature $[;]: (R^m, R^n) \to R^{m+n}$).

Algorithm 6. Combined classifier (predicting)

```
Get new image: I(x) ← new image
Get face shape from it: s ← aamfit(AAM, I(x))
Warp new image to the mean shape: A(x) ← W(I(x))
Flatten appearance: a ← fl(A)
Combine features: x_i ← [s_i; a_i]
Apply SVM to get prediction: P ← svmpredict(C, a)
```

In the following section we discuss our experiments and results of all 3 described methods.

V. EXPERIMENTS AND RESULTS

We used Extended Cohn-Kanade dataset (CK+)[10] to evaluate our algorithms. This dataset was specifically collected to support research in facial expression tracking and recognition. Currently, it consists of 327 sequences of video frames (from neutral expression to a strongly pronounced emotion) totalling in 10708 images. Each image comes with corresponding shape file, containing coordinates of key points, and every sequence additionally has label of expressed emotion. CK+ uses set of 6 basic emotions proposed by Paul Ekman (e.g. see [11]) and considered the de facto standard for their recognition. These emotions are: happiness, sadness, surprise, fear, disgust and anger.

For training AAM we used AAMToolbox [12], which is freely available for research purposes. Using 4-core CPU Intel i7 and CK+ dataset training AAM took about 3.5 hours. Training SVM classifier on 327 labeled images (only last image from each sequence – the one with maximally expressed emotion – was used) took about 7 seconds.

These timings, however, cover only training stage: during fitting AAM can locate key points within 200 ms, while SVM gives prediction in about 25 ms, which makes it possible to uses our algorithms in near-real time systems.

For evaluating results we used standard method of cross validation. After 10 experiments we got following results:

TABLE 1

ACCURACY OF 3 CLASSIFIERS

algorithm	accuracy
shape-based	89.4%
appearance-based	86.3%
combined	93.5%

As we can see, appearance-based algorithm was able to achieve results pretty close to those of shaped-based one. This means, in particular, that appearance holds pretty large amount of information about facial expression. Also, we see that combined classifier outperformed both of these separate algorithms, which proves that appearance doesn't simply reflect shape variations, but rather adds some amount of unique information.

VI. CONCLUSION AND DISCUSSION

This paper describes and evaluates 3 methods for facial expression recognition, based on shape, appearance and their combination. Results suggest that information about appearance, previously mostly ignored, holds valuable amount of additional information that can be used to significantly improve classification performance. Although here we used raw pixel intensities as appearance features, more sophisticated options are available. In particular, recent progress in deep learning allows obtaining better representation for appearance features. This will become basis for future work.

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Automatic Universal Decimal Classification based on frequency advanced method

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Abs*tract*—Text classification is one the most valuable domain of Text Mining. It can helps identify a category of a text. Universal Decimal Classification (UDC) is wide-spread system at ex USSR territory. UDC—is a category tree. Each scientific publication should be related to the class. In Belarus, publication acquires UDC code only in libraries of universities with librarian worker. This article dedicated to automation of this task.

***Keywords*—**Classification, Artificial Neural Network, Text Mining, Universal Decimal Classification.

I. Introduction

Today, there are large number of disordered text information. Therefore, a search and a classification of the information by keywords are the most important tasks. It is too actually, because researchers often have to read a lot of scientific articles, before finding something important for them. Sometimes they can just look for an article, to identify its sense, and, sometimes, that is necessary to read most of the text to understand its meaning.

To identify a class of an article, it was invented Universal Decimal Classification (UDC). It is a mandatory attribute of any printed scientific work. With UDC it is easy to classify the information in the world of science, literature and art, periodicals, different kinds of documents and scientific articles [1].

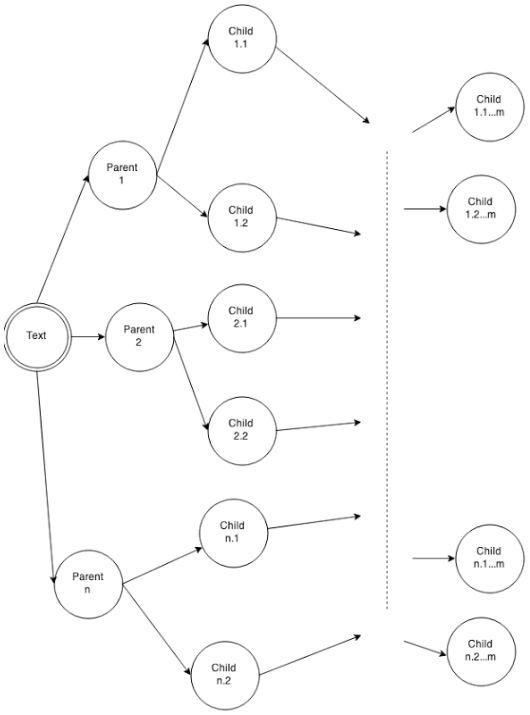

Fig. 1 UDC hierarchy

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Currently, UDC is assigned manually at librarians or specially trained people. This article dedicated to methods and models to automatically assign the UDC, without involving humans. Therefore, the purpose of the work can be defined as the automation of the Universal Decimal Classification (Fig. 1).

II. Ways to Solve a Problem

The objective is to assign for each text from *n* texts a category *m* with UDC.

Subject of research work is Universal Decimal Classification of texts.

There are a lot ways to solve the problem. At first, there is should be defined resolving rule and a dividing function. The system processes texts and searches metrics, which will be substituted as parameters in the dividing function, and as a result text will be related to one of classes.

One of the significant factors influencing the choice of the class is the language of the text [2]. This article deals it with Russian text. Therefore, to build a classification algorithm, there are will be used features of Russian language.

One of the most popular ways of classification is to find the full match. However it can born the collision. For example, the user specifies the search word *koshka* (cat—in English). So, in the text or in the set of texts will be highlighted words which consist of a *koshka* (cat) and any extension of the word. This search is clear, but it cuts off the results, which could be useful to the user. For example, words *koshachiy* (cat's), *kot* (cat). This method is the fastest, but with low accuracy. But software that will created based on this method will not real-time based, so high-performance is not main goal [3].

Russian language has difficult structure and a lot of word-parts. So, the situation, when two words should relate to one class is too often. And to increase accuracy, the best solution is to select a part of a word that reflect its sense. This can often be the root of the word, but it is difficult to select it. For example, some part of a word like a fugitive vowel can't be easy separated, so it decreases accuracy [4] [5].

Stemming—is a one way to select a sensible part of the word [5]. The problem of finding the sensible part of word is a long-standing problem in the field of computer science. The first publication on that dates back to 1968. Stemming is used by search engines to increase accuracy of the user's search query and it is a part of the process of text normalization. Nowadays, there are a lot of various implementations of Stemming algorithms. They are used for various tasks of intelligent processing of text information.

Stemmer—it is a method that implements Stemming algorithm [5]. It can extract a sensible part of a word (stem). However, the stemmer can create issues that classified next way.

A. Stemming issues of the 1st class

Stem gives too much generalization, and this way one part of a word can be related to more that. This is the largest group Stemming issues. For example, the Stemming of a word *vami* (by you) gives a stem *vam* (to you), but it can be happen it a word *vampir* (vampire). In Russian, it can be very difficult to completely avoid such errors. For example, a modification of a word *past'* (fall) gives forms *pad* (fall) and *pal* (fell). The result of Stemming gives stems—short forms of words, and this is a great extension in the field of the search. To fix such kind of issues, it should be completing removing of *stop words* from text using Ziph's algorithm and *stop-words dictionary*.

B. Stemming issues of the 2st class

A truncated form gives too long tems that are not matched with certain grammatical forms of the same word. Such issues lead stemmer's developer desire to find a compromise with the issues of the 1st kind in the case, when word's form changing. In English, there are exists the

same thing. For example, a group of irregular verbs. In Russian, this means that, different forms of a word change the first stem, and this phenomenon is very often. As an example, which is usually born many implementations stemmer. For example, words *koshka* (cat) and *pachka* (pack) have forms *koshek* (cats) and *pachek* (packs). Usually stemmer perform in these cases truncation to *koshk* (cat) and *pachk* (pack) that are not comparable with forms of the genitive and accusative plural.

C. Stemming issues of the 3st class

Stem can not be built because of the changes in the root of the word, which leaves a single letter in tem. Either model inflection involves the use of prefixes. The second event occurs within the grammar dictionary for comparative degree of adjectives and adverbs in Russian. For example, a word *pokrasivee* (more beautiful) as a form of an adjective *krasivyj* (beautiful) or an adverb *pomedlennee* (slower) as a form *medlenno* (slow).

Among all implementations stemmer can be represented two types:

1) Which use a dictionary to extract words;
2) Which use a heuristic model [4].

To isolate the word's root, there was developed a software module that implements Stemmer algorithm. Stemmer uses a heuristic model.

III. Stemming algorithm

To create the a heuristic stemmer, there are be should used dictionaries of endings, gerunds and participles forms, prefixes and suffixes. Stemmer will heuristically determine the part of speech based on dictionaries content. The essence of the algorithm is reduced to the determination of parts of speech to words by them endings, using dictionaries endings. For example, the ending of the sacraments can not be confused with anything else, so, this way, Stemming begins with them.

Stemming will use the following algorithm.

1) Complete a search for participles and gerunds endings in the word. If them found, them should be removed and algorithm goes to step 3.
2) Search the endings of adjectives, verbs or nouns. If they were found, they should be removed.
3) If a word ends in *i*, it should be removed.
4) From the beginning of word, there is seeking the sequence kind *vowel-consonant*. All letters after this combination will be called block *n*. If it not exists or *n* is empty, the process should go to step 7.
5) There are looking for a block *m* in the block *n*. This is a sequence of *vowel-consonant* too. If it is not exists, or it is empty, the process should go to step 7.
6) There are looking for word parts *ost* and *ost'* in the block *m*. If they are found, they should be removed.
7) If a word ends with endings *ejsh* or *ejshe*, they should be removed.
8) If at the end of word a double letter *n* situated, the second letter *n* should be deleted.
9) If at the end of the word is letter *'*, it should be removed.

Stemmer allows you to search the text in Russian more accurately. The issue is the complexity of the module.

IV. Text parser module

Next past is a text parser module. To apply Stemmer, text should be split by words. It can be done by representing the text like a line and parse it by non-word symbols.

Not all words are significant for classification. They are called stop words. There are

removing prepositions and erroneous words.

Another thing is help the system to select keywords—is the Ziph's Law. It allows to exclude words that has no sense for processing. There are words that misspelled, word-parts and so on.

There is an algorithm of keyword finding:

1) Split text *t* by words by ". , ! ? *space tab lineend*".
2) Remove non-valuable words by stop word dictionary multiplying (just vector multiplication).
3) Select keywords by Ziph's law.

V. Classification module

The next step is to create a classification module.

The classification method will be based on the Stemmer.

The UDC represented like a tree and consists of 126 441 categories. This is to much to start a classification directly. This method will has to low performance and to avoid it, it is a great improvement to use embedded feature of UDC—the hierarchy. The searching of a category reduces to passing the tree. But it require the special tree extension of tree—the siblings. So the algorithm will be built as following:

1) There is the processing of descriptions of all categories with the module by extracting the roots of words and put the result in the *word dictionary*. Every line in this dictionary is a key, which is the root of the word, and the value in a row—the number of word forms by a key from the description of the category.
2) Complete the Step 1 for all texts, applying them to these abstracts.
3) Select the initial list of categories. Let it be the children of the invisible parent category (the root UDC category).
4) Select begging category set. Its number is determined by the value of the variable *T*, calculated by formula 1.
5) There is a variety of categories for the text, where *T* is the maximum. If such *T* more than *1*, then the system will process all trees parallel the result is the UDC-code connected by + a list of categories.
6) When this category has a subcategory, next searching set is a category's children plus the category, because the text could refer to it. This case method goes to step *7*. If subcategories do not exist, the algorithm ends.
7) Look *T* for selected categories. If the largest *T*-value for the parent, then select it and finishes the algorithm. If subcategory "wins" (*T*-value for it is maximal), the system goes to step *6*.

$$T = \sum_{i=0,\,j=0}^{n,m} Ai \times Bi$$

VI. Artificial neural network

The result obtained with this classification can be improved if it will be introduced machine learning. All words selected form texts can be divided by two groups: existed in the text or not. And the words that are not included in the text's dictionary are markers of a category. Hence, they should be marked as belonging to the category. The ideal solution for this case is artificial neural network (ANN).

Artificial neural network is machine learning and cognitive science, artificial neural networks (ANNs) are a family of statistical learning algorithms inspired by biological neural networks (the central nervous systems of animals, in particular the brain) and are used to estimate or approximate functions that can depend on a large number of inputs and are generally unknown.

Artificial neural networks are generally presented as systems of interconnected "neurons" which can compute values from inputs, and are capable of machine learning as well as pattern recognition thanks to their adaptive nature.

A neural network is convenient to build on the basis of the perceptron. It will be a single-layer linear activation function, since there is no need to introduce some complex logic. There is a representation of the artificial neural network in the form of a tree.

To start the system need to train a neural network. First selection is 10000 texts.

VII. Results

Now it is necessary to compare the methods in the field of accuracy. In the case of absolute precision: the method of frequency classification based on the full-text search (A), the method of frequency classification using Stemming (B), the frequency method without the Stemming but with the ANN (C), frequency method using both the Stemming and the ANN (D), a semantic reference expert system (pseudo-reference confidence 90%) (E) (Fig. 2).

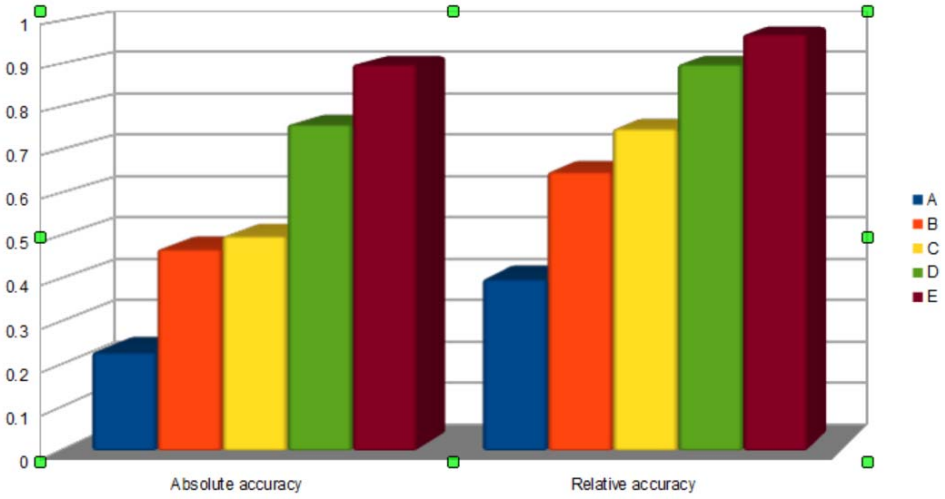

Fig. 2 Results

The graph shows that D (76%) is very close to the format of E. At the same time as the difference between B (47%) and C (50%) is not so much. Full-text frequency method gives the accuracy of only 23%. This chart reflects the confidence of the classifier with the choice.

If there are using relative accuracy, then it is E 97%, D show excellent results—90%. The difference between C and B increases—75% and 65% respectively. For A is—40%.

VIII. Conclusion

With stemmer, texts can be classified with high accuracy. The minus is the complexity of the architecture of the module.

To demonstrate the performance of this algorithm must be integrated into a software package.

The package has the following specification:

1) Receive an input text.
2) Classify.
3) Push the text in the database with the appropriate index to account for this result in the following classifications.
4) Print the results to the user on the screen.

The result is a system that allows user to assign UDC to text with high speed, accuracy and it is automated.

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The RPE – The Security Analytical Tool

Lucia Duricova Prochazkova, Martin Hromada

***Abstract*—**This article will discuss the issue of primary of an analytical method for security analysis. The method define the purpose of analytical tool for evaluating the security in objects, which we know as soft targets and others object, where the risk management is not implied in process. The document describes the primary architecture for analytical tool, which will be used for next analytical processes. It is development of analytical tool, which will be using for early detection of risks.

***Keywords*—**Risk, analytical tool, soft targets, evaluation.

I. Introduction

In this article we define special principles of the new analytical method, which we want to use for next security analysis. This tool can improve making decision in next crises situation. It is oriented for soft targets and objects, which are in state ownership and there are not special security actions. This article writes about primary principles, which we can develop for next better and better tools and we want to apply it in analytical processes and we will develop it during analyses. The RPE is developed for a wide range of applications. The RPE could be permanently applied for objects as soft targets, but other objects too.
This document is a template for *Word (doc)* versions. If you are reading a paper version of this document, so you can use it to prepare your manuscript.

II. The Analytical Function Scheme

The analytical function scheme describes the primary principles of using for objects. The using we can define as application for objects, which we know as soft targets. We can determine this, as place, or building, where is a lot of people on one place, and this place or building has not been applied some special detection tools or security options before the attacks.

A. The Calculation of RPE (Risk, Probability, Effect)

The calculation of RPE based on similar foundations as calculation in systems of quality and it is called RPN. RPE is about Risk, Probability and Effect. These three indicators have values in interval from 1 to 10. Risk represents kind of event, or security threat. The Probability represents how many percent is probably that the event can happen in the object. The Effect describes how damaged for object and visitors, or for society is. The RPE is non-dimensional quantity [6].

The proposal of the calculation is in the next formula.

$$\mathrm{RPE} = \mathrm{R} * \mathrm{P} * \mathrm{E} \tag{1}$$

This method we define for using to two processes. In the first it is in analyses in first step for the assessments of objects. And in second time, it is used after the process proposal security systems, and it is as control analyses.
The resulting values can be determined for interval:

$$\mathrm{RPE} < 125.$$
$$\mathrm{RPE} > 125.$$

Special conditions – will be specified after observation.

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Special conditions mean that we must be careful in analytical process. We must prepare all conditions and we must rate it. After analytical conclusion we can specify it. It will be refilling during analytical processes. After more application it can be changed and equation can be evolution for long time.

TABLE I
THE DESCRIPTION OF RPE

RPE - Risk Probability and Effect				
	Interval	The Explanation	The definition	The advantage
Risk	1 - 10	What kind of negatives event is threatened?	The description of negatives events. It depends on the kind of event. It is precisely identified by the same distinguishing features. We will define this identify project from characteristics.	It can be applied in some others specifics object by the purpose.
Probability	1 - 10	How much percent is probably that this event can happen?	For this analytical part we must prepare analytical tools from analytical methods, which will be prepared assessment of the probability, based on past incidents and other contexts.	We can use some others analyses from others specialists. It will be compatible.
Effect	1 - 10	What happens it after the event?	We can identify some other risk after the first security incident. We anticipate response from others stakeholders and we must prepare scenarios. Precautions will must be lest financing costs as corrective actions or repair.	We must make the linking with other analytical tools and we make it compatible.
		How is damage?		
		How is hard to repair it?		

B. Processes of RPE Modelation

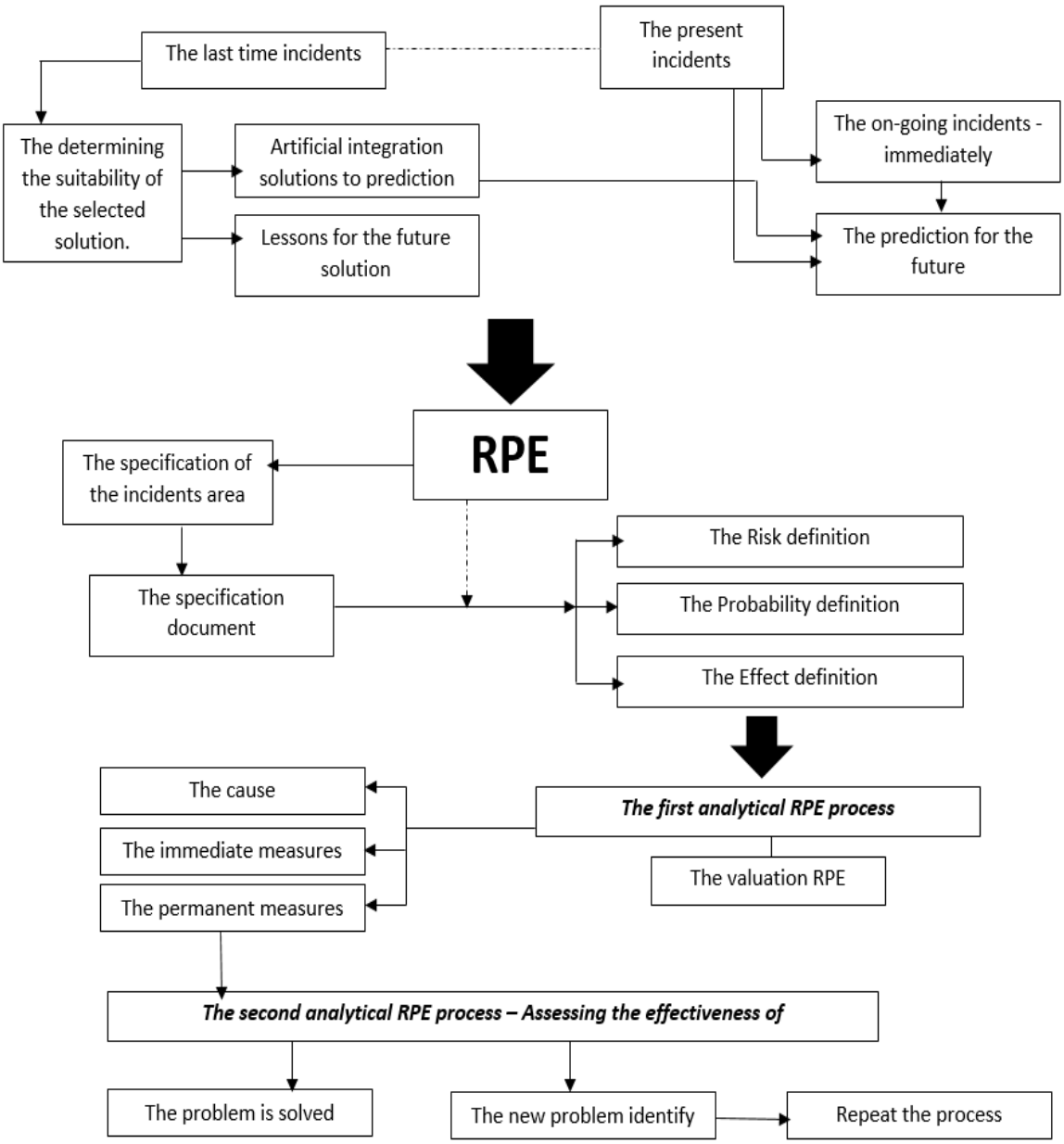
Processes of RPE were modelled function links and relations between each other analytical part of security analysis. In the next time, we can this relations and terms implicate to software for the automated process of analyses.

On the top of the Fig. 1, we can see inputs. Inputs are from the past or we can define inputs in the present. We call this inputs as sustainable input variables, which are permanently valid for the problem. After the valuation we can change conditions which were linking with invariably input variables. We can define the main asset in the studies. The studies will define the causes and measures of problems. It can be helpful for quickly and efficiently decisions in critical situations. We can see in the figure link between the present and the last incidents. This method for analyses is about studding last events and after we can apply results for next events in the future.

The next, RPE analyses starts with filling inputs and makes analytical process and validation. This process consist from two step of validation. The first validation is analysing inputs and in final, it makes decision. The second validation is controlling the effectiveness of measures. The last, we make final decision and it solved or it didn't solve problem. After we must define new problem and analysis is repeated again with new definition of problem [9].

Aims of analyses:

- Inputs – it was validation.
- Outputs – it was validation for two steps.
- Studies of causes, permanent measures and immediately measures.
- The risk, probability and effect definition.



- Fig. 1 Links between processes in RPE

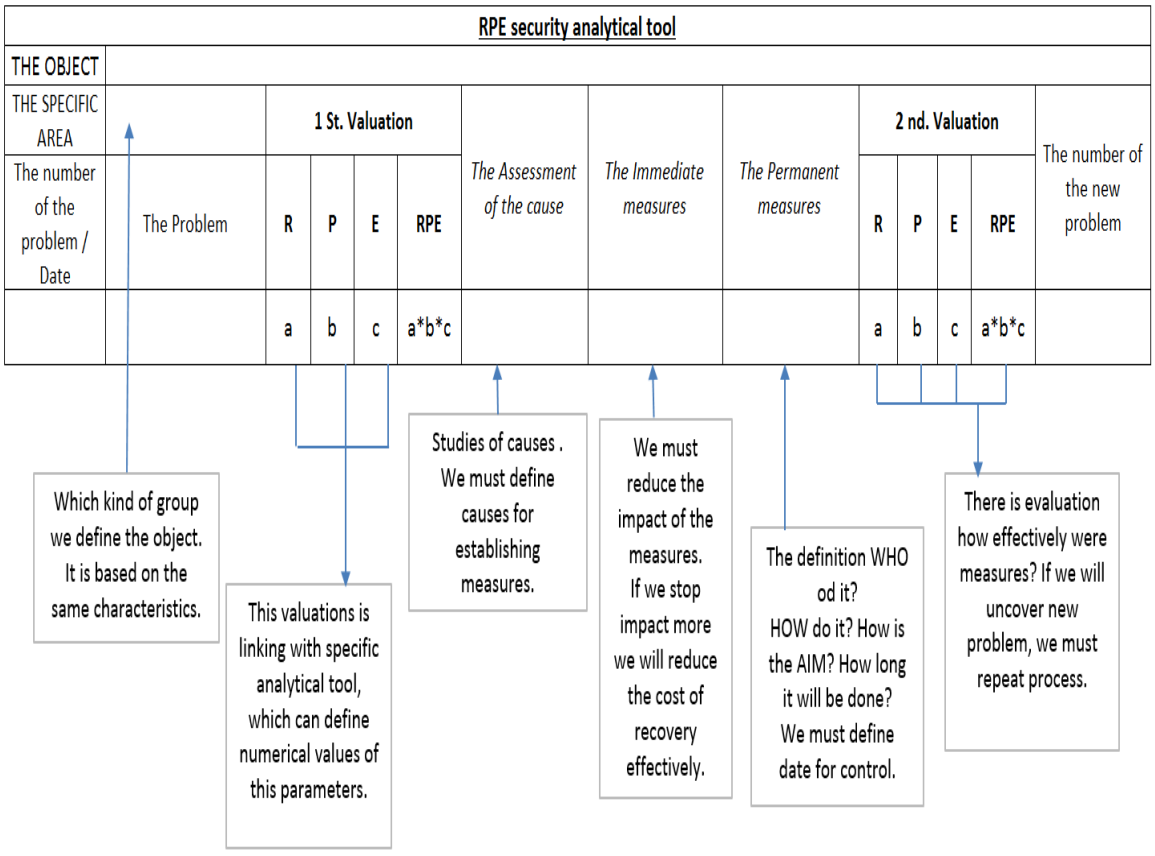
III. The Security Analytical Tool RPE

We can define the security analytical tool by the following figure. The RPE is realized by automated calculation. It will be connected with other analytical part of analyses. We determine others analyses as inputs and outputs. Inputs analysis were calculated in other tool, which done with other compatible processes. We can define the object, the specific area, where is problem and we must define the point of the problem. After this processes, we can rate RPE parameters [9].

After the first valuation we must define causes of the problem. We can study causes and after we can define the permanent measures. Permanent measures focus causes and eliminate conditions of causes. The second valuation is controlled for accordingly measures. After controlling we can define new problem, it is when one problem consists from other smaller problems, but this problems are important for solving security too [9].

After this analyses we will make some special studies of causes. When we make some special tool for solving the similar problems, after we can support making decisions in the next time.

TABLE II
THE SECURITY ANALYTICAL TOOL RPE



When we define permanent measures, we must define next points:

- The responsible person.
- The time interval for solving it.
- The aim of solution.
- Control dates and terms.

The immediate measure reduce the impact of the measure, which made problem, it improves causes and conditions of causes. This studies can improve the automatic decision-making in similar situations.

IV. INPUTS FOR RPE ANALYSIS

Inputs for RPE analysis are oriented for the primary identification of the problem and surrounding, where is problem. This problem has causes and causes have special conditions where causes make problem.

A. The Specification Document

The specification document defines how object is and where object is. It is suggested with numerical value and numerical value will be counted by equation, which we will determine by examining in the future research.

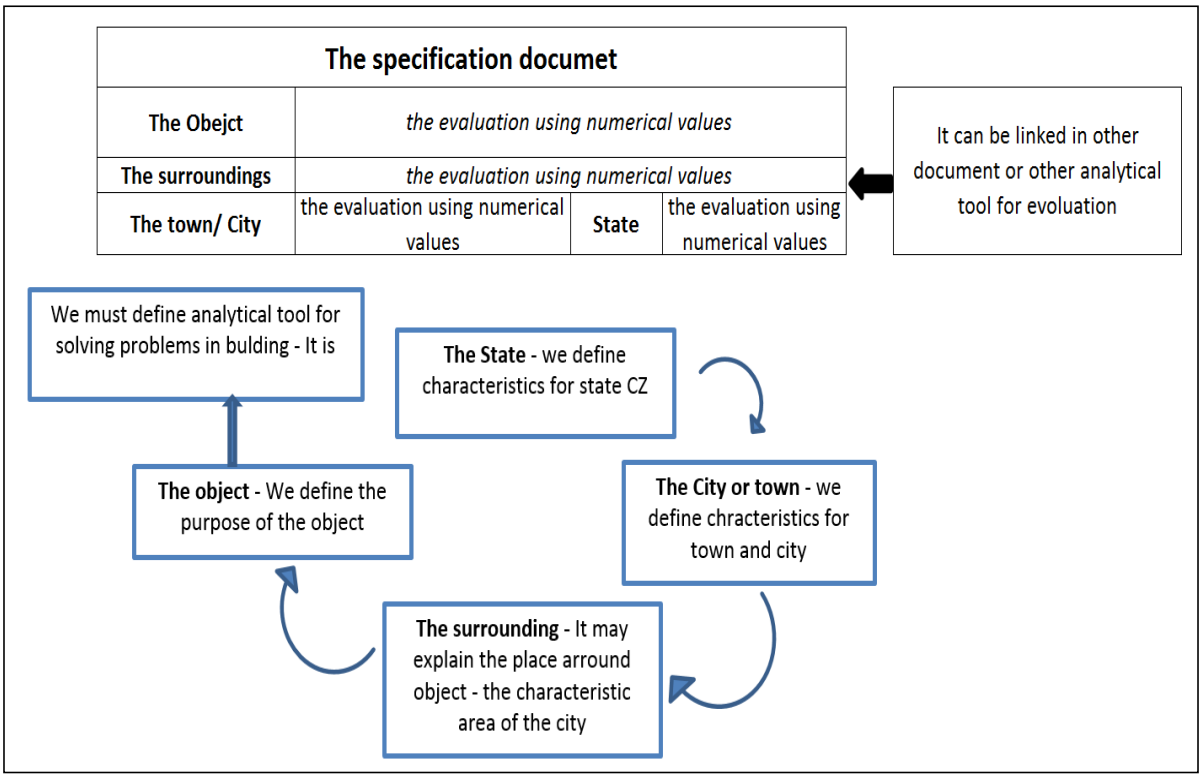


Fig. 2 The specification document

In the process valuation we must follow the rule of compatibility in other tools. It must be compatible for the achievement single system as analytical tool.

TABLE III
THE SPECIFICATION OF THE OBJECT, SURROUNDING, TOWN AND STATE [7]

The object of analyses	Specification	Coefficient
State	CZ	*It must be specify for the future*
	SK	
The town / City	Prag	*It must be specify for the population and attractiveness for attackers*
	The large city	
	The medially city / town	
	The small town	
	The village	
The surroundings	With the presence of a potential offender	*It must be define analytical process for special location in town*
	With the possibility of a potential offender	
	It is clean surround	
	It is surround with security option	
The object	The specification	*It is individual*

The specification and coefficient are linked in analyses. We use numerical value for better valuation in next processes and we could make this processes more practice as before.

B. The Problem

The problem is one of inputs. The problems can be situations, techniques and setting processes or it can be in human resources. It could be situation, which makes some special conditions, where risk has a higher degree of efficiency for the emergence of the problem. This description of the problem can be expressed by numerical values for better analyses.

V. Outputs for Rpe Analysis

Outputs from RPE analysis studies consist from causes, immediate measures, and permanent measures. After studies we can set links in prevent measures, we can support decisions in next event.

VI. The Risk, Probability And Effect Definition

The risk, probability and effect definition must consist from analyses of processes. It will be developed for next research. It will be linked with numerical values in the main analysis RPE.

A. The Risk Definition

The risk will be developed for a long time, because we must answer a lot of specification of problem. We can define parameters:

- Interval and time for continuance.
- The threat.
- The point of problem.
- The degree of deterioration.
- The reference to past incidents.
- The range of threat.
- The anticipates level.
- And others (fill in after next research).

[7]

B. The Probability Definition

It will be consisted from linking in values the percentages given a numerical expression for the next evaluation. The probability is identified by last events, or it could be identified by others analyses. The aim of this definition is finding one and together valuation for RPE analysis.

C. The Effect Definition

The effect is the most important from this three definition. We can see here for some special links and others terms. The valuation is linking with the probability and the risk too. We must know, how range for risk is, and how this situation is serious, and how is her speed for extension.

The risk, probability and effect are the basic parameters for the evaluation. It is the base for the valuation in the first step of analysis. We will develop special conditions for this definition, that we need exactly values for this type of analyses.

VII. Conclusion

The aim this paper is define new analytical tool for the assessment. Author define primary principles, but not special specific causes. This method will be using in specific causes, but it is the second step in research.

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This project is realized as the research with doctoral student and it is the basic input for next research, which we will develop in next term. It was realized with support of the university. This work was supported by Internal Grant Agency of Tomas Bata University under the project No. IGA/FAI/2015/015.

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Method of Hyperspectral Satellite Image Classification under Contaminated Training Samples Based on Dempster-Shafer's Paradigm

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Abstract **-** The aim of this paper is to show that evidence theory of Dempster-Shafer may be successfully applied to supervised classification in remote sensing. A new method to classify hyperspectral satellite images under contaminated training samples based on the use of the evidence theory is proposed. The flowchart of the classification process is described. The algorithmic and software support is developed for the evidence theory-based method. The results of experiment with real hyperspectral image showed the effectiveness of the proposed method.

Keywords - contaminated training sample, evidence theory of Dempster-Shafer, hyperspectral satellite image, image classification.

I. INTRODUCTION

The process of solution of actual scientific and practical problems, using hyperspectral satellite images (HSI) as a rule includes a procedure of its classification [1]. The most accurate results are provided by supervised classification method, which uses a priori information about the characteristics of the classes. This information is extracted from the training sample. But, in fact to extract completely pure training samples is not possible. For example, the training subsample of the vegetation may contain spots of bare soil, paths, artificial objects, etc. In addition, the adequacy of the pixel signals can be influenced by the conditions of sunlight and atmospheric correction. Altogether, these factors lead to deterioration in the quality of training sample. In such cases we'll use the term "contaminated samples".

The impact of the training sample contamination on the classification accuracy was studied in number of publications. C. Ruwet and G. Haesbroeck have explored impact of contamination of training dataset in statistical clustering using the k-means algorithm [2]. Theoretical framework for determining the loss in the accuracy of remote sensing image classification was proposed and studied by D. Yan [3]. C. Persello and L. Bruzzone have investigated classification problems characterized by few training samples and affected by sample selection bias [4].

In general, it was shown that even small amount of contamination in a training sample can lead to appreciable errors. Thus, the problem of effective classification under contaminated training samples has not yet received complete solution and saves its relevance.

In the second half of the past century, A. Dempster and G. Shafer put forward new paradigm the essence of which is to simulate uncertainty by using a probability range rather than a single probability value [5]. This paradigm got embodied in the evidence theory, which has some advantages over traditional probability-theoretical approach and expands the range of practical applications [6]-[8]. In this study, we show that the methods of Dempster-Shafer evidence

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theory (DST) can be useful in solving the above problem image classification under contaminated training samples.

The paper is organized as follows. After the formulation of the problem we provide basics and notions of DST and describe the essence of the proposed method of classification of the HSI. With the necessary degree of detail there has been described the organization of the classification process and content of its procedures. In the final part the article considers the results of experimental studies of the accuracy assessment of the proposed method with various degrees of contamination of the training samples.

II. PROBLEM

The hyperspectral image (HSI) consists of a set of spectral images:

$$S_k = \{\pi_n, u_{nk}\}_{n=1}^{N_\pi}; \quad k = 1,2,...,K, \tag{1}$$

where S_k is the *k*-spectral image; K is the total number of spectral images (spectral bands); π_n is the *n*-th pixel; N_π is the total number of pixels in the HSI; u_{nk} is the *k*-component of full signal $\mathbf{u_n}$ of the pixel π_n.

The full signal $\mathbf{u_n}$ of an arbitrary pixel π_n convenient to consider as a vector with components u_{nk} in the spectral space Λ^K which created by axes $(\lambda_1,...,\lambda_k,...,\lambda_K)$, i. e.:

$$\mathbf{u_n} = \{u_{nk}\}_{k=1}^{K}; \quad u_n \in \Lambda^K. \tag{2}$$

Each π_n pixel of the HSI displays an object of some class; aim of pixel-wise classification is to determine the class of the pixel object π_n as accurately as possible, based on the analysis of the $\mathbf{u_n}$ signal.

In this paper, the problem of HSI pixel-wise supervised classification is solved under the following assumptions and limitations:

1. The nomenclature of the classes to which objects in the image can belong to is known, and training sample with representatives of each class is also available;
2. The results of classification must be unambiguous; i. e. is each pixel may belong to only one class it most closely resembles;
3. Quality of training samples is limited, within the training samples may be present extraneous elements and noise. In addition, forming a training sample, the expert can make mistakes.

The objective of our research is to develop a simple and effective method to HSI classification for above assumptions and limitations. Since in developing this method we lean on the Dempster-Shafer's paradigm, so it is useful to outline the basic concepts of the evidence theory.

III. BASIC CONCEPTS OF DEMPSTER–SHAFER EVIDENCE THEORY

Suppose Ω is a set of hypotheses about membership of pixel or object. DST allows considering any subsets of the Ω set. Total number of such subsets can be 2^Ω (the empty set Ø and the set Ω also included in this number). Applied to image classification, it means that not only single classes (singletons) but also any combinations of classes may be considered.

In DST with every hypothesis A $(A \in 2^\Omega)$ is associated so-called mass $m(A)$. The $m(A)$ mass value represents the degree of belief allocated to the hypothesis *A*; it belongs to the interval

[0, 1] and satisfies the following conditions:

$$\sum_{A \subseteq 2^{\Omega}} m(A) = 1;$$

$$m(\varnothing) = 0.$$

The mass $m(A)$ also referred to the basic probability. Any subset A whose $m(A) > 0,$ is called the focal subset [5].

Having the basic probability distribution, one can compute the level of hypothesis support. For this purpose it was introduced two measures: belief function *Bel(A)* and plausibility function *Pl(A).*

Belief function (4) measures the minimum or necessary support for the hypothesis whereas plausibility function (5) reflects the maximum or potential support for that hypothesis. These two functions are respectively defined as follows:

$$Bel(A) = \sum_{B \subseteq A} m(B), \tag{3}$$

$$Pl(A) = \sum_{B \cap A \neq \varnothing} m(B). \tag{4}$$

An important advantage of the DST is the presence of simple rule of combining data provided by many sources [5]. Suppose one source appointed to the hypothesis *A* the mass value $m_1,$ and the other source independently appointed to the same hypothesis the mass value m_2. The rule of Dempster allows combining these masses; the resultant is given by the following equation:

$$m_1 \oplus m_2(A) = \frac{1}{1-K} \sum_{B_1 \cap B_2 = A} m_1(B_1) \cdot m_2(B_2), \tag{5}$$

where

$$K = \sum_{B_1 \cap B_2 = \varnothing} m_1(B_1) \cdot m_2(B_2). \tag{6}$$

The *K* value reflects the degree of conflict among the sources and so it is called the conflict coefficient. The range of values of the conflict coefficient lies within the interval [0, 1], where zero value indicates the absence of contradictory assessments of the sources. The more contradictions we have, the closer is the *K* value to 1.

P. Smets suggested a concept of pignistic probability [9], which proved to be very fruitful in decision-making sphere, including classification tasks. Pignistic probability *BetP* of focal subset *B* is expressed in the following way:

$$BetP(B) = \sum_{A \in 2^{\Omega}} m(A) \frac{|B \cap A|}{|A|}; \quad B \in \Omega. \tag{7}$$

The value of pignistic probability always lies within the confidence interval: $Bel(B) \leq BetP(B) \leq Pl(B)$. Like any other probabilities, pignistic probability is normalized to 1.

In this work, when we determine the class of pixel, we will rely on the criteria of maximum of pignistic probability:

$$D = \arg(\max_{A \in 2^{\Omega}}(BetP(A))), \tag{8}$$

where *D* is the decision taken on the set of the considered classes.

IV. CLASSIFICATION FRAMEWORK

Since, as mentioned in the formulation of the problem, information about the representatives of the classes under consideration is available to the expert, that's why we select the supervised classification method [1]. In this case, we propose the method for the HSI classification which is represented by the scheme in Fig. 1.

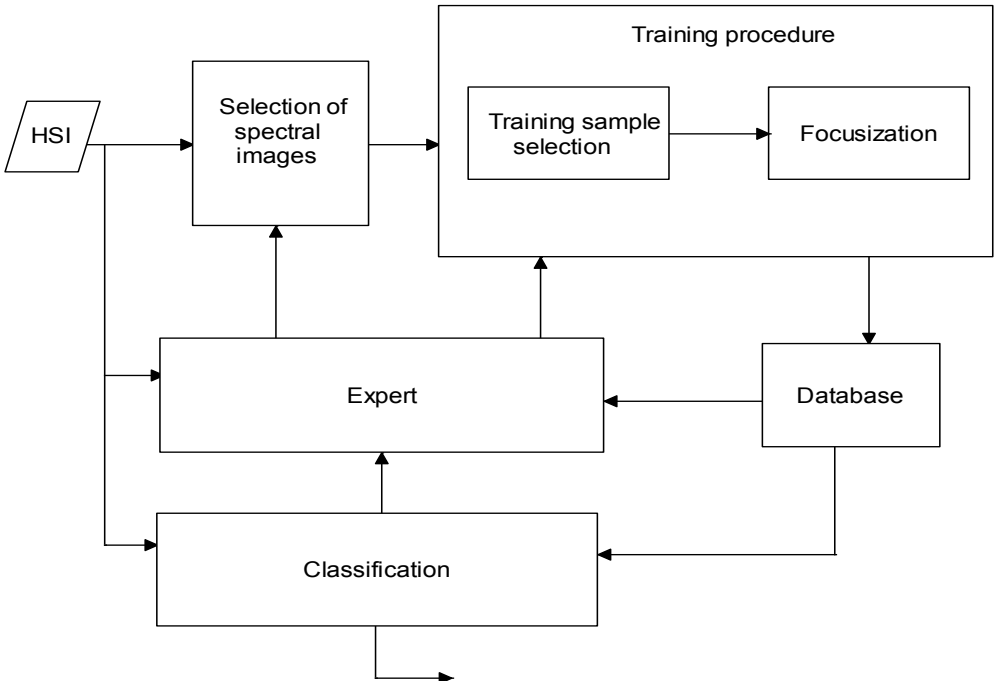


Fig. 1 Scheme of HSI supervised classification method

1) Selection of spectral images

Usually, the part of the spectral images of HSI has high level of noise. Moreover some spectral images of HSI are very similar to each other. Both very noisy and similar images have insufficient informativity, and therefore can be removed from consideration in the classification. Spectral images with significant level of noise can be determined and removed by an expert. The similarity of spectral images can be estimated using correlation coefficient.

Consider the basic procedures that conjointly implement the proposed method. Applying procedure of the selection of spectral images (the pseudo-code of algorithm for the selection of the spectral images is represented in Fig. 2) we are setting up the sub-list of spectral images $\{S_k\}$, the length of K^* which is substantially the shorter than the length K of the original list of spectral images $(k=1,2, ..., K^*; K^*<<K)$. The sub-list $\{S_k\}$ is the shorter, however it still retains the amount of information needed to deal with the task of classification successfully.

Upon completion of the spectral images selection procedure, we get a possibility to reduce the dimension of the spectral space R from K to K^* $(K^* << K)$ and to make HSI classification in the spectral space $\Lambda^{K^*} = (\lambda_1, ..., \lambda_k, ..., \lambda_{K^*})$. Therefore, instead of expression (3) the pixel signal u_n will be described below by the following expression:

$$\mathbf{u_n} = \{u_{nk}\}_{k=1}^{K^*}, \quad \mathbf{u_n} \in \Lambda^{K^*}. \tag{9}$$

It should be noted that the reduction number of correlated spectral images from K to K^* not only reduces the volume of further computations, but also satisfies the requirement of the mutual independence of the data sources that are combined by the rule of Dempster [5].

```
N: number of spectral images S_i
r_max : threshold
K_min: minimum number of spectral bands

i = i + 2: step size

For i = 1 to N
S is a vector of images S_i
Sort S
begin
write ("For spectral image S_i we calculate: a_i, cov_i, δ_i");
readln (a_i, cov_i, δ_i);
write ("For spectral image S_{i+1} we calculate: a_{i+1}, cov_{i+1}, δ_{i+1}");
readln (a_{i+1}, cov_{i+1}, δ_{i+1});
write ("For spectral images S_i and S_{i+1} we calculate: r_{i,i+1}");
readln (r_{i,i+1});
if r_{i,i+1} ≤ r_thr then we choose images S_i and S_{i+1}
else
begin
if δ_i > δ_{i+1} then we choose image S_i;
else: we choose image S_{i+1}
end
write ("we get a new number of spectral bands, K*");
end.
begin
if K* < K_min then we correct r_thr and / or K_min
else
begin
if K* > 2·K_min then write ("For the sub-list of spectral images with
length K* we calculate: r_{i,i+1}")
else: we use these K* spectral images for the following
classification
end
end.
```

Fig. 2 The pseudo-code of algorithm for the selection of the spectral images

2) Training procedure

A training data set is formed by the expert from pixels of the HSI. Suppose the HSI displays objects of *L* classes. Expert analyzes the image and selects compact groups of pixels to obtain the training subset for each of the *L* classes. Thus, we get a training sample *TS* that includes *L* training subsamples *ts*, i.e. $TS = \{ts_l\}_{l=1}^{L}$.

The training sample must satisfy a number of requirements [10], [11]. The key requirements include completeness, sufficiency and purity.

The completeness means that the classes must be presented in the training sample in approximately equal proportions.

The sufficiency supposes the presence of the minimum size of training sample $N_{TS}^{\min}$ which ensures the correctness of the classification accuracy estimation. Let's denote a size of training sample *TS* as N_{TS} , then sufficiency requirement is expressed by the inequality

$$N_{TS} \geq N_{TS}^{\min}. \tag{10}$$

There are some ways to calculate $N_{TS}^{\min}$ value, the simplest way is to use binomial model [10], [11], according to which the minimum size of training sample *TS* is calculated as:

$$N_{TS}^{\min} = \frac{Z_{\alpha}^2 \, P_0 \, (1 - P_0)}{b^2}, \tag{11}$$

where P_0 is a prior estimate of correct classification probability; Z_{α} is the normal score for the desired two-tailed probability α of Type I error; *b* is the desired absolute precision as a proportion.

The purity of a training sample is defined by the proportion of pixels of extraneous classes in the total number of pixels of the given sample. That may be so-called mixed pixels, the failed pixels and so on.

The set of pixel signals of training sample allows to represent each class by a set of intervals in the spectral space Λ^{K^*} . To do this, each of the axes $(\lambda_1, ..., \lambda_k, ..., \lambda_{K^*})$ of the spectral space Λ^{K^*} is divided into intervals according to the number *L* of the classes and each of the intervals gets a mark of corresponding class. The order of the interval formation for the class, for example for the class *l*, we'll describe using Fig. 3.

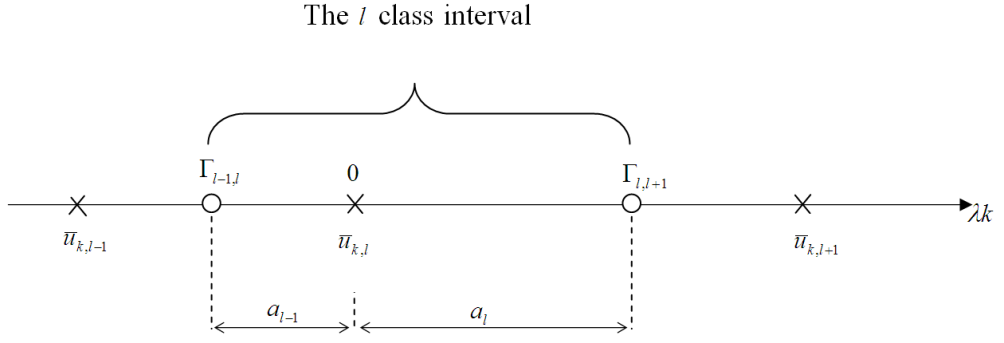


Fig. 3 Forming spectral intervals for classes

The point for the interval forming on the spectral axis λk is point *O*, its position is determined by the expectation signal $\mu_{k,l}$ of pixels belonging (according to the expert opinion) to the *l* class. The left and right boundaries of the interval are limited by points $\Gamma_{l-1,l}$ and $\Gamma_{l,l+1}$. Positions of these points are determined by segments a_{l-1} and a_l respectively.

Let $\sigma_{k,l-1}; \sigma_{k,l}; \sigma_{k,l+1}$ be standard deviations of the signals of pixels of (l-1), (l), and (l+1) classes respectively. Under such notations values a_{l-1} and a_l are calculated from the relationships:

$$\frac{a_l}{a_{l+1}} = \frac{\sigma_{k,l}}{\sigma_{k,l+1}} \text{ and } \frac{a_l}{a_{l-1}} = \frac{\sigma_{k,l}}{\sigma_{k,l-1}}. \quad (12)$$

In the same way, other intervals can be constructed for each of the classes represented in the HSI.

Upon completion the construction of the spectral intervals for each of the considered classes we conduct focusization procedure. By focusization of the class interval we mean the procedure of obtaining the list of focal pixel subsets, whose signals are located in this interval and the calculation procedure of the basic probabilities for them.

Having contaminated training sample we have any reason to assume that interval with certain class mark may contain not only the signals of the pixels of the same class, but the signals of the pixels of other classes as well. Therefore, forming focal subsets we need to consider a number of hypotheses about the class membership of the pixels.

One focal subset is built from a single hypothesis that the pixel whose signal is located within the interval, really belongs to the same class as the interval. Each of the other focal subsets comprises two hypotheses; one hypothesis states that the class membership pixel corresponds to a given interval, and another hypothesis states that the pixel belongs to another specific class.

Each of the focal subsets has corresponding basic probability. To explain the rule for basic probability calculation, consider the following example.

Suppose, the signals of the Q_Σ pixels are located in the spectral interval of the l_1 class. The class membership of pixel has been evaluated by the expert as follows: Q_1 pixels belong to the class with the same name (i. e. (l_1)), Q_2 pixels belong to the l_2 class, and Q_3 pixels belong to the l_3 class.

In this case, the list of focal subsets for the spectral interval will include three subsets: $\{l_1\}$, $\{l_1, l_2\}$, $\{l_1, l_3\}$. Basic probabilities (masses) for these focal subsets are calculated as:

$$\left.\begin{aligned} m(\{l_1\}) &= \frac{Q_1}{Q_\Sigma} \\ m(\{l_1, l_2\}) &= \frac{Q_2}{Q_\Sigma} \\ m(\{l_1, l_3\}) &= \frac{Q_3}{Q_\Sigma} \end{aligned}\right\}, \quad (13)$$

where $Q_\Sigma = Q_1 + Q_2 + Q_3$.

Thus, the focusization procedure is completed and we have formed a database (DB), comprising:

- description (including boundaries and class marks) for each of the formed intervals within the spectral space Λ^{K^*};
- the focal subsets and its basic probabilities (masses) for each of the formed intervals within the space Λ^{K^*}.

Thus, the training procedure is completed and further classification procedure can be run.

3) Classification algorithm

Each pixel π_n of HSI displays an object of some class and the aim of pixel-wise classification is to determine the class of the pixel's object π_n as accurately as possible, based on the analysis of the $\mathbf{u_n}$ signal.

In pixel-wise approach, the pixels of HSI are analyzed and classified consistently and independently. Therefore, it is sufficient to consider the content of the classification procedure for the case of only one pixel, say of an arbitrary pixel π_n.

The algorithm that performs classification procedure consists of the following steps:

Step 1. Extract the known signal $\mathbf{u}_n = \{ u_{nk} \}_{k=1}^{K^*}$ of the pixel π_n.

Step 2. Knowing components u_{nk} of the vector signal $\mathbf{u_n}$ identify all spectral intervals within which corresponding components are located.

Step 3. Using information from DB compose the list of focal subsets and their basic probabilities (masses) for each of the spectral intervals, which have been identified in step 2.

Step 4. Applying the rule of Dempster (5), perform the calculation of the combined masses for the focal subsets from the list that was composed in step 3.

Step 5. Based on the results of calculations performed in the previous step and using the formula (7) calculate the pignistic probability BetP value for each of focal subsets – singletons.

Step 6. The calculated values of pignistic probability for focal subsets - singletons are ranked and further we define (using the criterion (8) of maximum pignistic probability) the most likely class membership for the pixel π_n.

This algorithm is applied sequentially to each pixel of the hyperspectral image and in the end we get the classified HSI in whole. Thus, the classification process is completed.

V. EXPERIMENT AND RESULTS

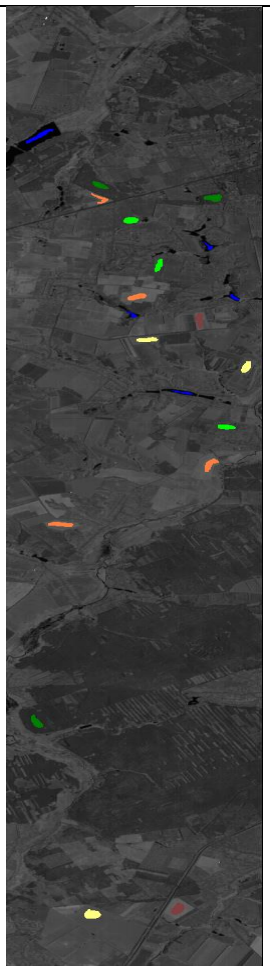
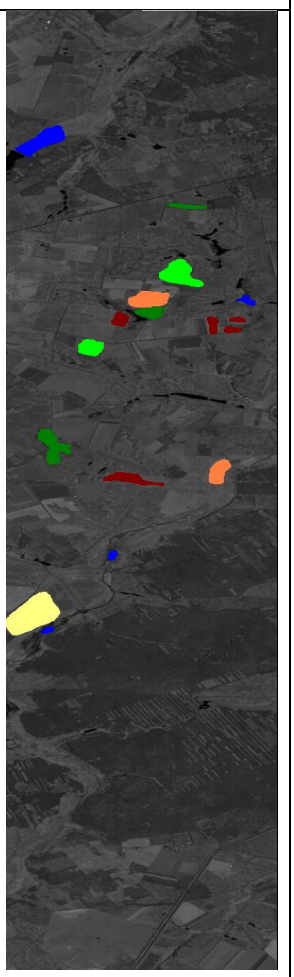
Accuracy assessment of the developed method was conducted on base EO1H1810252014211110KF hyperspectral image received 30.07.2014 by Hyperion Imaging Spectrometer of EO-1 satellite. A Hyperion HSI consists of 242 narrow spectral images which together cover the wavelength range from 400 to 2500 nm. All spectral images have the same spatial resolution of 30 meters. All spectral images have same spatial resolution 30 meters.

The Hyperion imager filmed the strip of the terrain at the junction of three districts of the Kiev's region: Makariv's, Kiev-Svyatoshin's and Fastiv's (shown in Table 1 in RGB representation). On the terrain there are objects of the following classes: water (1), coniferous forest (2), deciduous forest (including garden and forest plantations) (3), grain fields (4), vegetable fields (5), and harvested fields (6).

For hyperspectral images proceeding and analysis the special software was developed. With its help very noisy and similar spectral images have been removed. We used the following criterion: the correlation coefficient r_{thr} between neighboring spectral images should not exceed of 0.8. After that for further work 17 spectral images have been selected. The spectral bands in which these images have been obtained are enumerated in Table II; numbering of the spectral bands corresponds to the EO-1 technical documentation [12].

The spatial location of the training subsamples and the number of pixels in each of them are shown in Table I (left image). To assess the accuracy of the proposed method, examining subsamples (ground sites) were selected which have no intersections with the training subsamples (see right image in Table I). The sizes of training sample and examining sample have been calculated given the sufficiency requirement (the formula (11) and meeting the condition (10)).

TABLE I
CLASSES, TRAINING AND EXAMINING SUBSAMPLES

Classes of objects	Training subsamples		Examining subsamples	
	Number of pixels	Location in the Hyperion image	Number of pixels	Location in the Hyperion image
1. Water	335		1394	
2. Coniferous forest	397		1471	
3. Deciduous forest	344		1541	
4. Grain fields	525		1349	
5. Vegetable fields	440		2059	
6. Harvested fields	315		1347	
Total pixels	2356		9161	

In experimental research, we have tested the proposed method (below in tables and charts, this method is denoted as DST) in comparison with the SVM method [1]. We have selected the SVM method, because most researchers agree with the opinion that namely this method provides the most accurate classification [13], [14]. Moreover, SVM method is conveniently implemented in software in the ENVI image processing system [15]. In the experiment, we used 8 versions of the same initial training sample. The versions differ in the degree of contamination, specifically: 0, 10, 20, 30, 35, 40, 45, and 50%. Sequentially for each version, the Hyperion hyperspectral image was independently handled using both DST and SVM method. Each time the error matrix was formed, that allows evaluation of the classification accuracy.

The results of the experiment have demonstrated that when we use non-contaminated training sample our method shows overall accuracy 0.859 whereas the overall accuracy of the SVM was found to be 0.778 (Fig. 4).

The classification accuracy decreases monotonously with the increase of contamination degree of training sample. In the case of 50%-contaminated training sample we obtained the following results: the overall accuracy for the DST and SVM methods equals 0.629 and 0.475

respectively. Therefore, the accuracy of the DST method is better by 8-16% compared to the SVM method accuracy.

TABLE II
Selected spectral bands of Hyperion Imaging Spectrometer

Spectral Band	Average Wavelength, nm	Full Width at Half the Maximum, nm
21	559.09	10.93
33	681.20	10.33
36	711.72	10.53
43	782.95	10.88
77	912.45	11.05
88	1023.40	11.05
95	1094.09	10.99
111	1255.46	10.73
136	1507.73	11.11
140	1548.02	11.25
153	1679.20	11.55
183	1981.86	10.92
186	2012.15	10.91
198	2133.24	10.73
202	2173.53	10.63
217	2324.91	10.41
222	2375.30	10.41

In Fig. 5 we can see the distribution of the errors of omission for the considered classes in the case the non-contaminated training sample. The numbering of classes corresponds with the numbering in Table I.

The average omission and commission errors of Hyperion HSI classification by DST and SVM methods for the non-contaminated training sample case are shown in Table III. Their comparison shows, that the DST classification method is on 9% more efficient than the SVM method.

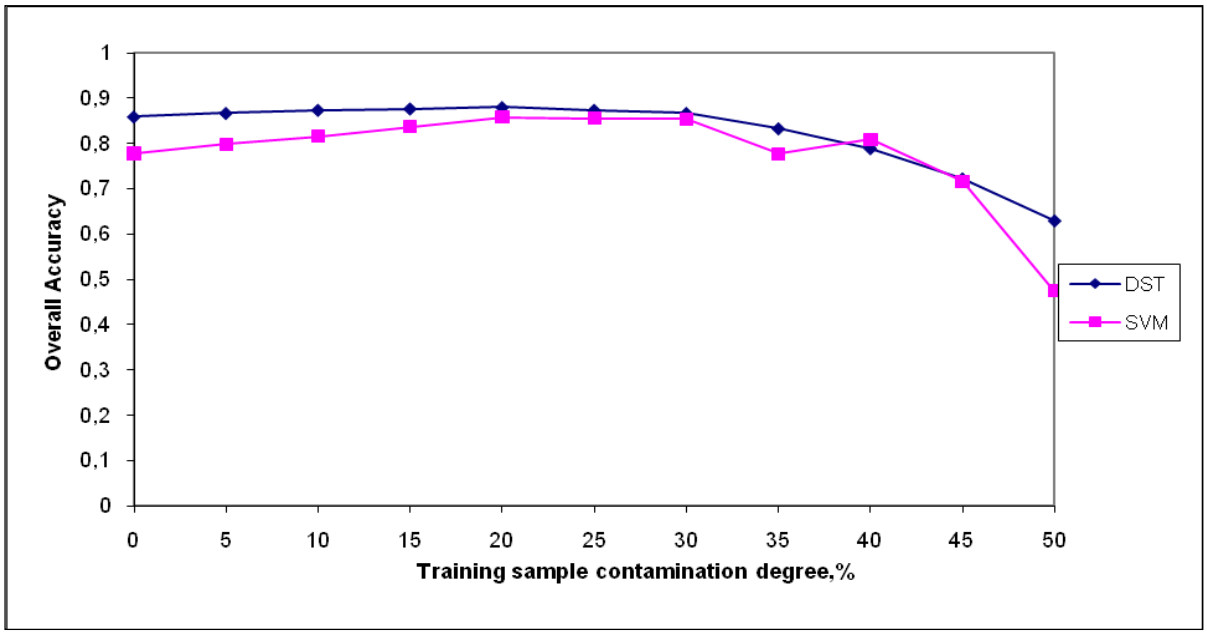


Fig. 4 Accuracy of DST and SVM methods as a function of the training sample contamination degree

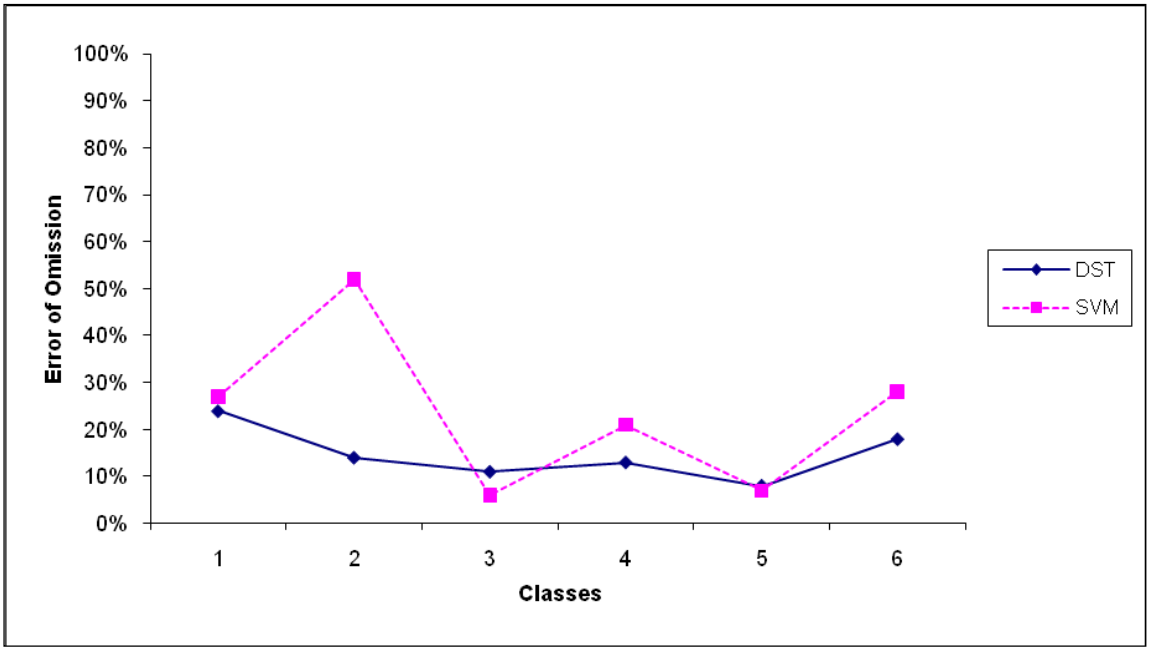


Fig. 5 Error of Omission distribution for the considered classes (non-contaminated training sample case)

TABLE III

Average Omission and Commission Errors

Method	Average Omission Error	Average Commission Error
DST	15%	13%
SVM	24%	22%

VI. CONCLUSION

Thus, in this paper we have proposed a new method of supervised classification of hyperspectral images especially for prevalent cases when the training sample is contaminated, including significant contamination. The method is based on the use of Dempster-Shafer paradigm.

The flowchart of the classification process is described. The algorithmic and software support are developed for the evidence theory-based method. The results of experiments with real hyperspectral image showed sufficiently high accuracy of the proposed method.

Further development of the proposed method the authors associate, primarily, with the improvement of the procedure of classes' description formulation procedure. In particular, it is advisable to provide the optimization of the class intervals on spectral axes, and explore other possible approaches to the focusization procedure, etc. The actual task is also the development of recommendations to use the proposed classification method in various thematic applications.

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Metamodel describing a relational database schema

Matus Chochlik, Jozef Kostolny, Penka Martincova

***Abstract*—** In this paper we present the design of the foundation of an expert system for clinical interpretation of "-omics" data using methods of big data processing. Such an expert system should be able to classify tumors processing vast volume of input data of different nature (demographic, genomic, clinical, epidemiological, diagnostic) and to be ready to append data in real-time, to update itself, to learn, and ultimately to be an instrument for clinical oncologists in evaluating predispositions and disease prognosis and for selecting the most appropriate therapy.

***Keywords*—** metamodel, metaprograming, database, genetic data

I. Introduction

Metadata-driven programming and metaprograming can be used in a broad range of programming tasks. We have implemented a metamodel which contains metadata describing various aspects of a relational database and can be used for several di erent purposes like dynamic generation of application user interfaces, dynamic generation of SQL, visual exploration and visualisation of the database, automatic generation of the documentation and of visual diagrams of the database model, etc. The metamodel is stored in the database which it describes and the metadata is accessed through the same interface as the regular data. Some of the metadata is automatically generated during the generation of the source SQL script, by out custom build system, some is extracted from the standard database catalogs and the rest, for example the localized descriptions, has been filled-in manually. The metamodel also implements several functions which simplify the usage of the metadata (some are described below). Using the metadata instead of hard-wiring database model-related logic into applications has the advantage that the applications handle changes in the database much more gracefully and it makes the maintenance or further development of the system easier.

Large national and international studies are currently dealing with an individualized approach in the prediction, diagnosis and therapy of cancer. Individualized approach laid the foundations for the development of a new discipline Personalized medicine. In the past it was customary for all oncological diseases to apply a uniform standard treatment methods -regardless of whether the individual patient's symptoms and peculiarities of the disease. In the recent years, research has produced many changes in medicine - today we can far more accurately characterize cancer disease in each individual and it is still more accurate to describe individual molecular biological tests. Rapid advances in human genomics and postgenomic studies of comprehensive molecular data, collectively called "omics" such as transcriptomics, proteomics and metabolomics, give rise to new possibilities in medicine. These methods are widely used in molecular diagnosis of inherited diseases, infectious diseases, prenatal diagnosis, pharmacogenomics, and not least in the molecular diagnosis of cancer and prognosis. The tumor disease is caused by the accumulation of mutations in different genes in a single cell. These mutations, which may be genetic (inherited from parents) and somatic (obtained in the course of life) have a fundamental effect on oncogenes, suppressor genes or genes that are responsible for DNA repair, allow escape control cellular mechanism leading ultimately to tumor formation.

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In the last few years have new generation sequencing (NGS) technologies made possible to produce a large number of studies providing a comprehensive molecular characterization of cancer and led to the discovery of new genes associated with particular tumor types and to identify a large number of recurrent mutations (identical mutations detected in a large number of samples) that have been missed by standard cytogenetic techniques. Post-genomic data provide detailed information on the structure of molecular evolution diseased cells. This is a clinically and pathologically unobservable information that can be used for detailed classification. Structure of gene expression not only provides information about the microscopic molecular activity of diseased cells, but also shows a close relationship to the macroscopic manifestation of the disease, especially the prognosis of the disease, which can not be correctly predicted purely based on clinical and pathological findings. It is therefore necessary to be able to make the best use of genomic, analytical and clinical data in clinical medicine, so we can innovate conventional medicine and open the possibility of new medical care that we could call post-genomic medicine [1].

II. Overview of the database model

The database contains clinical and other medical examination data and a large amount of genomic data. The it provides input for analysis using data mining techniques (decision trees) and other traditional and modern methods of Big data processing (Graph theory and MapReduce). In order to search for hidden dependencies, derived data are used for the monitoring of various types of intergenic interactions and interactions at the phenotype level. For this purpose it is necessary to provide software support for testing a constructing hypotheses associated with prediction, prognosis and therapy of cancer diseases.

The database has been designed and implemented with the following considerations in mind:

- it should be able to handle large amounts of data (in the order of 109 of records) in terms of storage space requirements and database operation performance,
- it should efficiently provide the stored data in a form suitable for statistical analysis and data mining,
- it should provide strong support for semi-automated application GUI generation (further work by the authors related to metadata-based semi-automated GUI generation was described in [2], [3], [4]). and support for dynamic, user-driven exploration and visualization of the database,
- texts in the type-tables (like `diagnosis`, `gene`, `attribute_type`, `examination_type`, `value_type`, `enumeration_type`, etc.), should be translated to database user's preferred language, in order to enable international cooperation in the future,
- physical units of the stored values should be properly handled (see [5] for details on how this can be accomplished in a relational database).
- storing sensitive personal information should be minimized and all such data should be protected from unauthorized access.

The database consists of roughly 70 main relations (tables or views), most of which are shown (with the exception of the relations belonging to the metamodel) in Figure 1. These relations can be divided into several groups:

- *database users* - basic information about the database users and their privileges.
- *localization* - related to the localization of the texts in the database.
- *dbSNP* - data imported from the single nucleotide polymorphism reference database [6].
- *polymorphisms* - list of all known DNA polymorphisms, their classification and relation to genes.

- *basic* biochemistry - nucleic acids, nucleobases and aminoacids referenced by other parts of the database.
- *patients* - basic information about the patients and the members of the control groups.
- *examinations* - physical and medical examinations of the patients (mostly numeric values or intervals including the proper units of measurement).
- *attributes* - various attributes (mostly text or pre-defined enumerated values) of the patients and their anamneses, including personal data which is stored encrypted in the database.
- *ontology* - a simple graph-based categorization of the records in the database.
- *metamodel* - contains metadata describing various aspects of the database itself.

Most of the basic business logic is implemented directly in the database by approximately 180 PL/SQL functions.

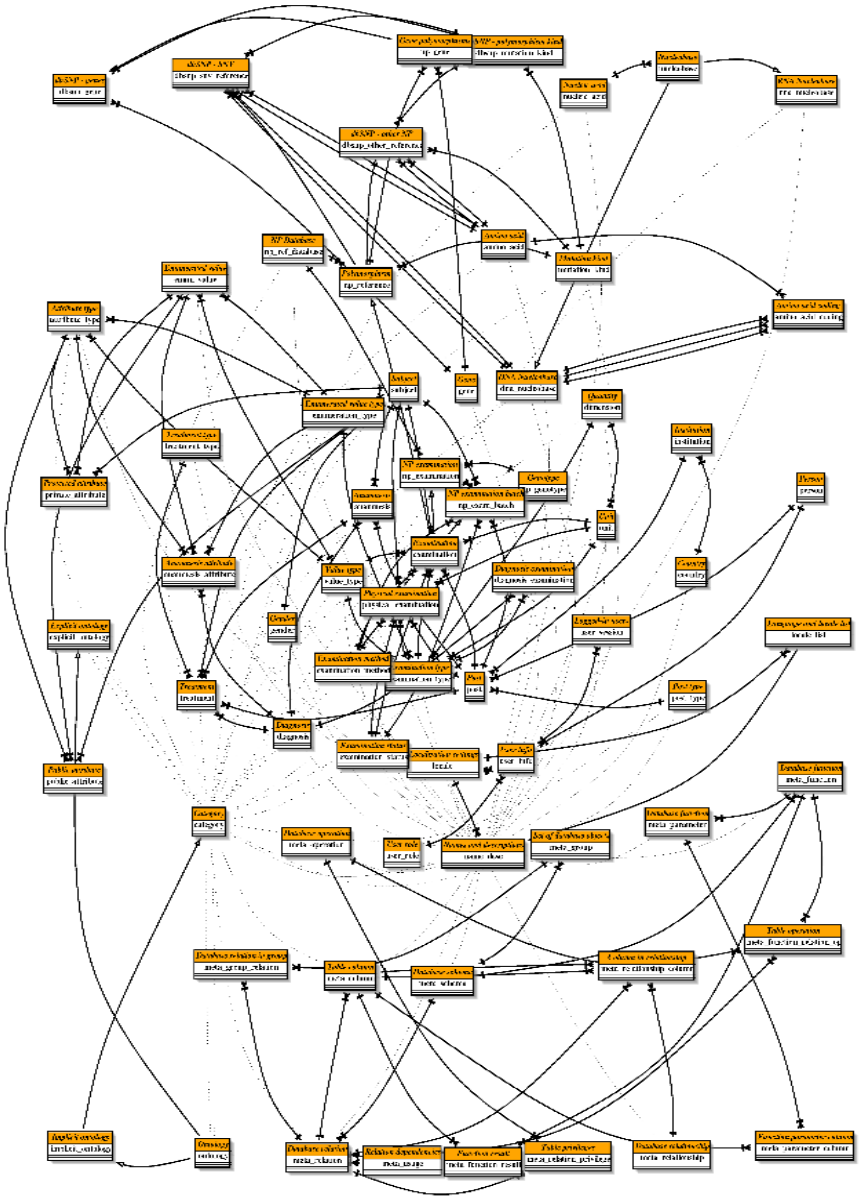

Fig. 1 Overview of the database model

III. The build system

The database source script is generated by our custom bash-based build system (called basql), which translates source files written in a domain-specific SQL-like language into a valid SQL script for a particular database system.

This build system has several purposes:

- it allows to keep the naming of database objects, like table columns, functions, etc. consistent, and makes changing them, if necessary, much simpler,
- it translates symbolic data types like `UID`, `STRING`, `BOOLEAN`, `COUNTRY_CODE` and many more, into concrete data types supported by the target database system,
- it assembles metadata describing the database model and creates SQL statements for storing them in the metamodel,
- it implements the auto-assignment of record identifiers,
- it automates the implementation of helper functions and triggers used to support localization, temporal history, classification of records into the ontology, etc.
- it automatically generates some of the data manipulation functions,
- it implements various types of relationships in the database, since for performance reasons and to simplify maintenance, some of them are not implemented by using foreign keys, and it imports initial data from external formats.
- `basql` allows to keep the implementation of these patterns consistent throughout the whole model, and keeps it portable.

The following code snippet shows an example of a schema source script in the basql language defining the physical_examination table.

```
CREATE  TABLE  physical_examination
WITH REFERENCE_TO subject
WITH REFERENCE_TO examination_type
WITH REFERENCE_TO examination_status
WITH WEAK_REF_TO examination_method
WITH REFERENCE_TO value_type
WITH WEAK_REF_TO unit
WITH ROLE_REF_TO post examiner
WITH HISTORY examination;

ALTER TABLE physical_examination
ADD COLUMN num_value $(FLOAT) NULL;

ALTER  TABLE  physical_examination
ADD  COLUMN  num_value2  $(FLOAT)  NULL;

ALTER  TABLE  physical_examination
ADD  COLUMN  notes $(STRING  500) NULL;

ALTER    TABLE    physical_examination
ADD PRIMARY KEY
  $(TABLE_PK_NAME subject),
  $(TABLE_PK_NAME examination_type),
  $(TABLE_HISTORY_COLNAME    physical_examination);

ALTER  TABLE  physical_examination
WITH SUBJECT_HISTORY examination_type;

CREATE   INSERTER   FOR   physical_examination;
CREATE  UPDATERS  FOR  physical_examination;

GRANT SELECT ON physical_examination TO $(EDITOR_ROLE);
GRANT INSERT ON physical_examination TO $(EDITOR_ROLE);
GRANT UPDATE ON physical_examination TO $(EDITOR_ROLE);
```

This example shows, that relationships are defined by highlevel statements and the details, like determining the names of the primary and foreign key columns and the formatting of the low-level SQL commands to the syntax of a concrete database system is left to the build system.

Also note that `basql` allows to query the real names of primary key and other special columns and substitutes symbolic type name statements like `$(FLOAT)` and `$(STRING 500)` or database role names like `BROWSER_ROLE` with their lowlevel equivalents.

The `WITH HISTORY` and `WITH SUBJECT_HISTORY` statements create additional columns, indexes and functions which simplify querying the records in this table in relation to their date and time. The build system also automatically prefixes the identifiers with the database schema name (`gen_seq.`) where necessary.

The next snippet shows several examples of data source scripts:

```
INSERT  TYPE  attribute_type
WITH ATTRIBUTE str_code 'PERSON_NAME'
WITH ATTRIBUTE $(TABLE_PK_NAME value_type) \
  $(PREFIXED   get_value_type('STRING'))
WITH ATTRIBUTE is_private $(TRUE)
WITH ATTRIBUTE exclusive_enum $(FALSE)
WITH ATTRIBUTE mandatory_enum $(FALSE)
WITH ATTRIBUTE mandatory_string  $(TRUE)
WITH NAME_DESC 'sk_SK' 'Meno' 'Meno osoby'
WITH NAME_DESC 'en_US' 'Name' 'Person''s first name'
;

INSERT COUNTRY 'SVK'
WITH  NAME_DESC  'sk_SK' 'Slovensko' 'Slovenska republika'
WITH NAME_DESC 'en_US' 'Slovakia' 'Slovak Republic'
;

INSERT INTO config ($(TABLE_PK_NAME config), value)
VALUES('GUEST_LOCALE_CODE',   'sk_SK');
```

IV. The Metamodel

The metamodel consists of 15 tables (shown on Figure 2). Some of the metadata is automatically generated by the build system during the generation of the source SQL script, and the rest (mostly the localized names and descriptions) has been filled-in manually.

- `meta_schema` - localized names and descriptions of relevant database schemata.
- `meta_relation` - localized names and descriptions of a database tables or views.
- `meta_column` - localized names and descriptions, ordinal positions, data types and other information about relation columns.
- `meta_group` - localized names and descriptions of logical group of relations.
- `meta_group_relation` - associations between groups and a relations, one relation can belong to several groups.
- `meta_operation` - localized names and descriptions of basic data manipulation operations like INSERT, UPDATE, DELETE and SELECT.
- `meta_relation_privilege` - permissions granted to users to perform data manipulation operations on relations.
- `meta_usage` - associations between views and relations on top of which the views are defined.
- `meta_relationship` - localized names and descriptions of relationships between views and tables.

- `meta_relationship_column` - lists of relation columns forming a particular relationship.
- `meta_function` - localized names and descriptions of database functions.
- `meta_function_result` - the return types of functions and possible relationships with particular relation columns; it can for example indicate that a function returns a value to be stored in a table column.
- `meta_parameter` - localized names and descriptions of function parameters.
- `meta_parameter_column` - relationships between function parameters and table or view columns; it can for example indicate that the parameter only accepts values which are present in a particular relation column, etc.
- `meta_function_relation_op` - indicates which basic data manipulation operations does a function perform on a particular table or view; this information can be used for example to determine, which functions can be invoked by a particular database user, depending on their privileges.

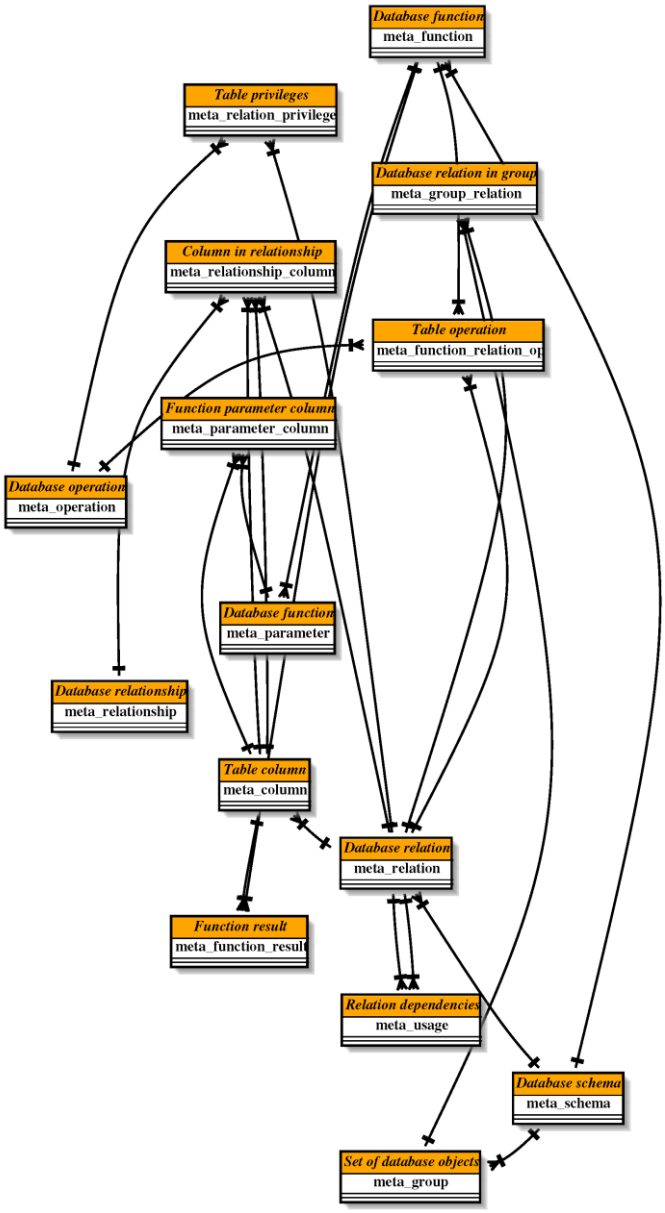

Fig. 2 Overview of the database metamodel

The metadata can be used for several different purposes:

- Automated generation of the documentation and of visual diagrams of the database model.
- Dynamic generation of application graphical user interfaces. For example an application serving as a front-end for PL/SQL functions implementing the business logic can query the metadata describing a particular function, including its localized name, the return value, the list of parameters and their names, types, ordinal positions, etc. and possibly their relationships to table columns and dynamically generate appropriate visual components and in case of parameters with enumerated types populate them with relevant values from which the user can select.
- Visual exploration and visualization of the database, where the user is presented with a visual representation of the database and can execute functions, query or search the data stored in the individual relations or even join them through the relationships described in the metamodel.
- Dynamic generation of SQL which is described in greater detail below. Using the metadata instead of hard-coding everything into the applications has the advantage that the applications handle changes in the database much more gracefully and the whole system is easier to extend and maintain.

V. Automated generation of SQL statements

In order to avoid hard-coding complex SQL queries and to allow ad-hoc exploration of the stored data, applications can generate SQL queries containing `JOIN` operations dynamically, with the help of the metadata stored in the metamodel. The database even provides several functions which simplify the generation of the `JOIN` statements.

The `get_relationship_join_predicate` function can for example return the `USING` or `ON` clause which should be used to join two particular relations through a selected relationship. For example in order to find out how to join the `anamnesis` and `subject` relations the following invocation of `get_relationship_join_predicate` can be used:

```
SELECT        gen_seq.get_relationship_join_predicate(
'gen_seq',
'anamnesis',
'subject', NULL, NULL
)
```

which returns the following clause that can be appended to the query string:

```
USING(subject_id)
```

The `get_relationship_join_expr` function is similar, but returns the whole join statement (joining the child table or view in the relationship). Also note, that relation aliases can be specified, which allows to join the same relation multiple times in case of a more complex query:

```
SELECT    gen_seq.get_relationship_join_expr(
'gen_seq',
'anamnesis',
'examiner',
'a',  'e'
)
```

which returns this join clause:

```
JOIN  gen_seq.anamnesis  a
ON((a.examiner_id=e.post_id))
```

which can be appended for example after

```
FROM  gen_seq.post e
```

where `post` is the master table in this relationship.

Multi-column relationships are also supported as can be seen in the next example (that the metamodel also describes itself.).

```
SELECT gen_seq.get_relationship_join_expr(
       'gen_seq',
       'meta_parameter_column',
       'meta_parameter',
       NULL, NULL
)
```

for which the following SQL fragment is generated:

```
JOIN gen_seq.meta_parameter_column USING(
    function_catalog,
    function_schema,
    function_name,
    parameter_name
)
```

VI. Conclusion

In this paper we described the database model used by a software that will be used for the collection and evaluation of data from genetic analyzer. The resulting data can be analyzed and retroactively classified to the data required for the determination of the final evaluation. When collecting sufficient number of reference samples, will be these genetic polymorphisms analyzed, correlated and used in research of association of these polymorphisms to tumor formation [7].

Part of this database is a metamodel, stored in the database itself, which provides useful metadata and conceptual data helping with front-end application development.

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"Podporujeme výskumné aktivity na Slovensku/Projekt je spolufinancovaný zo zdrojov EU "

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