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Design of intelligent component of hierarchical control system

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Abstract. One of the main tasks of modern hierarchical systems management are integration of technological, organizational and economic management functions and processes. Another important task is creation of unified information space with accurate, complete and current information. Efficient hierarchical systems management requires intelligent processing of large amounts of heterogeneous information. It is appropriate to process information via intelligent components that are built using artificial neural networks. Strategic information about macroenvironments, microenvironments and internal environments are the input data for intelligent components of upper management levels. Intelligent components may solve different tasks which could have features like: large amount of data, data diversity (quantitative, qualitative, text), contradiction and incomplete data, consistency and high intensity of incoming data, high computing amount with dominance of computing operations over logical operations, recursions and regularity of data processing using neural network algorithms, continuous complications of processing algorithms and increasing requirements for results accuracy, possibility to process data in parallel. The method of synchronized spatio-temporal mapping algorithms for intelligent operation component that provides synchronization of data flow intensity with computing intensity (hardware implementation) and takes into account the processor architecture (software implementation) has been designed. It has been proposed to use following principles: conveyor and spatial parallelism in data processing, modularity, specialization, uniformity and regularity of the structure, programmability architecture. during design of intelligent hardware components. Evaluation of structure of intelligence hardware components carried out using test equipment efficiency. Equipment efficiency takes into account number of interface outputs and number of interneuron connections. At the next step it links performance costs of equipment and evaluates elements by device performance. The method for designing of intelligent component management system that uses synchronized spatio-temporal mapping algorithm has been described. Current method takes into account the components, the requirements of the specific application and provides implementation of intelligent components with high efficiency.

Key words: design, energy efficiency, intellectualization of control systems, assessment, prediction.

INTRODUCTION

The major goals of the modern hierarchical control systems are that of integrating control functions of technological, business processes, creating a unified information space with reliable, comprehensive and latest data. The effective operation of the hierarchical control systems requires intelligent processing of a large amount of information of different types. It is advisable to carry out such kind of processing in the modern hierarchical control systems through the use of intelligent components. These are built by using artificial neural networks. The strategic information about macro- and microenvironment along with an internal environment of an enterprise represents input data for the intelligent components of upper management levels. These components are used to boost management efficiency of financial, business, administrative activities and manufacturing. At the lower levels of management, input data for the intelligent components is the information about the state of manufacturing process and data received from sensors. The results obtained at the outputs of the intelligent components are used to produce signals for managing sensors, actuators, apparatuses and units [1, 2].

The main problem of designing the intelligent components of the hierarchical control systems is as follows [1 – 5]:

- Formulating the requirements and choosing means of implementation (software, hardware or both software and hardware),
- Choosing a neural network architecture corresponding to the problem to be solved,
- Forming a learning test sample and selecting a learning algorithm,
- Designing highly efficient intelligent components.

In relation to this, the issue of developing highly efficient intelligent components of hierarchical control systems becomes of special relevance.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In recent years, there have been a lot of researches and publications dealing with the issue of management at all levels of a hierarchy – from manufacturing processes to the governance of financial, business and administrative activities. One can consider the most important of these publications.

Challenges arising at the highest levels of management, including planning of resources and materials, are discussed in great detail in [6]. The drawback of this work is that it paid little attention to the development of the intelligent components using artificial neural networks.

Not only books but also separate articles have examined resource planning. In particular, although all of the aspects of this theme have been covered in [7], it pays little attention to the problem of intellectualization of data processing. The researches carried out in [8 – 9] are of great importance. Their authors have demonstrated that for the effective support of business functions and business processes, the systems should be integrated with other information systems.

In the work [10], an attempt was made to summarize the latest developments in the field of production planning. Nonetheless, it lacks attention on use of the neural network technology. Control means of industrial processes are covered in [11 – 13]. The feature of these methods is that they focus on the use of cloud-based technologies.

The works [14 – 17] consider the issue of developing those components that control manufacturing processes. There is a lack of attention on the intellectualization of sensors and data processing in these studies.

LEVELS OF HIERATCHICAL MANAGEMENT

The control systems with a hierarchical or multilevel structure have been used most widely. A hierarchy is the location of parts and components in order from highest to lowest. Thus in the systems with such a structure, control functions are divided into units or subdivisions of various levels or ranks. A managing body of some hierarchical level manages several lower-level units under its authority and itself is controlled by a higher-level organ. Modern enterprise management systems have mostly four-level structures.

The first management level involves the management of financial, business and administrative activities. At this level of management, planning and analysis of manufacturing activity of an organization is performed by using the following software IRP (Intelligent Resource Planning), ERP (Enterprise Resource Planning) and MRP (Material Requirements Planning).

The second level of management controls the manufacturing processes with the use of the MES (Manufacturing Execution Systems) software for synchronization, coordination, analysis and optimization of products.

The third level represents control and operation of a manufacturing process. To solve these problems, the SCADA system is used. Its main function is to create an operator's interface and collect data on manufacturing. For controlling and handling the manufacturing process, a software tool is utilized, which is an assembly of devices, communication channels and algorithmic-based software. Programming logical controllers (PLC) are used as equipment, in which the operating system represents programming utilities for these controllers or PC-like controllers with the built-in DOS systems. This level exhibits the use of the intelligent tools of data processing, devices of visual control and manufacturing process performance. Preprocessing and intelligent data processing are done in the controllers. The control and operation systems use, as the PLC, a wide nomenclature of devices both of domestic and foreign manufacturers, which are able to process per unit time from a few to hundreds of variables.

The fourth level represents touch sensors (primary transducers), actuators, microcontroller-based systems for gathering information and controlling assemblies, apparatuses, installations and actuators. At this level primary information is obtained by using the touch sensors. Based on the processing of this information, the signals are generated to control assemblies, apparatuses, installations and actuators. This level of management is characterized by using the PLC and the DCS (Distributed Control System) software.

At each of the four levels, information is supplied in parallel and, if possibly, processed in parallel. Managers can also take decisions either in parallel to or independently from each other.

LEVELS OF HIERATCHICAL

Defining problems for the intelligent components of the hierarchical control systems. The use of the intelligent components in the hierarchical control systems ensures greater management efficiency of manufacturing processes, industrial, financial, business and administrative operations of the company. At each level of management, there are objectives focused on implementation in terms of the intelligent components.

For the intelligent components of the first and second management levels, there is a following rough list of problems:

- financial forecasting (nonlinear forecasting of financial data while predicting the stock market and forecasting the state of the market),
- detection and reduction of a fraud level (credit cards, transactions, etc.),
- modeling and control of the enterprises' performance,
- segmentation and market clustering, which provides an analysis of immense amount of data without human intervention, and proves to work well together with automated data collection (which is popular among online surveys, etc),
- data mining and business analytics,
- visualization of multidimensional data,
- decision support systems,

- management by weak signals allows an organization to increase flexibility reserve beforehand to avoid the risks at their early stages of occurrence,
- credit scores when approving loans and calculating credit ratings, credit risk assessment based on data about a client,
- valuation and value prediction of property, getting quality information about various factors that potential buyers of real-estate prefer,
- evaluation of staff while selecting applicants for the job (a forecast of future results of a candidate's performance based on his/her biographical data),
- information security of computer systems.

For the intelligent components of the third and fourth management levels, there is a following rough list of problems:

- preprocessing and estimation of data from sensors under conditions of hindrance and incomplete information,
- operation of actuators and complex objects,
- processing of video streams, recognition of images and scenes in vision systems,
- traffic management, traction control and supporting services in vehicles,
- autonomous control and traffic forecast,
- prediction and control of manufacturing processes and complex objects,
- load balancing of electricity networks for work optimization,
- optimization of resources costs and operating modes of industrial systems,
- setting parameters according to the environmental conditions.

FORMULATING REQUIREMENTS FOR THE INTELLIGENT COMPONENTS OF THE HIERARCHICAL CONTROL SYSTEM

The first and second management levels of an enterprise are characterized by accumulation of huge amount of information about various aspects of its activities, the dynamics of its development, the history of interaction with different suppliers, partners and customers. The intelligent analysis of this information through the use of neural networks, genetic algorithms, neuro-fuzzy logic allows one to gain knowledge, based on which the future performance of the enterprise can be predicted, and potential threats or opportunities identified.

The third and fourth management levels are concerned with the control of manufacturing processes and with a direct operation of assemblies, apparatuses, installations and actuators. The intelligent components of the third and fourth levels are applied to solve these problems:

- preprocessing and estimation of data from sensors under conditions of hindrance and incomplete information,
- operation of actuators and complex objects,
- processing of video streams, recognition of images and scenes in vision systems,
- prediction and control of manufacturing processes and complex objects,
- optimization of resources costs and operating modes of industrial systems,
- setting parameters according to the environmental conditions.

The implementation of the IACS (integrated automated control system) intelligent components is proposed to be done on the basis of artificial neural networks. The main problem of using artificial neural networks for implementation of the IACS intelligent components lies in the selection of necessary input data for a specific problem, choosing a neural network architecture corresponding to the problem, forming a test sample for testing a neural network and selecting a test algorithm. Typically, the strategic information about macro- and microenvironment along with an internal environment of an enterprise represents input data for the intelligent components of the first and second levels of management. The third and fourth levels represent information from sensors, apparatuses, assemblies and actuators. At the output of the intelligent components of the first and second management levels signals are generated, based on which management decisions are made. The output of the intelligent components of the third and fourth management levels generates control signals for actuators, apparatuses and assemblies [1 – 3].

The analysis of the main problems that are solved by the intelligent components of the control system shows that the considerable part of applications involves processing of intensive data streams in real time through means that satisfies the constraints on dimension, power consumption and cost. In particular, these problems include the ones to be solved at the third and fourth levels of management.

The features of problems solved by the intelligent components of the control system are as follows:

- enormous amount of data,
- data heterogeneity (quantitative, qualitative, text-based),
- contradictory and incomplete data,
- invariability and high intensity of input data arrival,
- large amount of computations with computing operations outnumbering logical operations,
- regularity and recursiveness of neural network algorithms for data processing,
- constant complication of algorithms for processing and increasing requirements for accuracy of results,
- parallelization of data processing both in time and in space.

One of the most common requirements imposed on the intelligent components of the control systems is to ensure their high performance.

As a rule the same problem occurs when using the IACS intelligent components for problem-solving situations in real time that puts certain constraints on data processing [1 – 3]. To ensure processing of data flows in real time, the hardware performance should be:

$$\Pi \geq \frac{R\beta F_d K_d n_k}{N n_d}, \quad (1)$$

where: R – means the algorithmic complexity for solving problems, β – is a coefficient that considers implementation means of the algorithm, F_d – denotes the frequency of incoming data, K_d – is a number of channels of incoming data, n_k – number of bits of incoming data channels, N – a value of input data set, n_d – number of input data bits.

The use of the intelligent components in the third and fourth levels of management with equipment located close to the sensors and actuators puts tight constraints on their weight and size characteristics. At the same time such devices are imposed by strict requirements for power consumption affecting a size of power sources as well as devices of heat transfer. These requirements can be met by reducing the length of a bit grid, using fixed-point operands, minimizing a list of commands together with a number of address lines that determine the memory capacity available for a user. Furthermore, the intelligent components of the control systems have to ensure high survivability, reliability, performance check and rapid fault localization. The problem of high survivability of the intelligent components arises when they are utilized in the control systems by specifically responsible objects located at a large distance from a person or objects of high external effect. For high survivability of the intelligent components, its structural parts are to be interchangeable.

A weight and size reduction as well as the reduction of energy consumption, the increase in reliability of the intelligent components and real-time operation could be achieved through the use of state-of-the-art integrated technologies and very-large-scale integrated circuits (VLSI).

ANALYZING TYPES OF IMPLEMENTATION OF INTELLIGENT COMPONENTS

For the development of the intelligent components of the control systems we will use artificial neural networks. The main problem of using the artificial neural networks is that there is a need to select input data for solving a problem specified, choose a neural network architecture corresponding to this problem, form a test sample for testing the neural network and select a test algorithm. The artificial neural network with multiple inputs and outputs is designed to convert input signals into output signals. Typically, the strategic information about macro- and microenvironment along with an internal environment of an enterprise represents input data of the intelligent components of the first and second levels of management. The third and fourth levels represent information from sensors, apparatuses, assemblies and actuators. At the output of the intelligent components of the first and second management levels we obtain information that is used for decision making. The output of the intelligent components of the third and fourth levels generates control signals for actuators, apparatuses and units [2].

From the set of existing types of implementation of the intelligent components of the control system, we will examine the following:

- software type uses the universal CPU (Central Processing Unit) and graphic GPU (Graphics Processing Unit) processors, allows the development of dedicated software for them,
- software - hardware type deploys a universal compute core, aimed at tasks of neural network processing and is supplemented by specialized hardware and software tools that implement basic neural network algorithms and operations,
- hardware type shows how the architecture and arrangement of a computational process within it represent a structure of the operation algorithm of an intelligent component.

The first type is available to the general public. Its distinct advantage is that it allows for using previously developed programs. The disadvantage of this type is, however, low speed, functional and structural redundancy of computer tools. This type is designed for implementation of the intelligent components at the first and second levels of management.

The second type is a union of general-purpose and special-purpose tools. Interpenetration of general-purpose into specialized, hardware into software ensures a high efficiency of equipment utilization as well as data processing in real time. When it comes to this approach, the development of software and hardware with given technical parameters supplements a computing core with the necessary special-purpose hardware components.

The third hardware type focuses on the processing of intensive data flows by using complicated algorithms. The principal advantage of this type is in ensuring high performance. Besides its high performance, the hardware type has the following disadvantages:

- dedicated hardware is developed for performing only specific tasks,
- enormous equipment costs for their implementation,
- high cost of hardware and time-consuming development of specialized tools.

The second and third types are used to implement the intelligent components of the third and fourth levels of management with the feature to operate in real time.

THE METHODS OF SYNCHRONIZED SPATIO-TEMPORAL REPRESENTATION OF OPERATION ALGORITHMS OF THE INTELLIGENT COMPONENTS

For the development of the intelligent components of the control systems, there is a need in spatio-temporal representation for their operation algorithms treated with a different degree of detail, which is determined by means of implementation. Upon implementation of algorithms in a programmable manner, for their representation, it is advisable to use operations that are effectively performed by CPU and GPU processors. Representing algorithms at a level of elementary arithmetic operations is applicable in the hardware implementation by using custom and

semi-custom VLSIs. The spatio-temporal rendering of the algorithm must detect all types of parallelism and find necessary solutions both in time and space for its effective implementation. The multi-tier parallel structure (MTPS) of algorithm rendering meets the above mentioned requirements. While the MTPS is used for an expression of the algorithm, all its functional operators Φ_i are distributed by levels in a way so that the j-th level contains those functional operators that depend at least on one functional operator at the *(j-1)*-th level and are independent of the operators at subsequent levels. All functional operators of the same level are to be performed independently.

Each *j*-th level of the algorithm is expressed by the following parameters:

- sets of independent functional operators Φ_{ji}, where j denotes a level number, i is a number of a functional operator at the level,
- set of channels of data arrival and generation of intermediate results,
- number of bits for each channel.

In the MTPS algorithm the number of levels means its height h, and the maximum number of functional operators at a level determines its width L. With the use of spatio-temporal factors, the position of functional operators in a space-time coordinate system is specified. Such a representation of a directed graph we will call a flow parallel form or a flow graph [3, 18]. The parameters of the flow graph such as the complexity of functional operators Φ_{ji}, the width L and the height h are mutually dependent. A change in one of the parameters introduces changes in all the parameters.

In order to transform a functional graph into a flow graph, it is necessary to write the former as a matrix $n \times n$, where "*1*" denotes the presence of a communication channel, "*0*" means its absence [3].The matrix is arranged so that each functional operator Φ_{ji} of information source has a string representing its connection with other functional operators. If relevant columns of matrix are specified through vectors $\vec{V}_{\Phi 1},...,\vec{V}_{\Phi n}$, one can define the resultant vector:

$$\vec{V}_0 = \vec{V}_{\Phi 1} + \vec{V}_{\Phi 2} + ... + \vec{V}_{\Phi n}, \qquad (2)$$

In vector $\vec{V}_0$, we can determine the number of elements that equal zero, for example, the second element and the fifth one. The functional operators are found by just defined numbers having no descendants and, therefore, forming a zero level, Φ_2 and Φ_5 in this case. Then we calculate by the formula:

$$\vec{V}_1 = \vec{V}_0 - \vec{V}_{\Phi 2} - \vec{V}_{\Phi 5}, \qquad (3)$$

In vector $\vec{V}_1$, we find the numbers of zero elements that can be used to define those functional operators that form the first level. Similarly we calculate successive vectors and define the functional operators that form the following levels.

For an effective implementation of the operation algorithms for the intelligent components, it is proposed to represent the algorithms mentioned as a synchronized flow graph. This type of graph has been devised in four stages:

1) decomposing the operation algorithm of the intelligent component,
2) designing communications (data exchange) between functional operators,
3) consolidating the functional operators,
4) planning of computations while implementing the algorithm.

At a stage of decomposition, the operation algorithm of the intelligent components Φ is to be broken into functional operators Φ_{ji}, between which connections are established that correspond to this algorithm. Decomposition can be treated by the method of functional decomposition. Using a method of functional decomposition allows a structure of the operation algorithm for an intelligent component to be represented both in space and time with a required degree of detail. The first stage of the development has resulted in a graph-scheme algorithm, where the functional operators Φ_{ji} have approximately the same runtime, and their complexity is determined by means of implementation.

At the stage of communications design, it is necessary to define a structure and a number of bit channels of data exchange between the functional operators Φ_{ji} For this reason, the graph-scheme algorithm is transformed into a flow graph, in which the functional operator Φ_{ji} are located at space-time points and fixed to the tiers. The structure of connections in a flow graph between the functional operators Φ_{ji} of neighboring tiers is determined by the number of channels of incoming data and the number of bits.

Upon two stages of development, the flow graph ensures:

- evaluation of the computational complexity of the algorithm and defines the required performance of the universal CPU and graphic GPU processors during the software implementation of the intelligent component,
- choice of user-defined macros for software and hardware to be hardware-implemented,
- evaluation of data processing intensity for the hardware implementation of the flow graph of the operation algorithm for the intelligent component.

Here are output data for defining the data processing intensity for the hardware implementation of the flow graph of the operation algorithm for the intelligent component:

- number of channels of data arrival s and their number of bits n,
- complexity of functional operators Φ_{ji} and high performance of hardware components, specifying pipeline cycles T_k of equipment operation.

The intensity of data processing during the hardware implementation of a flow graph can be defined as:

$$D_{\kappa-a} = \frac{sn_s}{T_\kappa}, \quad (4)$$

The data processing by the intelligent component in real time requires synchronization of data arrival intensity

$$P_d = kn_k F_d,$$

where: k – denotes a number of channels of incoming data, n_k – is a number of bits of data channels, F_d – means the frequency of data arrival with the intensity of data processing D_{k-a}. To evaluate the synchronization of the data arrival intensity P_d with the computational capability D_{k-a}, one introduces a coefficient of synchronization which is given by:

$$L = \left\lceil \frac{P_d}{D_{\kappa-a}} \right\rceil, \quad (5)$$

where: $\lceil \ \rceil$ – means a sign of rounding to a greater whole number.

The synchronization coefficient L can be $L = 1$, $L > 1$ and $L < 1$.When $L = 1$, then the devised graph of the operation algorithm for the intelligent component is synchronized, and its hardware implementation ensures the highly efficient use of equipment.

In case $L > 1$, the devised graph of the operation algorithm for the intelligent component is not synchronized, and it is necessary for its coordination to increase the intensity of data processing D_{k-a}. An elevation in the intensity of data processing D_{k-a} can be achieved either by increasing the number of data sorting channels s and their number of bits n or by facilitating the complexity of functional operators Φ_{ji}. If changing the parameters under discussion has not yielded the necessary intensity of data processing D_{k-a}, then the parallel operation L of hardware components is to be used.

The third stage of development is reduced to the consolidation of operations by combining the functional operators Φ_{ji} as well as data transmission channels both within a tier and across tiers. This stage of development is utilized for the software implementation, neural-oriented and dedicated hardware implementations of the algorithm.

The software implementation of the algorithm uses a phase of consolidation to be adapted to the structure of the universal CPU and graphic GPU processors.

With the software and hardware implementation as well as just hardware implementation, the consolidation phase is applied in case when $L < 1$. That is, when there is a need to reduce the intensity of data processing D_{k-a}. As a result of such integration we will receive a graph, representing the operation algorithm for the intelligent component, that we will call a concretized flow graph. The consolidation phase is closely connected with the planning stage of sorting.

The fourth stage of planning of computations is reduced to storing information about the structure of the flow graph representing the operation algorithm of the intelligent component. At this stage the computational process is performed, the values of delay factors and data permutation are determined. To reproduce the data processing in the concretized flow graph, statements of control and delay along with permutation operators are to be introduced. One can consider two possible ways for consolidating operations (integration of functional operators) in order to get a concretized flow graph of data sorting.

The first way of getting the concretized flow graph of the operation algorithm for the intelligent component is a linear projection of this graph on the horizontal axis X. In this case the consolidation of operations is performed by combining functional operations across tiers along with data transmission channels. The latter falls into a class of SIMD architecture (Single Instruction Multiple Data) processor. SIMD processors have a distinct feature of simultaneously performing the same operation to process a set of independent data. For the software implementation of the concretized flow graph of the operation algorithm for the intelligent component, it is advisable to apply a cross-platform compilation system and the CUDA platform.

The second way of getting the concretized flow graph of the operation algorithm for the intelligent component is a linear projection of this graph on the vertical axis *Y*. In this case the consolidation of operations is performed by combining functional operations and data transmission channels both within tiers and across tiers. This kind of consolidation of operations results in the concretized flow graph allowing the synchronization of intensity of data arrival P_d from the computational capability D_{k-a}. These concretized flow graphs of the operation algorithms for the intelligent component can be hardware and software implemented as well as just hardware implemented.

THE METHODS OF DESIGNING THE INTELLIGENT COMPONENTS FOR THE CONTROL SYSTEMS

The purpose of designing the software intelligent components for the control systems is to enable CPU and GPU processors to work effectively [19, 20]. In general, the effectiveness of the software intelligent components of the control systems depends on that how the concretized flow graph of the algorithm has adapted to the architecture of CPUs and GPUs. Quantitatively the effectiveness of the software intelligent components is defined as:

$$E_n = \frac{t_{ei}}{t_{ps}}, \quad (6)$$

where: t denotes a period of time over which the i-th element of processors is occupied with useful operations, tps is a total time for solving the problem.

The purpose of designing the hardware intelligent components for the control systems is to get modular and regular structures based on VLSI technology. The output information for the synthesis of the hardware intelligent components is:

- concretized flow graph of the operation algorithm for the intelligent component,
- learning algorithm and a neural network performance,
- amount of input data N,
- data arrival intensity and weighting factors,
- interface requirements,
- number of bits of input data, weighting factors and the accuracy of computations,
- performance requirements and constraints.

The objective of designing the hardware intelligent components is to ensure their operation in real time with minimum hardware expenses [3].

The transformation of the concretized flow graph of the operation algorithm of the intelligent component into the hardware structure is, formally, that to minimize hardware costs:

$$W_{hk} = \sum_{j=1}^{M} W_{E\Pi_j} + \sum_{i=1}^{n} W_{HEi} + k_1 Y + k_2 P \,, \quad (7)$$

where: $W_{E\Pi_j}$ – means the equipment costs incurred in implementing the $j-th$ element of preprocessing, M – denotes the number of preprocessing elements, W_{HEi} – is the equipment costs incurred in implementing the $i-th$ neural element, N – is the number of neural elements, Y – presents the number of interface terminals, k_1 – is a coefficient that considers the number of interface terminals $k_1 = f(Y)$, P – the number of interneuronal connections, k_2 – coefficient that considers interneuronal connections $k_2 = f(P)$ provided that the following condition is fulfilled:

$$T_{ex} \geq T_{ps} \,, \quad (8)$$

where: T_{ex} – denotes the time of exchange, T_{ps} – is the time for solving a problem.

While designing the hardware intelligent components for the highly efficient use of equipment, one should:

- develop the operation algorithm for the intelligent component and represent it as a concretized synchronized flow graph,
- transform the concretized synchronized flow graph into the structure of hardware regarding performance characteristics and constraints,
- choose an architecture and model of a neural network as well as neural elements of preprocessing,
- develop the interface and data exchange system across the neural network's layers,
- with the flow structure of the neural network applied, determine an ordering of time implementation of a neural network's layer and synthesize the controls.

If the hardware structure of the intelligent component is selected, one should use the efficiency criterion for equipment utilization Eo, which considers the number of interface terminals, the number of interneuronal connections and associates the performance with the equipment costs, giving an estimation of elements (valves) by performance [3]. When the intelligent component is implemented with VLSI, the efficiency of equipment utilization Eo, is quantitively defined as:

$$E_o = \frac{R}{t_o\left(\sum_{j=1}^{M} W_{E\Pi_j} + \sum_{i=1}^{n} W_{HEi} + k_1 Y + k_2 P\right)}, \quad (9)$$

where: R – denotes the complexity of operation algorithm of the intelligent component, which is determined by the number of elementary arithmetic operations required for its implementation, t_0 – to is the time of implementing the operation algorithm of the intelligent component.

The specialized hardware structure of the intelligent component must exploit the capabilities of VLSI technology to the full extent and ensure the processing of intensive information flows in real time [1 – 3]. The cost of VLSI mainly depends on the area of a crystal and the number of pins. The number of VLSI-based external pins is limited by the level of technology and the crystal size.

To use the advantages of VLSI technology to the full extent during the development of the specialized hardware intelligent components, the following principles has been proposed [3]:

- pipelining and spatial data parallelism,
- modularity,
- specialization and adaptation of the architecture of the intelligent component to the structure of algorithms as well as data arrival intensity,
- uniformity and regularity of the structure,
- programmability of the architecture by using programmable logic devices (PDSs).

The use of the principles described in the design of the hardware intelligent components will reduce cost and time spent on development. If the PLD-based intelligent component is hardware implemented, one of the software suites of hardware design is to be used (for instance, Altera Quartus II or the Xilinx ISE) [21]. By using these packages, the libraries containing totalizers, multiplying units, evaluators of scalar product, implementations of the activation functions, neurons, etc., schematic editors and one of the hardware description language (for instance, VHDL) the specialized hardware intelligent components are designed. Correctness of the performance of the component developed is done by using functional and timing modeling. The final stage of development considers the choice regarding the hardware costs, high performance and cost of a certain crystal.

CONCLUSIONS

1. It has been analyzed and shown that the advantage of the software implementation of previously developed applications can be used. The advantage of the software and hardware implementation includes the required performance achieved through adding the specialized hardware. The hardware implementation has its advantage in processing intensive data flows in real time.

2. The method of synchronized spatio-temporal representation of the operation algorithms of the intelligent component that provides the consolidation of data arrival intensity with computing intensity (hardware implementation) and considers peculiarities of a processor architecture (software implementation) has been developed.

3. The following principles like pipelining, spatial data parallelism, modularity, specialization, uniformity and regularity of the structure along with programmability of the architecture have been proposed to be applicable for the design of the hardware intelligent components.

4. For the evaluation of the hardware structure of the intelligent components, it has been proposed to use the efficiency criterion for equipment utilization, which considers the number of interface terminals, the number of interneuronal connections and associates the performance with the equipment costs, giving an estimation of elements of the device by performance.

5. The method of designing the intelligent components for the control systems, which uses a synchronized spatio-temporal representation of algorithms, considers the features of hardware components along with the specific application requirements and ensures the highly efficient implementation of the intelligent components, has been developed.

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Analytical review of medical mobile diagnostic systems

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Abstract. This article analyzes the mobile medical diagnostic systems and compare them with the proposed HealthTracker system based on smart watch Apple Watch. Before the development of the system HealthTracker, there was conducted a review and analysis of existing similar systems to identify common and distinctive features of the future system. This analysis will improve HealthTracker system, based on the strengths and weaknesses of existing systems and help identify and justify the key benefits and unique system HealthTracker. The main goal is to provide a system HealthTracker convenient way to interact with the patient the doctor based on the vital signs of the patient. Apple Watch is an excellent watch presented in 2014 that has the capacity to collect and compile data on the health of the user and can be used for medical purposes. The main hardware components of the watch for collecting and analyzing health data is a technology Taptic Engine, infrared sensors and pulse. The main software components of the watch, that will be used in the design of the system is the 3 applications, each of which measures a user's vital signs. Integration with smartphone user makes data on the health of a quick and reliable. On the market today there are analogues of the system, but most of the systems are relatively new and require many improvements, some are under development prototypes. In addition, all the above systems require binding to certain equipment that is not always convenient in everyday use. To eliminate all the inconvenience in using existing systems need to create a system that is integrated into smart watches that provide ease of use, and the mechanism storing and analyzing medical data to cloud storage. An important aspect of the study is to analyze the general situation in the market of mobile medical diagnostic systems. Thanks to research the key advantages and disadvantages of the proposed mobile medical analysis system and shows its versatility compared with existing systems on the market

Key words: Medical system, diagnostic system, health tracking, WatchOS, Apple Watch.

INTRODUCTION

The modern world is moving towards globalization in all of it's key processes and phenomens, ranging from socio - economic to cultural processes. For information technology the globalization process is the fastest. More and more functions that were traditionally performed by personal computers, are transferred to mobile devices because people want to read and work with their digital data at any moment anywhere. Recently, the cloud technologies became widely spread because of carefully universal access and processing of data. Cloud technology in many times simplified the process of common access to several workstations data. The traditional expert systems gradually fade into the past because of the many exceptions to the rule and large databases. Instead of them, mobile expert systems are becoming widely and widely spread. However, there is a certain dependence on platforms, integrating data from various devices and more. Depending on the goal of developing a particular system one should choose the most suitable platform and work with the appropriate types of devices.

The main purpose and objective of the program system is to collect patient medical data directly without the use of special medical equipment and devices. Today becoming more common so-called "smart" watches. The main difference between these clocks from conventional counterparts is the ability to connect to the Internet and synchronization with a smartphone. In addition, some models have hardware and software that allows you to collect patient medical data (user). These models of watches have special sensors that provide a variety of human medical screenings, such as heart rate, pressure, etc. With these impressions doctor can monitor the patient's condition in real time and on time and quickly stanovlyuvaty patient diagnosis and provide recommendations.

As the clock, which will be used in developing I've chosen Apple Watch. This is one of the most functional "smart" watches today and its integration with the iOS are pretty well thought out.

Before the development of the system, I've conducted a review and analysis of existing similar systems to identify common and distinctive features of a future system. This analysis will improve the system HealthTracker, based on the advantages and disadvantages of existing systems, and will detect and justify the key benefits and uniqueness of the system HealthTracker. It is necessary to analyze the existing system, they identify unsolved problems in order to solve them in your system.

Many fitness - trackers on the market is relatively effective in mild calculations such as counting steps, but in more severe problems, such as heart rate measurements

even approximate accuracy mostly lost. In addition, the question of the value of clinical data provided fitness - trackers because the number of steps and heart rate data on the user not processed. It is this question solves the following system.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The newest similar system that was introduced in mid-2015 exhibition International Modern Hospital Show in Tokyo, is a system Silmee. This intelligent sensor measuring parameters of human life from Toshiba. This sensor is the ability to remotely monitor key indicators of the body, which is important for patients, pilots, rescuers and ordinary people who are constantly worried about the state of their loved ones. This sensor simultaneously collect data on body: does electrocardiogram measures the heart rate, body temperature, record the motion of the media, etc. These data can be transferred over a wireless connection, such as Bluetooth, to your smartphone or tablet, and then - at any point on the planet. The new sensor is equipped with 32 - bit chip, wireless data transmission system. The collected sensor will have dimensions of 2.5 to 6 cm and weighs only 10 grams. Such small size and weight allow you to use it in a variety of applications, from monitoring the patient to postoperative surveillance of soldiers during training.

The basis of the system is Silmee two prototypes bracelets - Silmee W20 and Silmee W21. Modification additional W21 is equipped with GPS, which is especially useful for the elderly. This option allows relatives ever see the place where they are based on their smartphones. In the body of the unit taken out button SOS, because of this, when you click on the device is passed through the smartphone alarm in the medical institution or ambulance services.

In addition, Toshiba has shown sensor Silmee Bar type Lite. This device is secured to the chest in ADR for helium pads and allows to measure respiratory rate.

Detailed specifications of devices:

Toshiba Silmee W20 - wrist sensor having classifications IPX5 and IPX7, dimensions 20.5 x 65 x 12 mm and weight of 29.5 grams. The device is equipped with a lithium - ion battery, which in real terms is enough for 2 weeks. The cost of the device - $ 193.

Toshiba Silmee W21 different physical dimensions 25.5 x 65 x 12.5 mm, weighing 38 grams and the availability of GPS module. The cost of the device - $ 225.

Both devices are compatible with iOS version 7 or higher and Android 4.4 and above.

The advantages of this system is the high functionality, the large number of sensors that provide a lot of performance and price of human life in general. The presence of two versions allows you to select a suitable option for a particular user. In addition, the physical parameters of the device, such as dimensions, is relatively good compared to the competition.

The main disadvantage of the system is awkward to use software on a smartphone due to the relative newness of the system and not very thoughtful UI and UX. In order to use the system need to buy one of braceletes which is not very convenient for people using the watch. [1]

OBJECTIVES

The main objective of the research is to highlight most innovative and popular medical systems, investigate them and conduct main features of HealthTracker system.

THE MAIN RESULTS OF THE RESEARCH

1.1. iHealth Products

Another system that will be considered is the iHealth system from the same named company, developed in Silicon Valley in the US in 2009. In 2013 the company opened an office in Paris - iHealthLabs Europe. iHealth develops and distributes innovative, clinically tested products in the health sector.

The company's products pass rigorous testing before be issued on the conveyor. Blood pressure monitors are tested protocol ESH (European Society of Hypertension), blood glucose meters tested the protocol ISO15193: 2013.

Data on vital functions of the patient is stored on the cloud. The company has developed a series of special cloud data stores, which are regulated by international standards of data security. When a user synchronizes with each product with your smartphone or tablet, information is sent to one of the clouds. With this cloud storage, the user has access to their medical data from anywhere - any computer, smartphone or tablet at all - anywhere in the world. Medical patient data is completely anonymous and confidential, but at the request of the patient, these data can be sent to a doctor for the rapid analysis of health.

The company provides a choice of nine different products.

Connected Wrist Blood Pressure Monitor – the monitor that measures blood pressure, pulse and is able to detect arrhythmia. The device is placed on the wrist of the patient. Constant monitoring of patient's pressure is an important issue in medicine. This device allows the doctor to monitor blood pressure and heart rate to better conduct treatment for the patient and offset the cardiovascular risks. The device comes with iHealth MyVitals application that provides a simple user interface with a variety of graphs and tables. This application can continuously monitor blood pressure according to the standards of international public health data and to share these with your doctor. Due to the powerful battery device allows almost 80 times to measure and save data on patient pressure. [2]

Connected Arm Blood Pressure Monitor – similar to the previous device, difference is that ut's not placed on

the wrist, but on the hand. In addition, the device is 20% more expensive than the previous. [2]

Connected Scale – smart weight, allowing the patient's weight regularly monitored to prevent excess weight gain or loss. In addition, these weights allow to measure the effects of a balanced diet and regular physical activity. As usual weight, the device is instantly and accurately reflects the weight of the user, but by connecting to the mobile application iHealth MyVitals App, the product allows the user to accumulate statistics scales, save them to cloud storage and send data to the physician. It stores up to 200 measurements in memory thus saved great history of previous measurements of gravity that allows the patient to improve the quality of statistics. [3]

iHealth Wireless Body Analisys Scale – similar to the previous measures, but also calculate the index of body fat, bone mass, muscle mass and water weight in the body. Thanks to more parameters, the user is much easier to pick the correct and balanced diet and learn about the state of the organism as a whole. Compared with the previous scales, the product is more expensive by 30%. [3]

Connected Body Analisys Scale – weight that combine the two previous products, but also with a special algorithm to assess the optimal number of calories that the user should be taken in the near future for better health. This product is the latest product of the company and is expensive from the base weights of 40%. [4]

Activity & Sleep tracker – this device can be worn all day long, it measures the number of steps, distance traveled and calories burned during the day. Through synchronization with the corresponding application, one has the opportunity to check their results, view statistics and set a new goal in the number of passed steps (day norm is 10,000 steps). Bonus functionality of the device is silent alarm. [4]

Wireless Pulse Oximeter – device to monitor oxygen levels in the blood and pulse. This simple and reliable device allows you to monitor the level of oxygen in the blood, pulse and perfusion index. These measurements will be useful for people with chronic diseases such as asthma or obstructive disease pulmonarnoyu to fast track their health. In addition, the device will be useful for smokers that quit smoking because they constantly monitor the improvement of blood and it gives them motivation. Athletes will see the body's response to certain types of exercise. Due to the synchronization of the application, user can observe the progress of chronic diseases or the result of exercising. The device is extremely easy to use, just put your finger on it and in seconds you'll have the results. [4]

Connected Mini Glucometer – compact handheld device to measure blood sugar levels. The device is useful for people with diabetes to monitor blood glucose levels. On the output device gives blood glucose levels, writes them to the internal memory, and refers to cloud storage to continually inform your doctor. Also, there is the possibility of establishing notifications under certain limits blood sugar. The device connects to the smartphone via AUX - connector, it provides high portability. [4]

Wireless Smart Gluco – Monitoring System – device that has similar functionality to the preceding except much worse and fully informing the patient of data on blood sugar levels. Availability of algorithm that predicts changes in blood sugar levels allows conduction of better treatment of patient. [5]

The advantages of iHealth products is it's high accuracy and reliability, long experience on the market. A wide range of products and components makes the company an influential player on the market. A small price products ensures their availability to the end user. [5]

Disadvantages of iHealth products are too high differentiation and lack of versatility, use as many products, most of which is in constant use light is uncomfortable. In addition, technical devices are built so that in case of malfunctions the user is able to disassemble and repair their own. Also, products are not hit and water proof making them uncomfortable to use in the real world.

1.2. Another existing products

Another similar system is AiQ BioMan. The company was able to put a mobile medical system to an ordinary T-shirt. This is the ability to measure levels of heart rate, breathing and skin temperature. In addition, the more expensive versions of the product are sensors electrophysiological signals. The advantages of the product are innovative solutions , the drawback - low accuracy of measurements and their lack of analysis or sync with the repository. [5]

Metria Wearable Sensor is a compact device that is attached to the body and collects data on the number of breaths per minute, the number of hours of sleep manual. With WiFi, device sends the data to the smartphone user. The advantage of the device is the low price and the possibility of use in many activities, the lack is a small number of indicators and the lack of medical analysis results. [5]

BodyTel a set of devices that include measuring blood glucose levels and pressure. Each device has a Bluetooth - module, through which sends the data to the home station user. Upon receipt of the required data, the station sends data to a database that is available to the physician. In addition to viewing data, doctors can send notifications to patients based on restrictions of certain indicators that determined by the physician. Home station also provides feedback to a physician when one or more indicators of the health of the patient out of the limits of normal. The advantages of the system are established relationship with a doctor and thought-out system alerts, disadvantage is the attachment system to the home station, making it impossible to mobility system. In addition, sending data to the home station is only possible via Bluetooth. [7]

Imec – is a mobile electroencephalograph to monitor the state of the brain of the patient. All the data is automatically sent to the smartphone user. This system is currently under development and is a condition of existence prototype. The system is still incomplete and did not pass the necessary tests to entry. [6]

Moticon – a tech supinator, which works with the parameters of the movement of the carrier. The device measures the number of steps carrier weight and other parameters. The advantage is the ability to use in any type of shoe. The disadvantage of the device is a connection with a computer only via USB - Beacon which is not very convenient to use and allows you to get the required data in real time. [8]

Preventice BodyGuardian RMS – system for continuous monitoring of the health status of patients with heart arrhythmia. It allows the doctor to view patient's required performance thanks to the small sensor that attaches to the chest of the patient. Then smartphone data is sent to the physician. The advantages is high accuracy results, the drawback is the complexity of use [9].

2. Apple Watch overview

Apple Watch is a smart watch, designed by Apple Inc. It includes a fitness track and the possibility of reviewing the state of health as well as integration with iOS and other products and services Apple. The device is available in four versions: Apple Watch Sport, Apple Watch, Apple Watch Hermès, and Apple Watch Edition. Watches vary with different materials body and screen size. Apple Watch is based on wireless connected iPhone to perform many of its functions by default, such as the integration of call and offers a set of text messages. It is compatible with iPhone 5 or later models running iOS 8.2 or later, through the use of Bluetooth or Wi-Fi. The device was announced by Tim Cook on Sept. 9, 2014. Apple Watch quickly became a bestseller from the release of more than 4200000 units in the second quarter of 2015, according to research firm Canalys. [10]

The aim of a device was to free people from their phones. Apple Watch works when connected via Bluetooth or Wi-Fi to your phone and then using it to access all applications that are downloaded to the mobile device. Development Apple Watch took place in secret and was relatively unknown until then, until the article was published Wired, which can be found online. [11]

The hardware part. In Apple Watch uses the system on a chip - S1. It uses linear drive called "Taptic Engine" to ensure connectivity tactile feedback upon receipt of notification or communication and is used for purposes other relevant applications. Clock features a built-in heart rate sensor, which uses both infrared and visible spectrum of light and photodiodes. All versions of Apple Watch clock with 8 gigabytes of memory, the operating system allows the user to store up to 2 gigabytes of music and 75 megabytes of photos. The main factor why it was chosen Apple Watch in the development of the system is that it can create a pair with the iPhone and sensors transmit data to the program Apple Health, through which you can get the necessary information about the patient's condition. Battery of Apple Watch maintains more than 18 hours of mixed use. Clock charged via inductive charging cable, which is similar to the MagSafe from the MacBook. If the battery is less than 10%, the clock will switch to power saving mode that allows you to see just an hour. In addition, the product has waterproof elements, it potentially allows you to monitor the physical condition of swimmers. Special tests have shown that Apple Watch can operate in conditions of immersion under water in different conditions, though the sensor then becomes less accurate. [12]

The software part. Apple Watch runs on OS - WatchOS, whose interface is based on the home screen with circular icons set programs. Moving the home screen takes place by means of sensors or corona side of the clock. The watch is able to receive messages and calls using paired iPhone. "Views" allow users to switch between pages containing widgets. WatchOS supports Handoff, to send content from Apple Watch for iOS or OS X and used Siri voice commands. Apple Watch also supports Apple Pay, and can be used with older models of iPhone, do not support NFC. Applications of Apple Watch are designed to interact with iOS - analogues, such as e-mail, phone, calendar, messages, maps, music, photos, reminders, etc. With the development of HealthTracker system, the application we are interested in is Fitness app that keeps track of physical activity of the user and sends the data back to the iPhone Health App. WatchKit - application runs in the background of the iPhone as an extension applications and send data about the physical condition of the media to the phone. Thus, WatchOS - applications must be paired with the iOS - application and automatically sync with iPhone. [13]

In the future Apple Watch will use an operating system WatchOS 2, was presented at WWDC 2015. It added support for native applications, added night mode, new dials with customizable time - lapse video as the background, and many other changes. [14]

Also there are new opportunities for programmers in WatchOS 2. The main innovation is a native SDK, which improves parameters benchmark programs, because they are written by native WatchOS 2. In addition, developers granted direct access to the accelerometer, microphone, crowns, and moreover, to medical devices and sensors TapTic Engine, that will be used in the development of the system.. [15,16]

Apple Watch was selected for appropriate device for health tracking for next reasons:

- The display device is extremely sensitive. Apple has been able combine small screen sizes with very accurate sensitivity of the screen. This makes it easy for navigate throughout the screen and choose appropriate programs and controls. In addition, the display reacts differently to the pressure force. Also Retina - display provides high clarity of screen elements.

- The main radial menu. All the programs are of the screen and scroll works in all directions.
- High stock battery. Apple claims that the battery keeps watch about 18 hours of active use, various tests have shown that by the end of the day is about 25% of the battery, which is a fairly good indicator in comparison with analogues.
- Built-in integration with Siri. This technology allows voice commands to perform a great variety of tasks without requiring user attention, including Dictation typing, content tagging, ratio reminders and searches on the Internet.
- Ability to answer the phone. Currently it's the only clock that allows direct incoming calls when paired with a smartphone.

Despite the considerable number of advantages clock has its drawbacks.

The main disadvantage is that without connection with the iPhone, most of features of the watch are nullified, including the ability to track health, a key necessity in the development system. [17]

Another drawback of the device is its price. The price varies depending on the type of clock. In developing the system will be used and Apple Watch Apple Watch Sport with displays 38 and 42 inches respectively, watches materials are aluminum and stainless steel. Apple Watch Edition is an exclusive product with a price of $ 10,000, which does not mayuye no advantage in terms of functionality and differ only cost materials (18 - carat gold). Apple Watch Sport price starts from 349 $, Apple Watch from $ 599. But in the increase in the dollar price of such a device are considered a disadvantage.

The third potential drawback of the device is that due to changes in color, such as tattoos, working sensor device is inaccurate, making it impossible to establish the exact state of health of the patient. The reason is that monitoring clock pulse user svityst green flash on the skin and recording the number of green light that is absorbed by the blood. However, after the change of color, this functionality can not fully correct opratsovuvavty rates of absorption of green light, causing possible inaccuracies in the results. [18]

One of the main applications, which is useful in exploring the physical condition of the user and is used to design the system is Activity App. This application provides a simple visual representation of daily physical activity guide with three rings, showing all relevant information. The so-called "Stand ring" shows how often people got up from their seats. "Move ring" indicates the number of calories burned by the user. "Exercise ring" shows how many minutes of exercise done. The main purpose of this program is the ability to install your daily limit individually and closing these rings. [19]

Stand. Sitting too long has some health risks. Apple Watch Sensors determine when the user stands up and record it. If you sit for more than an hour, the clock is reminiscent of the media. "Stand ring" closes when the user gets up and moves at least 1 minute every hour of the day. This may seem trivial, but frequent breaks from sitting a positive effect on health in general.

located radially from the corners

Move. Every week, Apple Watch offers a new goal in terms of traffic every day to burn some calories, given recent indicators user. "Move ring" completes when the user closes the established amount of burnt calories for the day. The user can change the proposed amount of calories, increasing or decreasing it depending on the state of health of a day. The main purpose of "Move ring" is a small but constant improvement in traffic every week for progress of health of the user.

Do the exercise. Apple Watch stores data on physical activity every day user. "Exercise ring" closes when the media do at least 30 minutes of exercise every day. Exercise is not necessary to perform row for half an hour, the user himself distributes their number during the day depending on their own recommendations.In addition to these general functions of the program Activity App, there are many other applications built by different companies to promote their products. With these applications, the clock will be useful for cyclists, people do yoga or gymnastics. [20]

CONCLUSIONS

Today there are a large number of mobile medical systems that measure a variety of indicators of human activity. However, most of the systems are relatively new and require many improvements, some of them are just development prototypes. In addition, all the above systems require binding to certain equipment which are not always convenient in everyday use.

To reduce inconvenience in the use of existing systems we need to create a system that is integrated into the smart watch that will provide ease of use, and the mechanism to store and analyze medical data to cloud storage.

With all bound by these clock capabilities, there can be made a conclusion about the suitability of its use in medicine, probably the best device for recording each change in the physical activity of the patient and establishing an early diagnosis. The system integrates directly with the clock for convenience and requires no additional devices or settings. All the carrier's physical performance will be processed and stored system in the cloud, which will have access to a doctor. This will help to maximize the effectiveness of the system in real conditions.

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Social and communicative engineering as the newest type of engineering

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Abstract. The authors describe a scientific substantiation of the concept "social and communicative engineering", outline the object and the purpose of study of a new type of engineering, which is being actively formed and is objectively demanded in today's information society. Social and communicative engineering forms rules of the correct construction of social groups, of the setting of internal relations in them and regulations of the building of relationships with the outside world. The methods of social and communicative engineering are specific techniques used for the designing and the construction of social and communicative technologies and systems, and also scientific, where the leading one is the system analysis. Social and communicative engineering, in the authors' interpretation, is a set of methods, tools and means which, when is used systematically, allows to design and create the qualitative and effective social and communicative technologies and systems. In other words, social and communicative engineering is the science that investigates the processes of construction, projecting and creation of social and communicative technologies and systems. Social and communicative engineering, as the science that studies the processes of designing and creating of social and communicative systems, is in demand, particularly during the formation of the system of relations between members of different parties and political platforms, ideological beliefs of various communities through the establishing of communications, particularly with the engagement of possibilities of the information spreading through social networks.

Key words: social communication, social institution, social engineering, social and communicative engineering.

INTRODUCTION

The multifaceted and the most essential activity of social institutions, as important constituents of a system of social communication, determine the necessity of the use of different methodological approaches to their research. The analysis of social and communicative processes in the society is complicated by the necessity to study their impact on the functioning of social institutions, their interaction with the environment, the need to consider the social and communicative processes, taking into account the following levels: of individuals, of the individual and social institution, of two social institutions, of social institution and society or social and communicative system of a higher rank.

Nowadays, scientists are seeking to explore and analyze social and communicative processes and fix into them certain patterns, to make a systematic review of the methods, ways and means of the distribution of information flows in social and communicative systems, and to examine thoroughly the processes of the functioning of social networks.

The purpose of the article is to analyze systematically and to present scientific substantiation of the concept and definition of the term "social and communicative engineering", to describe an object, a subject and methods of investigation of a new type of engineering, which is being actively formed and is objectively demanded in today's information society.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICFTIONS

A lot of scientists, both foreign and Ukrainian, repeatedly addressed the profound research of methodological foundations of social communications, among which in the first place it should be named N. Vinner [1], V. Rizun [2] and others. However, the scientific substantiation and the definition of the concept of social and communicative engineering, in the proposed sense by the authors of this article, as a separate type of engineering that focuses on the study of social communication and its components, have not been used yet.

OBJECTIVES

The aim of this article is to analyse of the concept "social and communicative engineering" as one of the newest types of engineers, her subject and object of study, methods that she uses.

THE MAIN RESULTS OF THE RESERCH

The definition of the concept "social and communicative engineering".

The term "social communications" appeared in 1963 at the Second Vatican Council. At the second session of the Council the term "social

communications" was first coined [3], although these concepts existed until 1963 and were defined by means of other concepts. In particular, the concept “communication” (“communicatio”) was understood as a unity, a transfer, a message, and its meaning came from the word “communico” – making joint, inform, connect.

The first paragraph of the “Decree on social communication” adopted by Pope Paul VI, says that among the technological discoveries that talented people, especially in the current era, have made with God's help, the Church welcomes and promotes with special interest those, which are directly related to the human mind and which opened new opportunities for communication, extremely quick acquaintance with news, views and teachings of every kind. The most important of these inventions are media, such as newspapers, cinema, radio, television and others, which may, by their very nature, comprise and influence not only the separate individuals, but also the masses of people and all human society, and thus can be rightfully called the media of social communication [3].

In the third article of the first section it was stated that the church considered as one of its duties to announce the good news of salvation also with the help of the media of social communication and to inform people about their proper use [3]. The decree emphasizes the importance of freedom of dissemination of information in the modern world. Thus, it can be reasonably stated that the church was one of the active factors in the development of social communications.

A wide range of information and social and communicative technologies is used to implement social communications. Social communications is an interesting object of scientific study, research and analysis. The presence of technologies that implement these processes determines the need for the formation of such a scientific field which analyzes, learns and explores them. The authors of the article propose to give it the generalized name – social and communicative engineering. Social and communicative engineering, in the authors’ interpretation, is a set of methods, tools and means which, when is used systematically, allows to design and create the qualitative and effective social and communicative technologies and systems. In other words, social and communicative engineering is the science that investigates the processes of construction, projecting and creation of social and communicative technologies and systems. A new kind of engineering must inevitably be originated in modern conditions which from historical interpretation of the Greek term “engineering” means science that studies and investigates the processes of projecting, creation and construction. The basis of engineering activity consists of five phases: the definition of the goal, the analysis of materials, needed to achieve the objectives, the analysis of means of achieving this goal, the modeling and prototyping, the management of the processes of achieving the aim [4].

Thus, an appropriate type of engineering must be arisen in the medium of social communication, which methods and tools allow properly and correctly to design and create social and communicative systems. A professional look at conceptual foundation of the information society, the interpretation of which is given in the documents of the World Summit on the Information Society, and which recorded the basic profile of its informatization, and, unfortunately, could not define by what means, methods and ways such society should be built and how, after all, correctly to “design” and to “form” it. It should be noted that in these documents, according to the authors, the natural assertion is that the social and communicative engineering is the science, which should work out such methods and means of proper construction of the modern information society, and further knowledge of the society. Social and communicative engineering is emerging as one of the newest types of engineering and certainly should have its subject and object of the investigation. According to the authors, the object of social and communicative engineering is social communications and their components, the subject – is methods, tools and means of designing and the construction of social and communicative technologies and systems. The methods of social and communicative engineering are specific techniques used for the designing and the construction of social and communicative technologies and systems, and also scientific, where the leading one is the system analysis.

Subject of study of social and communicative engineering.

Social communication has already become the subject of study of a large number of branches of science. Analyzing the processes of formation of social communications L. Amlinskiy pointed out that the centre of social life in pre-industrial societies was the market square; in industrial society the information area was considerably expanded: the printed sources of information appeared - newspapers, magazines" [5]. It is obvious, that the means of oral communication did not provide the qualitative transmission of information, the factor of preserving authentic information wasn’t taking into consideration, certain communication barriers existed such as separation of sources and receivers in space. With the appearance of writing the opportunity of more fully qualitative satisfaction of informational needs emerged. The appearance and active functioning of handwritten items, that played a significant role in the development and improvement of the processes of information spreading, should be mentioned while complementing L. Amlinskiy’s statement.

Decisive for the semantic definition of the field of “social communications” are the principles and analytical tools, formed on the basis of information cybernetic paradigm of Norbert Wiener [1], William Ashby [6] and others. Many researchers and leading scientists from all around the world constantly improved the theoretical foundations of the defined scientific branch.

M. McLuhan, considering the book as means of

communication, emphasized, that the invention of printing books gradually accelerated the act of reading to such an extent that the reader could feel the "hand" of the author, strengthened and expanded visuality of applied knowledge. The researcher made an interesting conclusion that in the era of handwritten sources, the transmitting of information, by means of copying and distribution of someone else's book was considered to be an act that deserved full respect, whereas in the era of printing books this way of information spreading was judicially prosecuted [7].

The means of communication [8], in his opinion, is a message, that defines, controls the scope, the form of human association and the human action. The change of scale or form of human activity is considered as a peculiar "message" in the system of social communications. M. McLuhan noted, that the mean of communication by itself is a message, and all means of communications is a kind of "translators" from the one type of experience and energy to another [7]. Analyzing the views of his contemporaries as to the development of social communications, the researcher demonstrates the original vision of this process.

However, the scientist emphasizes, that despite the widespread association of the term communication with roads and bridges, sea routes, rivers and canals, in the "electric" epoch, it received somewhat broader meaning – "the movement of information", including through the notification in the press and printing items. The innovative approach to the study of communication, according to the researcher, lies not only in the content analysis, but in the analysis of the means of communication and the environment (cultural matrix), in which this or that means is functioning, and every means of social communication has the ability to impose its understanding of the problem [8].

The scientist believes, that the appearance of book-printing accelerated the development of social communications, allowed to form a social memory, on the background of which previously existed individual memory has lost its relevance. The new technology quickly entered the social environment, arts and sciences. The printed book acquired qualities of portability and accessibility, which manuscripts lacked [8] that certainly made it an effective tool of social and communicative processes.

Harold Innis suggested the idea that the development of means of communication automatically affects a person. It interacts with cultures in such a way that the determination of national identity is impossible until the national language finds a printed form. The researcher regards to the means of communication, in particular letter, papyrus, radio, photoengraving, as products of manufacturing and resources that take an active part in social and communicative processes [9].

The appearance at the beginning of XX century of the new means of communication – radio, provided an opportunity to transmit information to geographically remote consumers, involving at the same time quite a wide listening audience. Television enhanced further more the possibilities of spatial transmission of information, ensuring its visualization and efficient supply of information from the places of events.

The representative of the communicative philosophy J. Habermas stated that "Communication is recognized by recent foundation and of consciousness, and of knowledge, and of social being", herewith communication is considered not only as a means of sharing information, but also as a socio-cultural phenomenon – an important aspect of human development, that directly correlates with the general nature of culture and the change of historical epochs. [10].

Communicative philosophy considers that it is necessary to justify rationally the universal foundations of human mutual understanding and harmonization of relations between people, and also between the individual and the environment [11]. To some extent, its task is correlated with tasks of, but for the latter their limits are much broader. The communicative philosophy is close to the social and communicative engineering on the subject and the research method, since it is based on a study of everyday speech communication between people [12].

From the standpoint of the theory of communicative action J. Habermas believes, that the resulting internal context would prevent from achieving the argumentative consensus in the implementation of daily communicative processes and from finding answers to the "practical questions", from describing and assessing the causes of certain events [10].

The researcher pointed out that communication between people operates only when it organizes the processes oriented to the cause. This means that participants of the communicative process should give up the desire to achieve the perfection of this process until they communicate; herewith their communication process has to be justified and is open to criticism. [10]

Thus, the representatives of the communicative philosophy consider social and communicative processes as daily processes of communication.

A. V. Sokolov [13] stated, that communicative issues became a part of fundamental social sciences – sociology, psychology, social psychology, cultural studies, social philosophy, and is also mastered by different applied sciences from the documentary and journalism to the theory of advertising and public relations, but a complete theory of social communication has not been formed yet. Each branch of science covers a particular area of social communication, but the whole structure of the communicative universe is not analyzed, although the notion of the social communication is interscientific and such sciences as hermeneutics, linguistics, logic, psychology, sociology, philosophy, and aesthetics take part in its development. A. V. Sokolov also analyses such category of social communication as a social memory. The scientist considers it to be the object of the history, and meanings of the past as its subject.

Social institutions were analyzed by researchers as a relatively stable form of social practice, due to the needs of society. Such studies have focused on their social role, public purposes, social functions, assuming

that the definition of the output social functions of social institutions gives an idea about the nature of their activities.

Social historically significant milestones in the development and improvement of social and communicative processes were so-called information revolutions, which, from the point of view of the prominent Ukrainian cybernetics, academician V. M. Glushkov [14], happened in the following order: first – the appearance of speech on the basis of sign communication; second – the emergence of writing; third – the appearance of printing; fourth – the invention and the use of the first computers. While continuing this scientifically innovative row, it should be noted that the formation of a global informational world infrastructure – the Internet network, certainly claims to be the fifth socially-oriented informational revolution. With a high degree of reliability and validity of scientific forecasting it can be assumed that the future (to some extent current) sixth informational revolution brings the maximum informational mobility and informational personalization for every member of the society based on modern informational and telecommunication technologies. In the nearest future, the implementation of the principles of mobile and personal possession of the actual informational resource on the principle "all the necessary information – here and now" is the main aim of social and communicative transformations. By achieving this global social and communicative goal, human civilization will practically complete the implementation of a particular cycle of the improvement of social and communicative technologies.

The above mentioned informational revolution can be considered as the revolution in the social and communicative industry. Social informational institutions, which ensure the accumulation, the storage and the distribution of social informational resources, played a significant role in each of them.

The author of the mathematical theory of communication K. Shannon [15] in his works drew parallels on how to exchange data between technical facilities and people, stating that the system of communication is a system comprising five components: a source of the information, which produces a message or a sequence of messages to be brought to the attention of the receiving terminal; a transmitter, that operates to create a signal suitable for transmission over the channel; a channel, which is only the medium, that is used for the signal transmission from the transmitter to the receiver; a receiver that usually performs the opposite operation to that done by the transmitter – reconstruction of the message; a person or a thing for which the message is intended to.

The actions of the communicant, which usually lead to social transformations, are determined by subjectivity, a characteristic of decoding. Moreover, in social and communicative systems it is quite difficult to estimate the level of informational "noise" in the "messages" provided by a system.

According to authoritative experts, such as A. I. Mikhailov, A. I Chornyi, R. S. Hiliarevskyi, in computer science the channel of communication is established between the communicant and the recipient, which is essential for the connection (the exchange, the transfer of information). Meetings, conferences, radio and television, publishing houses, editorial offices, libraries – are channels, which provide direct or indirect scientific communication [2]. Thereby they consider informational social institutions to be active participants of the exchange of scientific information, structures for the generating, the processing and the distribution of scientific knowledge.

Professor W. Rizun [2] states that social institution necessarily creates a predefined "system of social interaction", applying "the defined ways, methods, tools, principles of establishing and maintaining of the contacts through the professional and technical activity" with certain organized community, that are disposed "as full participants of social interaction".

Dominant trends of growth of the theory of social communication at this stage are concentrated on the focus of the research of communication environment, that enables to generalize organizational, methodological, technological, functional, content, managerial (including design) aspects of social communications in partial and applied studies of sciences in the system of communicative knowledge [2].

The research of many social institutions is based on the statements by Professor V. Rizun, that a methodological approach to the study of phenomena, processes, functions of social communication is obviously the social and communicative approach [2]. According to the researcher, the essence of this new approach is fixing, monitoring, description, analysis and interpretation of the given in the system concepts of social and communicative engineering. More specific this approach is focused on the impact on the society which is made by the object of the research, that was technologically laid, and how the society responded to the object of this influence [16]. The formation of the defined new scientific field by us, which is the social and communicative engineering, covers much broader aspects of the forming of social and communicative technologies and systems.

The researcher believes that the approach to social communication as engineering study for understanding the organization of social and communicative affairs, staff training, and also the carrying out of the research in this area, is of fundamental importance [2].

According to V. V. Rizun, the social communication is formed under the laws of communication, that's why any technological things anticipate the use of scientific knowledge about communication and organization of social and communicative affairs, without which there is no effective development of social engineering. The researcher projected technologies only on social engineering, believed that for the "social engineer" social and communicative network is a "vascular system" for the ensuring of the social connection and social impact on the society. However, the scientist

didn't fully decide on the terminology using the term social engineering and as the synonym the social and communicative engineering affair. He considered firstly being the science of social communications, and not the science of interaction (communication). In his opinion, the social engineering is the science of "the history (origin and development) of the study of social communication, the importance of that type of social engineering affair, which is now called social and communicative", of "social communications as the product of the social and communicative affair" [2].

This approach is supported by O. M. Kholod, who suggested to analyze engineering from the standpoint of social communication, considering it to be the social and communicative engineering, namely a process of "creating, forecasting, adaptation and implementation of communication technologies, strategies and models of social action, interaction and relationships between social persons (subjects and objects) for the purpose of manipulating (positive or negative impact)" [17].

The role of various social institutions in the information society, their social functions, focusing on the many institutional aspects, including interaction with the environment, requires clearer delineation. Other activities of social institution have not been an object of the study over the years. As J. Shira [18] stated, the social institution is "a set of social events, conventions and formal structures by which society fixes limits, controls and establishes the forms of the activity of all its members", herewith the researcher stresses that in this interpretation a library (with the readers) is the one of the "structures" of the system of social and communicative society. He regarded society as a social institution, which incorporates special institutions (services, organizations) and professional personnel, distributed among regions (subsystems) of the institution: practice, science, education, management, industry press. J. H. Shira considered library as one of the departments of the institution of education. As if continuing his view A. V. Sokolov [19] convincingly used the interpretation of the category "social institution" for analyzing social and communicative systems. Considering the social institution as a real social system consisting of interconnected and interdependent functionally specialized elements, the researcher constructed its structural and functional model, noting that each of the components of the social institution in different historical periods is embodied in different organizational forms and goes through its own way of the development. S. A. Basov [20] pointed out that A. V. Sokolov's opinions haven't been demanded for some time by the society, although social institutions, changing over time, constantly embody the function of utility for the society – no matter how this "utility" was understood.

These studies confirm the need for the investigation of the society from the standpoint of social communication. Thus improving the definition given by V. Rizun, social communication is thought of a complex of technologies that implement the functioning of the system of social interaction which provides communicative processes of social institutions, organized communities and individuals.

In this context, it becomes increasingly important to use a systematic approach to the study of the analysis, projecting and construction of the social and communicative system. This issue should be investigated by an individual scientific discipline, which we offer to call the social and communicative engineering.

Social and communicative technologies are used for the full realization of social communication on the condition that the postulate is accepted, which states that if there is social communication, as an object of the study, research and analysis, and if there are technologies that implement this process, then from the point of view of the system organization the need in the development of a particular type of engineering – social and communicative engineering – is an indisputable fact. It is the science that studies the processes of designing, constructing and creating of social and communicative systems.

A new scientific field should be, to some extent, formed similar to social engineering, which has a set of approaches, applied social sciences, oriented to purposeful changes in organizational structures, that determine human behavior and can control it, or – an integrated approach to the studying and changing of social reality based on the use of the engineering approach and the knowledge-intensive technologies [21].

Social engineering is the activity of planning, designing, creating and modifying organizational structures and social institutions; the complex of applied methods of sociology and other social sciences that make the set of tools for such activities. Experts in the field of social engineering are involved mainly in social problems at work or in public relations, and tend to have a complex training in a number of sciences, using in their research and practical activity data of sociology, social psychology, physiology, psychology, economics and others. [21].

In the context of a problem under investigation, it should be noted that along with social engineering, which has its object, subject and methodology, another kind of engineering – informational engineering, which has its specific object, subject and methodology is actively developed. P. Kazumi determines the informational engineering as the complex of activities in creation of different informational processes, modeling of the design and implementation methods to realize informational service [4], that in many works of contemporary researchers treated as synonymous with the engineering of data and knowledge.

Social and communicative engineering is a system forming type of social and informational engineering. Social and communicative component ensures the formation of the concept of the society, as the society began to emerge after the appearance of the functions of communication and the implementation of them.

Methodological basis of social and communicative engineering

The formation of the methodological basis of

social and communicative engineering involves close cooperation of the wide range of specialists, particularly in information sciences, library science, journalism etc. The process of designing of effective social and communicative systems should be based on the use of the methodology of the system analysis and the theory of modeling.

There is a need of forming rules and clear principles of building of social and communicative relationships in the informational society. Social and communicative engineering, as the science that studies the processes of designing and creating of social and communicative systems, is in demand, particularly during the formation of the system of relations between members of different parties and political platforms, ideological beliefs of various communities through the establishing of communications, particularly with the engagement of possibilities of the information spreading through social networks. Herewith one should not reject and dissociate from the theoretical developments of the "partial" engineering of K. Popper. The rationalism of his claims, regarding the inadmissibility of approaches to reform of the society based on "non-systematic and gross, but ambitious and decisive application of changes" [23] is of particular relevance in our time. The researcher states that the "partial" engineer must assess as accurately as possible the effect of any size on the public "whole". Within the "partial" approach, the possibility, that a number of "partial" reforms will be inspired by one common trend, is not excluded.

Social and communicative engineering should take into account this aspect in the study of the typical for social institutions social and communicative processes, to ensure the formation of their new organizational and content forms.

According to K. Popper, just as the main task of the engineer-physicist is the design, improvement and maintenance of machines, the task of the social engineer is the design and reconstruction of social institutions, as well as their management [23]. The term "social institution" is treated by the scientist in a very broad sense; it includes organizations (bodies) both private and public character.

The "partial" technologist or engineer knows that projected institutions are only small minority of social institutions, all others are just "appeared", and they are unintentional results of human actions. But no matter how impressed he is by them, the technologist or engineer will look at these social institutions from the "functional" or "instrumental" point of view. He will see in them the means to achieve a certain goal or believe that they can be turned to serve such objectives; they are machines for him, not organisms. Of course, he sees a fundamental difference between institutions and physical tools. The institutions are as fortresses [23]. They should be well designed and equipped with reliable staff. And the last element will be effective while using methods of social and communicative engineering.

The experience of researchers in the field of social engineering, which suggests that new social systems and institutions should be created only in an informational environment, must be taken into account. Such environment creates a certain cultural background, avoiding the blind copying and transfer the samples of foreign culture to the national ground without their prior adaptation and assimilation within existing institutions [24]. K. Popper believed that only a small portion of social institutions was deliberately projected, the creation of their majority is unintentional.

Social and communicative engineering forms rules of the correct construction of social groups, of the setting of internal relations in them and regulations of the building of relationships with the outside world. We shall consider the processes of formation of scientific research groups in setting up of the research within a new research project. The researchers are chosen and scientific problems are defined. The members of the group form social and communicative relations as between themselves, so with the external social and communicative systems.

The social network is a set of agents (peaks) that can interact with each other and between which there are social relations, it is professional, personal, political, religious and others, or ensure the procedures of their social and communicative interaction. From a formal point of view, it is better to present such networks in the form of graphs and to apply for their analysis corresponding mathematical tools [25]. However, the researcher singles out the distinctive feature of the formation of the majority of social network in the context of social and communicative connections as the orientation on the narrow interaction on a horizontal level "personality-personality". Such links provide the rapid spreading of information in the society. The scientist proposes to consider the social networking as software and hardware facility, a complex system, which is characterized by a number of parameters and is analyzed by using the totality of different models – purpose, structure, action in time and resources [25].

The analysis of the peaks and their connections allows creating a generalized idea of the system, which is studied and analyzed with the aim of better understanding and improvement of existing operations, the formation of more advanced system. The methods of modeling and systemic analysis contribute to better understanding of the nature of the information retrieval processes, the improvement of which, usually, allows making better the functioning of social and communicative systems.

Based on the statements of the K. Popper's theory [23] on social engineering, social and communicative engineering can also be divided into partial and holistic (generalized) engineering. According to the researcher, if the methods of engineering are applied partially, then stable things in a team, group and social institution are designed and studied. Using the holistic approach proposed by the researcher, the opportunity to study the general trends in social and communicative processes, which take place in society, is provided.

The study of the communicative interaction of

individuals can be treated using the egocentric method inherent to the sociological paradigm of network analysis, herewith the impact of the social world of a single social actor, who is at the center of the system and his connections, are analyzed [26].

The principles of the system approach allow to consider each social and communicative system both as a part of the global system, and as an independent separate complex system of the social and communicative type. A necessary condition for the successful functioning of the social and communicative system is the formation of the components that would ensure its effectiveness. The main basic elements of such a system are informational technologies, informational resources and a number of individuals.

V. Zotov in the monograph "The formation of the informational communicative environment of modern society: a sociological analysis of institutional transformations" proposes to conduct a systematic analysis of institutional changes in terms of the evolution of the informational communicative environment. Using the methodology of social communications as the substantial background for the functioning of social institutions and their analysis in the context of the interactions in the society, culture and personality allowed the author quite deeply describing the formation of informational and communicative environment in terms of modern society. The definition of the informational communicative environment was given by V. Zotov through the system of functions characteristic to the system of social communications. The author singled out at least two main communicative functions: the first, when the informational communicative environment is considered as "a certain infrastructure, organized on the basis of informational communicative technologies and is designed for storage, transmission and processing of large amounts of information"; the second one derives from the fact that "the informational communication environment is a network structure that combines interdependent social subjects that coordinate and agree on their own common activity for satisfying the emerging informational communication needs".

The systems approach

Social and communicative system is presented as the multifunctional material and ideal (conceptual), open, complex, dynamic, determined, teleological (purposeful) regulated system.

The application of main principles and positions of a systematic approach allows clearly formulating the requirements to the social and communicative system:

• The principle of the ultimate goal: the global purpose of the system is an absolute priority, because there is an urgent need for an innovative approach – the implementation of conceptual foundations of removing of barriers in the process of finding an access to information,

• The principle of the unity: social and communicative system should be considered both as an integrated organizational and technological social institution and as a set of separate components (technologies, informational content, etc.),

• The principle of the coherence: each component of the system is considered in the interaction with an appropriate environment,

• The principle of the modularity: the analysis of the social and communicative system is carried out by means of the decomposition into individual components, modules with different degrees of profoundness; the system is presented as a set of modules and the links between them are analyzed,

• The principle of the hierarchy: at formation of the social and communicative system the principles of hierarchical structure of its components are implemented,

• The principle of the functionality: the structure of the social and communicative system and its functions are examined in the context of the priority of the functional tasks of the structure,

• The principle of the development: the formation of the social and communicative system takes into account the possibility of improvement, the ability to develop, expand and store information,

Methods and means of social and communicative engineering provide the formulation of the conceptual goal; allow reflecting adequately the purpose of the social and communicative system that can evolve in time and space. It is said that the purpose of the social and communicative system is a behavioral concept, and communicative processes among the members of this system are extremely important and even are the determining factor in social and communicative systems. While building a system, studying its manifestations, based on social and communicative relations, there is a certain element of uncertainty and the need to consider the risks.

The methods of social and communicative engineering allow us to determine the tactical goals, the achievement of which is made in defined and relatively short period of time – primarily it refers to the organization and the setup of the functioning processes of the system and the formation of relevant informational resources.

Macrogoals are formulated in such a way that they should be achieved in a sufficiently long period of time and the prior obtaining of at least one of the tactical objectives is required. The macrogoal in the context of the social and communicative engineering tasks may for example be formulated as a need for the establishment and the implementation of the separate target socially-oriented program in the building of the effective social and communicative system, which is based on the construction and the use of modern, based on advanced informational communicative media, social networks by various categories and groups of users, within limits of the state.

The necessity to form the following aims should be taken into consideration:

• The functional aim, which is defined by functional tasks of the system and by technological operations, inherent in the system, including the analytical and synthetic processing of information, formation of the informational content, forming of the

technologies of the informational support of the users,

• The aim-analogue – an image which is obtained as a result of the activity of another system, as well as under other conditions of the outer environment. The construction of the social and communicative system is based on the analysis of foreign and best principles of domestic experience in this area,

• The aim of the development, or a new purpose, which determines all aspects of the functioning of social and communicative system and mainly involves the integration and the synthesis of the above mentioned objectives. Herewith, the fact that the above types of objectives are internally connected was taken into consideration. The aim of the development, on condition of its successful achievement by the system, becomes the aim-analogue for other systems. For certain social and communicative system, it becomes the functional aim on terms of constant external conditions and the aim-analogue on terms of changed external conditions.

The modern social and communicative system can be considered as a complex system and an informational factory, which, on the basis of its own and involved from the outside informational resources, creates a wide range of current consolidated informational services and informational products, provides a range of informational services to various categories of users.

Logical-mathematical approach allows us to give the formalized definition, determining social and communicative system as a set, on which a specified ratio in fixed properties is based.

It should be stated that the theory of systems studies the phenomena, based on the research of formal relationships between their elements and changes occurring under the influence of the environment. As a result, only the interaction of the components is analyzed, without the direct explanation of the nature of mechanisms involved in the phenomenon [4].

Thus, the properties of social and communicative system as a whole structure are determined not only by the summary properties of its individual elements or subsystems, but also by the specificity of its structure, special system-building, integrative bonds. In this context, informational social institution is an adaptive multi-functional, open cultural and civilization system, the purpose of which is the promotion of the circulation and the development of accumulated human knowledge by providing free access to it; the saving of documented knowledge as a social, the formation and the implementation of the functioning of the channels of exchange of socially significant information. Being the part of the information and communication system of the certain region, each of them implements the function of the broadcasting of information, data and knowledge in the social and cultural dimensions of time and space, giving the subjects and objects of the communicative process the opportunity to come to mutual understanding within their co-existence.

It should be considered, that the function of system is a combination of processes, which are performed or could be performed by the system according to its purpose. The function of each element should be understood as a set of conditions in space and time, and in interaction with other elements, as by the cooperation of the functions, a new feature that is not found in every single element of the system, quite often emerges.

The starting position is the presence of the main features of social and communicative system:

1) the simplest units – elements that constitute this system, in this work informational resources and technologies;

2) subsystems – the results of the elements interaction. In this research such subsystems as electronic libraries and digital collections, are highlighted;

3) components – the results of the interaction of subsystems that can be studied in relative isolation, without the connection with other processes and phenomena. In this investigation – the setting up of the interaction “user – a document”;

4) a certain level of integrity, which is featured by the system that due to the interaction of the component receives integral results of the operation;

5) system-building connections that bind components and subsystems as parts of a single integrated system. In our investigation it is the interaction between subsystems “electronic library”, “digital collections”, “user”;

6) connection with other systems of the environment – the participation in the processes of social and documentary communications.

The methodology of the systemic analysis is based on well-known laws of interconnection and interdependence of phenomena that in the context of social processes requires the analysis of social and communicative systems not only as independent systems, but also as the constituent elements (subsystems) of a much larger system. For social institutions of information industry the structure of a higher level is the system of documentary communications that includes the following components: author – editorial office – printing – distribution of documents – social institution – user, which in its turn is a constituent of the social and communicative system.

Applying a systematic approach to the study of the social and communicative system allows us to define it as a complex self-regulated system, formed in the process of the interaction between the user and the document, the exchanging of information with other elements of the environment. The bonds that are formed as a result of these processes affect the overall development of social institutions and determine their place and role in the informational society.

Any social and communicative system is not isolated from the outside environment; on the contrary it is connected with that environment by bonds through which it makes a certain influence, realizing its purpose, and achieving by its functioning the particular aim. In addition, there are other types of relations that influence and act on the system itself on behalf of the external environment. These relationships are

important in the study of the processes of the exchange of information between the system and the environment, and between elements of the system, which ensure the realization of the basic functions of the system. The research and the analysis of the bonds allow us to discover the objects not directly, but indirectly, through other objects that stand in some interrelation or interconnection with them.

Social and communicative system is characterized by several types of relationship:

- interactions (coordinations), among which connections of properties and connections of objects should be differentiated. Their specific is that they are mediated by the goals that are set by each component of the interaction,
- procreation (genetic) when one object is the basis, that brings another object to life,
- transformations, among which we distinguish those that are implemented through a specific object, providing this transformation, and those that are implemented by direct interaction of two or more objects, during which or through which these objects together or separately move from one state to another,
- forming (structural), which provide that the presence of some elements of the system necessitates the existence of other elements that interact with the first,
- operation, that provides the activity of social and communicative system. Its components are combined by such bonds that together perform a certain function. These bonds are divided into the bonds of the state (when the next state is a function of the previous) and functional bonds (where objects are related by the unity of the realized functions),
- development, which is considered as a modification of functional relationship of the system and the bonds of its states. The main meaning of this process is quite significant changes in the structure of the system and forms of organization of life. From this perspective, the functioning of the social and communicative system is the movement in the state of one and the same level, which is associated with the redistribution of its elements, functions and bonds. Thus each subsequent state either is directly determined by the preceding one, or anyhow is "re-informed" by the whole construction of the object and does not go beyond its history. The development of the social and communicative system provides the updating of its potentials, and leads to a sharp change of the functioning forms. Thus, the social and communicative system reluctantly goes to a higher level of functioning on the condition of reorganization of the organizational bases of its activities,
- management, which, depending on the specific type of technological embodiment can form a kind of functional relationship or relationship of the development.

Typical examples of a social and communicative system are social networks. For example, exploring social networks of scientific communities, in which co-authorship of scientists during the preparation and the publication of scientific papers is fixed, the inherent relations and the spread of scientific information can be seen. These communities usually combine more than one million members. Their functionality is investigated using the appropriate models. The model of the network of the scientific community M. Girvan, M.E.J. Newman offer to present in the form of a graph, whose peaks are individual scientists, and joint publications are treated as bonds between them. The emergence of several joint publications promotes the formation of several parallel connections.

The mathematician Paul Erdosh, who has long studied the network of the co-authorship, in his fundamental works proposed to use certain metrics of the cooperation activities in the research community network.

I. N Trofimova suggests using a model of social behavior for the prediction of the behavioral strategies, which play a significant role in the study of social networks. The given model takes into account the impact of several factors on the behavior of the community: the influence of the environment, the population size, the ability to establish contacts (sociability) and the degree of difference of the elements. Modern social network is a modern and popular tool for communication.

The information in social and communicative system should be considered as from the standpoint of its receiving, storage, transmission, conversion, filtering, and also from the position of its use in the communicative processes. Informational flows are considered in interrelation with certain structural schemes that have some common features: the sources and consumers of information volume, the forms of presentation, the direction of transmission, the place and the type of storage and others. These structural schemes are used for the analysis and minimizing the data flows and the reducing of their volume, identify as duplication of information, so the duplication of ways of its transmission and others. The concept of information has a high degree of universality and in the general sense the functioning of social and communicative system is considered as conversion of input data in the output one by means of taking certain decisions in the system.

It should be noted, that social networks are one of the areas of interest of social and communicative engineering.

CONCLUSIONS

Thus, having conducted the thorough analysis, we can state, that one of the urgent needs in the formation of informational society is the continuation of forming a new kind of engineering, which is social and communicative engineering, that is described as a set of methods, tools and means which by their systematic use allow to design and create qualitative and efficient social and communicative technologies and systems.

There is an urgent need to develop rules of the construction of social and communicative groups, forming the correct processes of communication in their environment and the establishment of the

effective internal and external social and communicative relations. Social and communicative groups and systems (including social networks) – are objects of study, research, design and construction of social and communicative engineering. The adoption of this paradigm allows avoiding spontaneity in the formation of the social and communicative system, to ensure the correct formulation of problems, to choose the correct and effective methods of their creating and designing. The subject of the research is social communication and social and communicative processes, herewith the social and communicative engineering uses general scientific methods of research, and, also the techniques, inherent to engineering and humanitarian sectors.

The tools of social and communicative engineering should develop models of describing current social networks, using the methods of various branches of science, the powerful mathematical tools, including developed for physical phenomena and processes of the material world, as clear analogies between natural phenomena in "inanimate" nature and processes of functioning of social groups, communities and networks are traced. This science-based and methodologically revised approach can ensure the correctness and predictability of the development of social and communicative system.

The system science approach to social communication allows clearly formulating the requirements to social and communicative system.

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Applications of the combinatorial configurations for optimization of technological systems

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Abstract: This paper involves techniques for improving the quality indices of engineering devices or systems with non-uniform structure (e.g. arrays of sonar antenna arrays) with respect to performance reliability, transmission speed, resolving ability, and error protection, using novel designs based on combinatorial configurations such as classic cyclic difference sets and novel vector combinatorial configurations. These design techniques makes it possible to configure systems with fewer elements than at present, while maintaining or improving on the other operating characteristics of the system. Several factors are responsible for distinguish of the objects depending an implicit function of symmetry and non-symmetry interaction subject to the real space dimensionality. Considering the significance of circular symmetric field, while an asymmetric subfields of the field, further a better understanding of the role of geometric structure in the behaviour of system objects is developed. This study, therefore, aims to use the appropriate algebraic results and techniques for improving such quality indices as combinatorial varieties, precision, and resolving ability, using remarkable properties of circular symmetry and non-symmetry mutual penetration as an interconnection cyclic relationships, and interconvertible dimensionality models of optimal distributed systems. Paper contains some examples for the optimization relating to the optimal placement of structural elements in spatially or temporally distributed technological systems, to which these techniques can be applied, including applications to coded design of signals for communications and radar, positioning of elements in an antenna array, and development vector data coding design.

Key words: Ideal Ring Bundle, circular sequence, circular symmetry, model, optimal proportion, vector data coding, self-correcting, resolving ability.

INTRODUCTION

The latest advances in the modern theory of systems of certifying the existence of a direct link of circular symmetry and non-symmetry relationships with delivering the totality of philosophical, methodological, specifically-scientific and applied problems, which allowed her to gain the status of theoretical foundation of system engineering in modern science. Particularly relevant emerging study of the physical laws of nature, what in their treatises paid attention even the ancient philosophers. Studies include the use of modern mathematical methods of optimization of systems that exist in the structural analysis, the theory of combinatorial configurations, analysis of finite groups and fields, algebraic number theory and coding. Two aspects of the matter the issue are examined useful in applications of symmetrical and non-symmetrical models: optimization of technology, and hypothetic unified "universal informative field of harmony" [1].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In [2] developed Verilog Analog Mixed-Signal simulation (Verilog-AMS) model of the comp-drive sensing element of integrated capacitive micro-accelerometer. This model allows simulate the reaction of the sensing elements effected by the applied force of acceleration, changes of its comb-drive capacities, output voltages and currents for determining its constructive parameters and for analysis of mechanical module the integrated device, but precision are of very important indices for these models. Proposed in [3] method of adaptive data transmission in telecommunication access networks with a combine modulation types ensures the lowest possible bit error rate during data transmission at some ratio of signal power to noise power. General problem of systems optimization relates to finding the best placement of its structural elements and events. Research into underlying mathematical area involves the appropriate algebraic structures and modern combinatorial analysis [4], finite projective geometry [5], difference sets and finite groups in extensions of the Galois fields [4]. We're seeing a remarkable progress in developing of innovative techniques in systems optimization and design combinatorial Sequencing Theory, namely the concept of Ideal Ring Bundles (IRB)s [6-16]. The concept of the IRBs can be used for finding optimal solutions for wide classes of technological problems. A new vision of the concept with point of view of the role of geometric circular symmetry and non-symmetry mutual relation laws allows better understand the idea of "perfect" combinatorial constructions, and to apply this concept for multidimensional systems optimization [17-20].

OBJECTIVES

The objectives of the underlying concept are as research into the underlying mathematical principles relating to the optimal placement of structural elements in spatially or temporally distributed systems, including appropriate algebraic constructions based on cyclic groups. Development of the scientific basis for technologically optimum systems theory, and the generalization of these methods and results to the improvement and optimization of technological systems.

THE MAIN RESULTS OF THE RESEARCH

IRBs are cyclic sequences of positive integers which form perfect partitions of a finite interval [1,*N*] of integers. The sums of connected sub-sequences of an IRB enumerate the set of integers [1,*N*-1] exactly *R*-times[8]. Example: The IRB {1, 2, 6, 4} containing four elements allows an enumeration of all numbers from 1 to 12= 1+2+6+4 exactly once (*R*=1). The chain ordered approach to the study of sequences and events is known to be of widespread applicability, and has been extremely effective when applied to the problem of finding the optimum ordered arrangement of structural elements in a sequence. Let us regard *n*-fold symmetric sequence as to an ability to reproduce the maximum number of combinatorial varieties in the sequence using two-part distribution. Clearly, the maximum number N_n of such variants in *n*-stage sequence is taken two connected sub-sequences of the sequence:

$$N_n = n - 1 \tag{1}$$

The maximum number of variants *N* in ring ordered (closed loop) sequence divided of two connected subsequence is a number of ordered combinations of *n* elements taken 2 at a time as below

$$N = n(n-1) \tag{2}$$

Comparing the equations (1) and (2), we see that the number *N* of ordered combinations for binary consecutive sub-sequences of close-loop topology is *n* as many the number N_n of combination in the non-closed topology, for the same sequence of *n* elements.

To extract meaningful information from the underlying comparison let us apply to circular *S*-fold symmetry as a quantized planar field of two complementary completions of the symmetric field.

Example: The 3-fold (*S*=3) circular symmetry combined with two complementary completions (Fig.1).

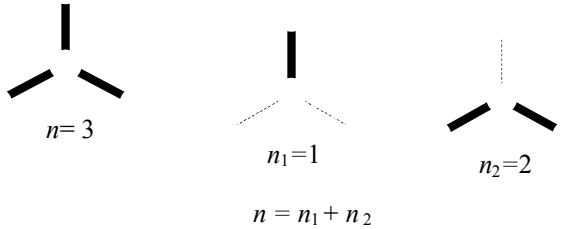

Fig.1. The 3-fold circular symmetry (left) combined with two complementary completions.

In general the order *S* of the circular symmetry may be chosen arbitrarily. The objectives of the proposed research and applications of circular symmetric and non-symmetric relationships are improving such quality of information technology as precision, resolving ability, and a better understanding of the role of geometric structure in the behaviour of natural objects. Underlying models help to understand the evolutionary aspects of the role of geometric structure in the behaviour of natural and man-made objects. In this reasoning, we precede from a visible geometric circular symmetry.

A plane circular *S*-fold symmetry, is known can be depicted graphically as a set of *S* lines diverged from a central point *O* uniformly (to be equal in spacing angles). Regarding n_1 and n_2 of *S* lines as being complementary sets ($S = n_1 + n_2$), we require all angular distances between n_1 lines enumerate the set of spacing angles $[\alpha_{min}, 360° - \alpha_{min}]$ exactly R_1 times, while between n_2 - exactly R_2 times, we call this a Perfect Circular Relation (PCR). Our reasoning proceeds from the fact, that minimal and maximal angular distances relation initiated by *S*-fold circular symmetry to be of prime importance for finding the PCR origin (Fig.2)

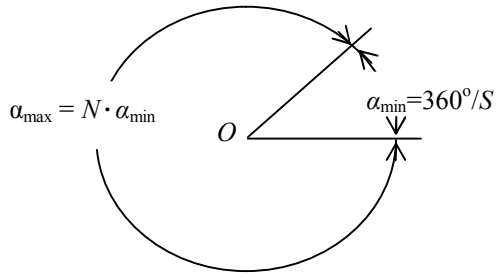

Fig. 2. The minimal- maximal relationship of spacing angles of a plane S –fold natural PCR origin

Clearly the set of all $N=n(n-1)$ angular distances $[\alpha_{min}, N \cdot \alpha_{min}]$ of *S*-fold PCR plane quantized field allows an enumeration of all integers [1, *S*–1] exactly *R*-times (Fig. 2):

$$N = (S-1)R \tag{3}$$

From equations (2) and (3) follows the integer relation, the PCR for $7 \le S \le 19$, $n_{1,2} \ge R_{1,2} + 2$ are tabulated (Table 1):

$$S = \frac{n(n-1)}{R} + 1 \tag{4}$$

Table 1. PCR for $7 \le S \le 19$, $n_{1,2} \ge R_{1,2} + 2$

№	*S*	n_1	R_1	n_2	R_2
1	7	3	1	4	2
2	11	5	2	6	3
3	13	9	6	4	1
4	15	7	3	8	4
5	19	9	4	10	5

Here are some examples of the simplest PCR. The elementary is 3-fold (*S*=3) circular symmetry that splits into 1-fold ($n_1=1$, $R_1=1$), and 2-fold ($n_2=2$, $R_2=1$) complementary asymmetries. The first of them

enumerates the set {1} by quantization level $\alpha_{min}=360°$, while the second {1, 2} by $\alpha_{min}=120°$ exactly once. The 7-fold rotational symmetry (S=7) splits into 3-fold (n_1=3) asymmetry, which allows an enumeration the set of all angular intervals [360°/7, 6×360°/7] of n_1=3, R_1=1, and n_2 =4, R_2 =2 by quantization level $\alpha_{min}=360°/7$, etc.[13].

From Table 1 we can see that PCR is two complementary asymmetries of even (n_1), and odd (n_2) orders, each of them allows an enumeration the set of all angular distances the precise numbers of fixed times.

Optimal numerical circular proportion is cyclic relationship of positive integers, which form perfect partitions of a finite interval [1, N] of integers. The sums of connected numbers of a relationship enumerate the set of integer [1, N] exactly R-times.

Let us regard a graphic vision of an optimal circular proportion as image segmentation, for example numerical circular proportion {1:3:2:7} based on 13-fold PCR, n=4, R=1 (Fig.3)

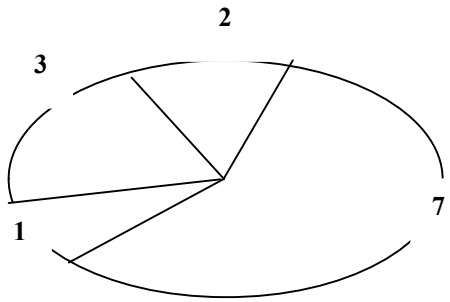

Fig 3. The {1:3:2:7} cyclic ratio segmentation

Observing the {1:3:2:7} image segmentation (Fig.3), we can form complete set of integer harmonious two-body cyclic proportions from 1:12 to 12:1 as follows: 1:12, 2:11, 3:10, 4:9, 5:8, 6:7, 7:6, 8:5. 9:4, 10:3, 11:2, 12:1. The numerical circular proportion {1:3:2:7} based on 13-fold PCR, n=4, R=1 provides the maximum number of harmonious two-body relationships with four (n=4) cross-sections.

Next we regard a graphic vision of the circular proportion {1:1:2:3} based on 7-fold PCR, n=4, R=2 (Fig.4)

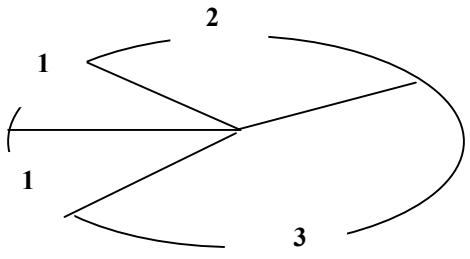

Fig. 4. The {1:1:2:3} cyclic ratio segmentation

Here is an example of complete set of harmonious two-body relationships from 1:6 to 6:1 obtained exactly twice (R=2) each of them over the {1:2:3:1} optimal cyclic segmentation. The cyclic relationship {1:2:3:1*} containing four (n=4) elements allows an enumeration of all numbers from 1 to 6 exactly twice (R=2): **1**=1=1*, **2**=2=1*+1, **3**=3=1+2, **4**=3+1*=1*+1+2, **5**=2+3=3+1*+1, **6**=1+2+3=2+3+1*. This property makes optimal cyclic relationships useful in application which need to partition sets with the smallest possible number of intersections exactly twice. Here we can see that underlying segmentation provide an ability to reproduce the maximum number of harmonious combinatorial varieties in the system using sequential parting technology.

To discuss concept of Torus Cyclic Groups (TCG)s let us regard structural model of t-dimensional vector ring as ring n- sequence $C_{nt}=\{K_1,K_2,..,K_i,...,K_n\}$ of t-stage sub-sequences (terms) $K_i=(k_{i1},k_{i2},...k_{it})$ each of them to be completed with nonnegative integers (Fig.5).

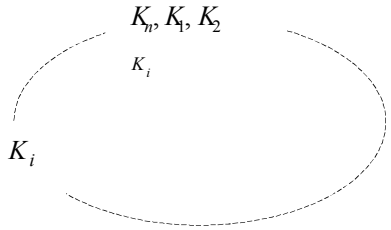

Fig.5. Schematic model of t-dimensional n-stage ring sequence.

Optimal 2D vector circular proportion is a cyclic relationship of 2-tiple (t=2) integers (2D vectors) based on S-fold PCR, which form consecutive 2D partitions over 2D torus surface exactly R times of fixed 2D quantization level. Here is an example of cyclic 2D vector relationship based on 7-fold PRC {(0,1):(0,2):(1,1)} containing three (n=3) 2D vectors, which form complete set of six (S-1=6) 2D vectors as lattice 2×3 covered torus surface exactly once (R=1), and all 2D vector-sums are taken modulo 2,3:

(0,0)≡(0,1)+(0,2)(mod2,3),
(0,1)=(0,1),
(0,2)=(0,2),
(1,0)≡(0,2)+(1,1)(mod2,3),
(1,1)=(1,1),
(1,2)≡(0,1)+(1,1)(mod2,3).

Next we see cyclic 2D vector circular proportion {(0,2):(1,1):(1,1):(1,0)} containing four (n=4) 2D vectors, which form complete set of 2D vectors covered torus surface 2×3 exactly twice (R=2).

The 7-fold PCR is common to optimal circular proportions {1:2:4}, {1:2:3:1},{(0,1):(0,2):(1,1)}, and {(0,2):(1,1):(1,1):(1,0)}. Clearly the set of these optimal proportions corresponds to set of IRBs as follows: {1:2:4}↔{1,2,4}, {1:2:3:1}↔{1,2,3,1}, {(0,1):(0,2):(1,1)}↔{(0,1),(0,2),(1,1)}, {(0,2):(1,1):(1,1):(1,0)} ↔{(0,2),(1,1),(1,1),(1,0)}.

In this we have 1D IRB {1,2,4}, and {1,2,3,1} as well as 2D IRB {(0,1),(0,2),(1,1)}, and {(0,2),(1,1),(1,1),(1,0)}. Both pairs of the IRBs come from the 7-fold circular symmetry. Moreover, the underlying combinatorial configurations are interconvertible dimensionality models of optimal distributed systems.

Regarding formula (4) with $n = m_1$, and n -1 = m_2 we have equation:

$$S = \frac{m_1 m_2}{R} + 1 \qquad (5)$$

Space coordinate grid $m_1 \times m_2$ forms a frame of two modular (close-loop) axes modulo m_1 and modulo m_2, respectively, over a surface of torus as an orthogonal two modulo cyclic axes of the system being the product of two (t=2) circles. We call this two-dimensional Ideal Ring Bundle (2D IRB).

Here is an example of set completed from the 2D IRBs with m_1=2, m_2 =3, R=1, and takes four variants as follows:

{(0,1),(0,2),(1,1)}, {(1,0),(1,1),(1,2)},
{(0,1),(0,2),(1,0)}, {(0,1),(0,2),(1,2)} (6)

To observe ring sequence {(1,0), (1,1), (1,2)} we can see the next circular vector sums to be consecutive terms in this sequence:

$$\left.\begin{array}{l}(0,1)+(0,2)=(0,0)\\(1,0)+(0,1)=(1,1)\\(0,2)+(1,0)=(1,2)\end{array}\right\}(\mathrm{mod}\,2,\mathrm{mod}\,3)$$

So long as the terms (1,0), (1,1), (1,2) of the cyclic sequence themselves are two-dimensional vector sums also, the set of the modular vector sums (m_1=2,m_2=3) forms a set of nodal points of annular reference grid over 2×3 exactly once (R=1).

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In much the same way can be formed sets of nodal points of reference grids for the rest 2D IRBs with m_1=2, m_2 =3, R=1. We call this torus cyclic group of 7-fold circular symmetry [18].

Here is an example of 3D IRB with n= 6, m_1 =2, m_2 =3, m_3 =5, and R=1 which contains circular 6-stage sequence of 3-stage (t=3) sub-sequences $\{K_1,...,K_6\}$: $K_1 \Rightarrow (k_{11}, k_{21}, k_{31}) = (0,2,3)$, $K_2 \Rightarrow (k_{12}, k_{22}, k_{32}) = (1,1,2)$, $K_3 \Rightarrow (k_{13}, k_{23}, k_{33}) = (0,2,2)$, $K_4 \Rightarrow (k_{14}, k_{24}, k_{34}) = (1,0,3)$, $K_5 \Rightarrow (k_{15}, k_{25}, k_{35}) = (1,1,1)$, $K_6 \Rightarrow (k_{16}, k_{26}, k_{36}) = (0,1,0)$. The set of all circular sums over the 6-stage sequence, taking 3-tuple (t=3) modulo (2, 3, 5) gives the next result:

(0,0,1) ⇒ ((0,2,2) + (1,0,3) + (1,1,1)),
(0,0,2) ⇒ ((1,1,2) + (0,2,2) + (1,0,3)),
(0,0,3) ⇒ ((0,2,3) + (0,1,0)),
(0,0,4)⇒((0,2,2) + (1,0,3) + (1,1,1) + (0,1,0) + (0,2,3)),
(1,2,4) ⇒ ((0,2,3)+(1,1,2)+(1,1,1)+(1,0,3)+(0,1,0)).

So, the set of all circular vector-sums of six (n=6) consecutive 3D vectors of this ring sequence covers surface of torus 2 × 3 × 5 exactly once (R=1).

Next, we regard the n-stage ring sequence K_{tD} ={(k_{11}, $k_{12,...,}k_{1t}$), ($k_{21},k_{22},\ldots k_{2t}$),... ($k_{i1},k_{i2},\ldots,k_{it}$),... ($k_{n1},k_{n2},\ldots,k_{nt}$)}, where all terms in each modular vector-sum to be consecutive t-stage sub-sequences as elements of the sequence. A modular vector-sum of consecutive terms in the ring sequence can have any of the n terms as its starting point, and can be of any length from 1 to n-1 exactly R-times.

Easy to see this verify of the next conditions:

$$\prod_1^t m_i = \frac{n(n-1)}{R} \quad , \quad \text{or} \quad \prod_1^t m_i = \frac{n(n-1)}{R} + 1$$

$$(m_1, m_2, \ldots, m_t) = 1 \ , \qquad (7)$$

where: n, R , and m_1, m_2,..., m_t are numerical parameters of a t-dimensional Ideal Ring Bundle (tD IRB) [8,10].

Remarkable combinatorial properties of 2D and 3D IRB can be used for improving the quality indices of optic or acoustic systems with non-uniform structure (e.g. overlapping masks utilizing the entire ultra-acoustic aperture) with respect to resolving ability due to avoid the interference of signal components of the same spatial frequency [11-13].

Characteristics of optimum cyclic IRB-code for some parameters of $7 \le S_n \le 103$ diapason is presented in Tabl.2.

Table 2. Characteristic of optimum cyclic IRB code for $7 \le S_n \le 103$

Optimum cyclic IRB code							
Parameters				Autocorrelation function			
n	S_n	t_2	C_n	+1	-1	Δ	$\lvert\Delta/S_n\rvert$
4	7	1	14	3	4	-1	0,143
5	11	2	22	5	6	-1	0,091
6	11	2	22	5	6	-1	0,091
7	15	3	30	7	8	-1	0,066
8	15	3	30	7	8	-1	0,066
9	19	4	28	9	10	-1	0,053
10	19	4	28	9	10	-1	0,053
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
49	99	24	198	49	50	-1	0,010
50	99	24	198	49	50	-1	0,010
51	103	25	206	51	52	-1	0,010

Here n- number of terms in an IRB, S_n – code combinations length, t_2 – number of corrected errors, C_n- code size, Δ- evaluated expression of autocorrelation function. The function calculates taking summation with respect to all items +1 and -1 after a full cycle set of step-by-step shifts an IRB –sequence. Clearly, the correcting ability of optimum cyclic IRB-code increase as length S_n of the code, and number t_2 of corrected errors tends to 25% in increasing this length non linearly, and sidelobe level ratio is better than Barker code [21].

IRBs are useful for high performance coded design of optimum discrete signals such as correcting cyclic codes [22], code of the better autocorrelation function than Barker code, and self-correcting monolithic codes [8].

Here is a set of two 2D IRBs -{(0,1),(0,2),(1,1)} and {(1,1),(1,0),(0,2),(1,1)}, which form complete set of cyclic 2D IRB code combinations (0,0), (0,1), (0,2), (1,0), (1,1), (1,2) over 2D ignorable array 2×3 covered torus surface exactly R-times. A developed view of the torus array 2×3 appears below:

(1,0) (1,1) (1,2)
(0,0) (0,1) (0,2)

Note, each of these code combinations forms massive symbols "1" or "0". We call this code a "Monolithic Ideal Ring Bundles" (MIRB) codes [8,10,19]. An example of 2D Monolithic IRB code with five (n=5) cyclic binary digits is tabulated (Table 3)

Table 3. 2D-IRB Monolithic Code {(1,3), (1,1), (2,3), (0,3), (3,3)}

Vector	Cyclic binary digits				
	(1,3)	(1,1)	(2,3)	(0,3)	(3,3)
(0,0)	1	1	1	1	0
(0,1)	1	0	0	0	1
(0,2)	1	1	1	0	0
(0,3)	0	0	0	1	0
(0,4)	1	0	0	1	1
…….. ……..	…… …….	…… …….	…… …….	…… …….	…… …….
(3,4)	0	1	1	0	0

This code forms complete set of cyclic 2D IRB code combinations (0,0), (0,1),…,(3,4) over 2D ignorable array 4×5 covered torus surface exactly once (R=1).

Code size of 2D MIRB coding system of five (n=5) binary digits coincides in number of cells in the array 4×5 that is $n(n\text{-}1)$ =20, and m_1 = 4, m_2 =5.

To see table 3, we observe all code combinations of the 2D IRB Monolithic code exhaust a set of collected similar signals in the combinations.In the same way can be formed 3D Monolithic IRB code {(1,1,2),(0,2,2), (1,0,3),(1,1,1), (0,1,0), (0,2,3)} (Table 4)

Table 4. 3D-IRB Monolithic Code {(1,1,2),(0,2,2), (1,0,3),(1,1,1), (0,1,0), (0,2,3)}

Binary digits					
(1,1,2)	(0,2,2)	(1,0,3)	(1,1,1)	(0,1,0)	(0,2,3)
0	1	1	1	0	0
1	1	1	0	0	0
1	0	0	0	0	1
0	1	1	1	1	1
…….. ……..	…….. ……..	…….. ……..	…….. ……..	…….. ……..	…….. ……..
1	1	1	1	0	1

To see Table 4, we observe:

3D vector (0,0,1) represented in cyclic binary digits as 011100, vector (0,0,2) as 111000, (0,0,3) as 100001, (0,0,4) as (01111) ……, finally vector (1,2,4) as 111101.

Hence the 3D-IRB Monolithic Code {(1,1,2),(0,2,2), (1,0,3),(1,1,1), (0,1,0), (0,2,3)}forms complete set of cyclic 3D IRB code combinations over 3D ignorable array 2 ×3×5 covered torus surface exactly once (R=1).

Code size of the coding system of six (n=6) binary digits coincides in number of cells in the array 2 ×3×5 that is $n(n\text{-}1)$ =30, and m_1 = 2, m_2 =3, m_3=5.

Underlying property makes MIRBs useful in applications to high performance coded design of signals for communications with respect to self-correcting, transmission speed, vector data information technology, and fetch protection [23].

The S-fold PCR is common to one- , 2D and 3D models for technologically optimum distributed processes on sequentially ordered of structural elements and operations.

The purpose of the study is to improve the quality indices of technology for accuracy, resolution and functionality by distributing of the minimal number of structural elements and interconnections of technological system in spatially or/and temporally distributed coordinates. The challenge is to find a method of the optimal placement of structural elements in technical systems with a limited number of elements and bonds, while maintaining or improving on resolving ability and the other significant operating characteristics of the system.

Application profiting from the PCR concept are for example optimum vector (two- and three-dimensional) technology, vector data computing systems, and development high speed vector information technology**.**

The Ideal Ring Bundles (IRBs) provide a new conceptual model of radio- and information technologies or systems based on symmetry laws [1].

It is known that cardinality set of IRBs increases out many times in increasing order n of circular symmetry, e.g., tabled 1D IRBs of order 168 have 4676 distinct its variants [8]. The cardinality set of two- and three-dimensional IRBs outnumber in part analogous to cyclic difference sets heavily, e.g., there are 360 distinct variants of 2D IRBs of order 7, and 180 3D ones [18], while the existence of the perfect difference sets [4] for n =7 is unknown yet.

Remarkable geometrical properties of real space-time based on perfect circular symmetry and non-symmetry reflected in the underlying models. These properties make useful in applications to high performance coded design of signals for communications and radar, positioning of elements in an antenna array and visual coding systems with respect to redundancy, signal reconstruction and low side lobe antenna design [11-13].

CONCLUSIONS

1. Applications of the Symmetrical and non-symmetrical combinatorial configurations for optimization of technology, namely the concept of Perfect Circular Relation (PCR), can be used for finding optimal solutions of technological problems in systems engineering.
2. The behavior of a self-locked quantum PRC system with parameters n, R is in step with S-fold circular symmetry.
3. Proposed code design based on the combinatorial configurations make it possible for reading a signal in signal/noise ratio under 1.
4. Application profiting from concept of PCR are for example vector data coding, self -correcting codes and problems of high-resolution interferometry for radar, data communications, and signal design.

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Generalized formal model of big data

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*Abstract.*This article dwells on the basic characteristic features of the Big Data technologies. It is analyzed the existing definition of the "big data" term. The article proposes and describes the elements of the generalized formal model of big data. It is analyzed the peculiarities of the application of the proposed model components. It is described the fundamental differences between Big Data technology and business analytics.

Big Data is supported by the distributed file system Google File System technology, Cassandra, HBase, Lustre and ZFS, by the MapReduce and Hadoop programming constructs and many other solutions. According to the experts, such as McKinsey Institute, the manufacturing, healthcare, trade, administration and control of individual movements undergo the transformations under the influence of the Big Data.

Key words: analysis, data, model, Big Data, information technology.

INTRODUCTION

These days there are a lot of Big Data sources. These are the data continuously received from the measuring devices, events from radio frequency identifiers, the message flow from social networks, meteorological data, Earth remote sensing data, data flows about the location of the cellular communication networks subscribers, audio and video recording devices. The mass distribution of the above mentioned technologies and innovative models using various kinds of devices and Internet services was the starting point for the Big Data penetration in almost all the spheres of human activity, primarily in research activities, the commercial sector and public administration.

Today the issues of the correct interpretation of the information flows are becoming more relevant and challenging at the same time. The volume of information is growing exponentially and its lion's share belongs to the unstructured data. The market of information technologies (IT) has reacted immediately. The large players acquired the most successful niche companies and began to develop tools for the Big Data. The number of startups exceeds all possible expectations [1].

Along with the growth of the computation power and the development of storage technologies the analysis of the Big Data is gradually becoming available to small and medium businesses and is no longer the exclusive prerogative of the large companies and research centers. To a large extent, the development of the cloud model computing contributes to it.

With further IT penetration into the business environment and the daily life, information flows (entitled to processing) continue to grow steadily. If today the Big Data are petabytes, tomorrow we will have to operate with exabytes, etc. In the observable future, it is obvious that the tools for such gigantic amounts of information still be too complex and expensive. It is considered that the modern software tools cannot handle such volumes within a reasonable time period. Obviously, the indicated range of values is very conditional and tends to increase upward as the computing hardware is continuously improving and becoming more accessible.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The concept of the Big Data is not new, it is originated in the days of mainframes and the related scientific computing [1, 2]. As is well-known, knowledge-intensive computing has always been challenging. As a rule, it is inextricably linked to the processing of the large volumes of information.

However, directly the "big data" term has emerged relatively recently. It is among the few titles that has its quite reliable birthday on September 03, 2008. Then a special issue of the oldest British scientific journal Nature has been released. The journal is devoted to the search for the answer to the question: "How can the technologies affect to the scientific future that open up the opportunities to work with the big data?" A special issue summarized preliminary discussions about the data role of science in general and in e-science in particular [3].

According to the report by McKinsey Institute entitled "Big data: The next frontier for innovation, competition and productivity", the "big data" term refers to the datasets whose size exceeds the capacity of the conventional database (DB) for the extraction, storage, management and information analysis [1]. Global data repositories, of course, continue to grow. The presented report of an IDC analytical company entitled "Digital Universe Study" in the mid-2011 (which was sponsored by EMC company) assumes that the total global volume of the generated and replicated data may reach in 2011

about 1.8 zettabytes (1.8 trillion gigabytes). It is about 9 times more than what was established in 2006.

However, “big data” entails much more than just analyzing the huge volumes of information. The problem is not that organizations generate huge amounts of data, but that the most of them are presented in a format that does not fit well with the traditional structured database format. These are web-magazines, videos, text documents, machine code, or, for instance, mapping data. All of the above mentioned are available in many different stores, sometimes even outside the organization. As a result, the corporation may have access to a huge volume of its data and does not have the necessary tools to establish the relationships between these data and make them the basis of meaningful conclusions. In addition, the data is now updated more often and we have a situation that the traditional methods of information analysis cannot overtake the huge volumes of constantly updated data which ultimately paves the way for the Big Data technologies.

The concept of "big data" considers working with the huge information volume and diverse composition. This information is very frequently updated and located in different sources with the aim of the efficiency increasing, new product generation and competitiveness improving. A consulting company Forrester gives a brief definition: "Big Data combine techniques and technologies that extract sense of data at the extreme limits of practicality" [1].

Worldwide information volume is growing annually by at least 59%. The corporate data sets and all the technologies needed to create, store, transfer, analyze, archive and extract are considered "big data". This huge information volume expands the limits of storage and security servers, creating a huge challenge for the IT departments that need to be solved. Therefore, the data volume, variety and velocity are the important challenges in the management of Big Data (on which the business and IT leaders should focus).

eWEEK submits the definition proposed by the research company Gartner: "Big Data are characterized by volume, variety and pouring rate through networks of structured and unstructured data, into the processors and storage devices, as well as the data conversion to business consulting for the enterprises" [4]. These elements can be divided into three categories as defining characteristics of Big Data ("three V"): volume, variety and velocity.

Volume (terabytes, petabytes and eventually exabytes). An increasing amount of business data is a major shot to the IT systems that try to keep safe and accessible all of this information for further use. Increase of data volumes in enterprise systems causes a significant scope of transactions over the traditional and new types of data. A large data volume is the problem of storage and analysis.

Variety. The number of data types that need to be processed is increasing, namely, the possibility of simultaneous processing of different types of structured, semi-structured and unstructured data. The variety includes tabular data (database), hierarchical data, documents, emails, accounting records, video, static images, audio, financial transactions, and the like.

Velocity. This refers to the velocity at which the data are moved from the endpoints to the processing and storage means. Velocity means how fast is the data produced and how fast must data be processed to meet the demand, and how fast is data saved.

Analyst Dan Kusnetzky (Kusnetzky Group) argues that the "big data" term refers to the tools, processes and procedures allowing an organization to create, manage and control the very large data sets and repositories [4].

In addition to the volume, variety and velocity, there is another "v" which fits in the overall data picture. It is a value. Values provide an accurate analysis of the large volumes of data. They help the businessmen to make the right decision at the appropriate time.

The “big data” term describes the data sets with a possible exponential growth that are too large, too plain or too unstructured for the analysis by traditional methods [6]. Big Data in information technology is a set of processing methods and means of structured and unstructured, dynamic, heterogeneous Big Data for their analysis and use of the decision support [7].

Bill Inmon considers the concept of "big data" as a new information technology [8]. Big Data is a technology that has the following features:

- it is possible to process a very large volume of data,
- the data media are inexpensive,
- data are managed by the "Roman Census" method,
- data managed with the Big Data are unstructured.

It is hard to find the industry to which the problem of Big Data would be irrelevant. The ability to handle the large volumes of information, analyze the relationships between them and to make informed decisions, on the one hand, carries the potential for the companies from different verticals to increase the attractiveness and profitability, efficiency. On the other hand, this is a great opportunity for the additional income to the vendor partners, i.e. the integrators and consultants.

The unsolved part of the overall problem. The main feature of the approaches in use within the concept of Big Data is the ability to process the information array perfectly to obtain the most reliable results. Previously we had to rely on the so-called representative information retrieval or information subset. Consistently the inaccuracies in this approach were considerably higher. In addition, this approach required a certain amount of resource consumption in data preparation for the analysis and bringing them to the required format. It is recommended to develop a formal model of Big Data technology to simplify the modeling component of information systems based on their features.

OBJECTIVES

The main objective of the paper is to develop a generalized formal model of the Big Data technology. It is necessary to formalize and describe the application features of the constituent elements of the model components.

GENERALIZED FORMAL MODEL OF THE BIG DATA TECHNOLOGIES

Generalizing the listed definitions of the "Big data" term as an information technology, it is possible to develop a formal model in the form of a quartet, which looks like:

$$BD = \langle Vol_{BD}, Ip, A_{BD}, T_{BD} \rangle, \quad (1)$$

where: Vol_{BD} is a set of volume types, Ip is a set of types of data sources (information products), A_{BD} is a set of techniques of Big Data analysis, T_{BD} is a set of Big Data processing technologies.

Hinchcliff divides the approaches to the Big Data into three groups depending on the volume [3], which looks like:

$$Vol_{BD} = \{Vol_{FD}, Vol_{BA}, Vol_{DI}\}, \quad (2)$$

where: Vol_{FD} is Fast Data – their volume is measured in terabytes, Vol_{BA} is Big Analytics – they are petabyte data, Vol_{DI} is Deep Insight – it is measured in exabytes, zettabytes.

Groups differ among themselves not only in the operated volumes of data, but also in the quality of their processing solutions. Fast Data processing does not provide new knowledge, its results are in line with the prior knowledge and enable to assess the process executions, to see better and in more detail what is happening, to confirm or reject some hypotheses. The velocity used for this technology must grow simultaneously with the growth of data volume.

Tasks solved by means of Big Analytics are used to convert the data recorded in the information into new knowledge. The system is based on the principle of the "supervised learning".

Processing information from different expressive power types of information sources, namely structured, semistructured, and unstructured is necessary for the Big Data technology. A set of information products is divided into three blocks, which looks like:

$$Ip = \langle St, SemS, UnS \rangle, \quad (3)$$

where: $St = \langle DB, DW \rangle$ is structured data (databases, warehouses), $SemS = \langle Wb, Tb \rangle$ is semi-structured data (XML, electronic worksheets), $UnS = \langle Nd \rangle$ is unstructured data (text).

There are operations and predicates on this vector and its separate elements that provide the transformation of various vector elements into each other, combining elements of the same type, search for items by the keyword. Computer programs are becoming closer to the real world in all its diversity, hence the growth in the volume of input data and hence the need for their analytics, moreover, in the mode maximally close to the real time. The convergence of these two trends has led to the emergence of an approach of Big Data Analytics.

Today, there is $A_{BD} = \{A_i\}$ set of different methods for the data set analysis, which are based on the tools borrowed from statistics and informatics (e.g. machine learning). The list is not exhaustive, but it reflects the most demanded approaches in various industries. Of course, the larger volume and diversified array are subject to analysis, the more accurate and relevant data are obtained at the output.

- Methods and techniques of the analysis applied to the Big Data are identified in the McKinsey report [9]:
- methods of Data Mining class: learning of association rules, classification (categorization methods of the new data on the basis of the principles previously applied to the existing data), cluster analysis, regression analysis,
- crowdsourcing is a categorization and data enrichment of the indefinite general public attracted on the basis of a public offer without entering into an employment relationship,
- mixing and integration of data is a set of techniques that allow us to integrate heterogeneous data from various sources for deeper analysis, for example, digital signal processing and natural language processing (including tonal analysis),
- machine learning, including supervised and unsupervised learning, as well as Ensemble learning that is the use of models based on the statistical analysis or machine learning to obtain a comprehensive prediction on the basis of the constituent models,
- artificial neural networks, network analysis, optimization, including genetic algorithms,
- pattern recognition,
- predictive analytics,
- simulation modeling,
- spatial analysis is a class of methods using topological, geometrical and geographical information in the data,
- statistical analysis, for example, A/B testing and time series analysis,
- visualization of analytical data is the presentation of information in the form of drawings, diagrams with the use of interactive features and animations of the results and for the use as the initial data for the subsequent analysis. Huge volumes combined with high velocity that distinguish Big Data Analytics from other programs require relevant computers and today virtually all major manufacturers offer specialized software and hardware systems.

New tools for analysis are necessary because there are not just more data than before but more of their external and internal sources, they are now more complex and diverse (structured, unstructured, and quasistructured), different indexing schemes are used (relational, multidimensional, NoSQL). It is impossible to cope with the data by the old man's, Big Data Analytics applies to large and complex arrays, so it is used the term of Discovery Analytics (which opens up Analytics) and Exploratory Analytics (which explains the analytics).

A collection of raw data uses the appropriate hardware and software technologies which depend on the control object nature (RFID, information from social

networks, text documents, etc.) [1]. These data are transmitted to the input of the analytical machine. The controller is based on the hardware and software platform which has its own analytical software, it does not provide the generation of the controlling actions sufficient for the automatic control. DBMS analytics are primarily prognostic or predictive (Predictive Analysis, PA). Data accumulated in the data warehouses are output of the PA systems in most existing implementations. For the analysis the data are primarily moved to the Independent Data Mart (IDM) where: the data representation does not depend on the used applications. Then the same data are transferred to the specialized Analytical Data Mart (ADM) and they are processed with the specialists using various development tools or Data Mining. Such multistage model is acceptable for relatively small volumes of data, but when they increase with growing demand for the efficiency there are a number of shortcomings in these models. In addition to the need to move data, the presence of many independent ADM leads to the physical and logical infrastructure complication, a number of instruments used in the simulation increase, the results obtained by different analysts are inconsistent, computing power and channels are not optimally used. In addition, the separate existence of warehouses and ADM makes analytics almost impossible in close to real time.

The solution may be the approach called In-Database Analytics or No-Copy Analytics, which involves the use of data that are directly in the database. Such DBMS sometimes refer to as analytical and parallel. The approach is particularly attractive with the advent of MapReduce and Hadoop technology. In the new programme of the In-Database Analytics class generation all kinds of the data development and other types of intensive work are performed directly on the data in the warehouse. Obviously, this significantly speeds up the process and allows you to perform real-time applications such as pattern recognition, clustering, regression analysis, various kinds of forecasting. The acceleration is achieved not only by getting rid of the motion from the warehouse in a data mart, but mainly due to the use of different parallelization methods, including cluster systems with unlimited scalability. The solution such as In-Database Analytics opens the opportunity to use the cloud technologies in addition to analytics. The next step could be the technology of SAP HANA (High Performance Analytic Appliance) the essence of which is the data allocation in RAM.

On the phases of the Big Data processing the following technologies are used, which looks like:

$$T_{BD} = \left\langle T_{NoSQL}, T_{SQL}, T_{Hadoop}, T_V \right\rangle, \quad (4)$$

where: T_{NoSQL} is the technology of NoSQL databases, T_{Hadoop} is the technology that ensures the massively-parallel processing, T_{SQL} is the technology of the structured data processing (SQL database), T_V is the technology of the Big Data visualization.

SN-architecture (Shared Nothing Architecture) is often stated as the basic principle of the Big Data processing that provides massively-parallel, scalable processing without degradation of hundreds or thousands of processing nodes [9, p. 31-33]. Thus, except for the technologies such as NoSQL, MapReduce, Hadoop, R considered by most analysts, McKinsey also considers Business Intelligence technologies and SQL supported relational database management system in terms of Big Data applicability.

NoSQL (Not only SQL) in computer science is a number of approaches aimed at implementing database warehouses which differ from the models used in the traditional relational DBMS with access to the data by SQL means. It applies to the databases in which an attempt is made to solve the problems of scalability and availability at the expense of data atomicity and consistency.

MapReduce is an engine of parallel processing. MapReduce is a model of distributed computing introduced by Google, which is used for parallel computing on very large data sets in computer clusters. MapReduce is a computing framework for the distributed task sets using a large number of computers that make up the cluster.

Hadoop is a project of the Apache Software Foundation, the freely available set of utilities, libraries and frameworks for the development and execution of the distributed programs running on the clusters of hundreds or thousand nodes. It is developed in Java within the computing MapReduce paradigm according to which the application is divided into a large number of identical elementary tasks that are feasible on the cluster nodes and naturally given in the final result. Hadoop is a capability set with open source code. Hadoop handles the large data caches breaking them into smaller, more accessible to applications and distribution across multiple servers for the analysis. Hadoop processes requests and generates the requested results in significantly less time than the old school of software analytics, it often takes minutes instead of hours or days.

As of 2014, the project consists of four modules: Hadoop Common (software for integration, a set of infrastructure software libraries and utilities used for other modules and related projects), HDFS (distributed file system), YARN (a system for task scheduling and cluster management) and Hadoop MapReduce (a programming and execution platform of the distributed MapReduce computing).

One of the technologies that should be used for Big Data is the data space. The data space is a block vector containing a variety of information products of the subject domain [10, 11].

A visual representation of the Big Data analysis results is crucial to their interpretation. There is no secret that human perception is limited, and scientists continue to conduct research in the field of improvement of the modern methods of data presentation in the form of images, diagrams or animations. We describe a few of the latest innovative visualization techniques.

The tag cloud. Each element in the tag cloud is assigned a specific weight factor which correlates with the

font size. In the case of text analysis the weight factor value depends on the use (citation) frequency of a particular word or phrase. It allows the reader to quickly get an idea about the key points of the arbitrarily large text or set of texts.

Clustergram. It is the visualization method used for cluster analysis. It shows how individual elements in the data set correspond to the clusters as their quantity change. The choice of the optimal cluster number is an important component of the cluster analysis.

Historical flow. It helps to monitor the document evolution. A large number of authors simultaneously create this document. In particular, this is a typical situation for the wiki services. The horizontal axis indicates time, the vertical one indicates the contribution of each of the co-authors, i.e. the volume of the entered text. Each unique author is assigned a specific color on the chart.

Spatial information flow. This chart allows you to track the spatial information distribution.

Unprecedented variety of data resulting from the huge number of possible transactions and interactions provide an excellent foundation for business on forecasts amendments, assessment of the development prospects of products and entire approaches, better cost control, performance assessment, and the like. On the other hand, the Big Data pose the challenging tasks for any IT department.

IT manager who intends to benefit from large structured and unstructured data must comply with the following technical considerations [5, 12, 13]:

- divide and conquer. Data transfer and integration are necessary, but both approaches increase capital and operating costs for the information extraction tools, its transformation and loading (ETL), so, do not neglect standard relational environments and analytical data warehouses,
- compression and deduplication. You should always remember what part of the compressed data may require recovery, and starting out from each specific situation you make a decision about using the same compression,
- not all data are equal. Depending on the specific situation the range of queries for the business analytics varies within wide limits. Often to obtain the necessary information is sufficient to answer the SQL query, but there are also deep analytical queries that require the business intelligence tools and have the all features of the dashboard and visualization. To prevent a sharp increase in operating expenses you need to be careful about the compilation of a balanced list of the necessary patented technologies in combination with the open-source Apache Hadoop,
- scalability and manageability.

Organizations have to solve the problem of heterogeneity of databases and analytical environments, and therefore the ability to scale horizontally and vertically is of fundamental importance. The easiness of the horizontal scaling became one of the main reasons for the rapid Hadoop distribution.

Craig Bati, the executive marketing director and director in Fujitsu Australia technology, indicates that the business analysis is a descriptive analysis of the results achieved by the business in a certain period of time, while the velocity of Big Data processing allows you to analyze the root to offer the business some recommendations for the future. Big Data technologies also allow analyzing more data types in comparison with business analytics tools that give you the opportunity to focus not only on the structured data warehouses.

Big Data are designed to handle the greater amounts of information than business analytics and it certainly fits the traditional definition of big data. Big Data are designed for processing of more quickly receiving and changing information; it means a deep exploration and interactivity. In some cases results are generated faster than a web page loading. Big Data are designed to handle the unstructured data which use we only begin to learn after they could establish their collection and storage, and we need the algorithms and the possibility of dialogue to facilitate the trends search inside these arrays. Big Data handling is not similar to the normal process of business analytics where: the simple addition of known values gives the result. When working with the Big Data we obtain the result in the process of their cleaning by sequential simulation: first, the hypothesis are offered, then statistical, visual or semantic model is developed; with reference to this model the offered hypothesis is tested and then the next one is offered. This process requires from the researcher either the interpretation of visual values or making interactive queries on the basis of knowledge, or the development of adaptive "machine learning" algorithms that are able to get the desired result. Moreover, the lifetime of this algorithm can be quite short.

By ignoring the role of information and data as a subject of research the same mine was planted that exploded now, at a time when the needs changed, when the computational load on the computers was much less than other types of works to be performed on the data. The goal is to obtain a new information and new knowledge from existing data sets. That's why it is meaningless to talk about solving the problem of Big Data within the restoration of the "information - data - knowledge" chain links. The information is processed to obtain the data that should be just enough so that a man could transform them into knowledge.

CONCLUSIONS

So, Big Data are not a speculation, but a symbol of the coming technological revolution. The need for the analytical effort with Big Data will significantly change the face of the IT industry and stimulate the emergence of the new software and hardware platforms. To achieve the desired goal, the development of a formal model of the Big Data information technology is made and its structural elements are described. Today for the analysis of large volumes of data the most advanced methods are used: artificial neural network (models are built on the principle of the biological neural network organization and functioning); predictive analytics, statistics and

Natural Language Processing (areas of artificial intelligence and mathematical linguistics that study the problems of computer analysis and natural language synthesis). Also, we use the methods that engage human experts, crowdsourcing, A/B testing, sentiment analysis, and the like. To visualize the results the known methods are applied, for example, tag clouds and completely new Clustergram, History Flow and Spatial Information Flow. Big Data is supported by the distributed file system Google File System technology, Cassandra, HBase, Lustre and ZFS, by the MapReduce and Hadoop programming constructs and many other solutions. According to the experts, such as McKinsey Institute, the manufacturing, healthcare, trade, administration and control of individual movements undergo the transformations under the influence of the Big Data. Further research will be devoted to the study of methods, models and tools to effectively support the overall activity of the model development.

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Development the methods of optimum placement undirected planar objects with piecewise non-linear boundaries in the multiply area

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Abstract. In this paper the statement of the problem is formulated and the mathematical model of optimization the placement of the undirected planar geometrical objects with piecewise non-linear boundaries in the multiply area is developed. It is shown the geometrical interpretation and derived the estimate of the number of restrictions in the model. On the basis of a mathematical model for finding the global extremum of the objective function was proposed modified method of branches and boundaries. It is also shown the solutions tree that takes into account the problems of optimal placement of undirected planar geometrical object with piecewise non-linear boundaries in the multiply area, and received the complexity of this method. For locally optimal solutions of the problem modified simulated annealing method has been developed. Thus the analytical expressions for the function of energy system were received, the function, that describes the decrease of temperature over time, function that forms a new state of system. The method of formation the new state of the system was investigated in more detail, which is based on a random permutation of numbers the pair of the objects, it is also based on a consistent placement of objects according to reshuffle their numbers and determining the probability of transition to a new state. It is shown the example of determining permissible points of placement the local coordinate system of the specific geometrical object. The conclusion is that to solve practical optimization problems of placement of the undirected planar geometrical objects with piecewise non-linear boundaries in the multiply area should be used the modified simulated annealing method.

Key words: optimal placement, the object with piecewise linear boundary, multiply area, mathematical model, branch and bound method, the method of simulated annealing.

INTRODUCTION

At present, for modeling of real technological and economic processes in the creation of technical systems that are associated with the processing of complex geometric information, there is a necessity of using effective methods of geometric and computer modeling. Important place among the tasks associated with processing of geometrical data, take the problems of geometric design optimization (optimization of placement, coverage, splitting the objects of the best lines). These problems arise in such sectors as light and heavy industry (designing of the cutting card), energetics, engineering, construction and so on.

Among the class of problems of optimization of the geometric design the problem of optimal placement of geometric objects is one of the most studied tasks. There are numerous methods for optimizing the placement of flat objects in simply, multiply and unconnected sectors, the methods of optimization the placement of three-dimensional objects and more. The peculiarity of the problems of optimal placement is that when the decision is necessary to satisfy the basic requirements for a mutual non-intersection of geometric objects that are placed in a given area, as well as supply of geometric objects of placement in the area. For analytical description of these requirements the constructive device of Φ-functions was developed in the professor Y. Stoyan's scientific school. Despite the fact that the wording of the main requirements is the same for all the problems of optimal placement of geometric objects, their analytical and geometrical interpretation appearance will vary considerably depending on the shape of geometric objects that are placed and area of placement.

One of the promising sector of researches is the geometrical modeling optimization of placement of the undirected planar geometry with piecewise non-linear boundaries in a given area. The peculiarity of these problems is as follows: first, the presence of fragments of nonlinear boundary leads to the necessity of considering the nonlinear constraints for parameters of placement the related objects; secondly, geometric objects are undirected, which increases the dimension of these problems by increasing of parameters of placement the objects. Thus, consideration of these features makes the development of new models and methods of geometrical modeling of optimization the placement of the undirected planar objects with piecewise non-linear boundaries in the given areas.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The development of mathematical models and methods of solving the problems of optimization of

geometric design is dedicated to a sufficiently large number of works. Thus, the analytical presentation of boundaries of geometrical objects is devoted such works as [1-3]. In publications [4, 5] the mathematical models and methods of optimization design are studied. The tasks of optimal routes are dedicated in [6, 7]. The problems of optimal coverage and breaking were studied, for example, in the publications [8-11].

The modeling of physical processes in different sectors are dedicated the works [12, 13]. In the work [14], the determination of the optimal structure of the territorial system of technological safety is described.

As for optimization of problems the placement oriented flat geometry, they were considered, for example, in the works [15-20]. Modeling of optimal placement undirected objects are, for example, in [21, 22].

In the work [23] the model and method of placement optimization oriented flat geometry of piecewise with piecewise non-linear borders is devoted. In this publication [24] the issue of geometric information in optimization problems placement of undirected planar geometry with piecewise non-linear boundaries was studied. The work [25] is devoted to development of mathematical models of optimization the placement of undirected planar objects with piecewise non-linear boundaries and researching its features.

OBJECTIVES

In this work it is necessary to develop the methods of minimizing the objective function in the problem of optimal placement of undirected planar geometry with piecewise non-linear boundaries, based on the method of branches and boundaries and the method of simulated annealing. It is also necessary to conduct a comparative analysis of these methods to justify their further use for solving practical problems.

THE MAIN RESULTS OF THE RESEARCH

Let us consider the setting of optimal allocation undirected planar geometrical objects with piecewise non-linear boundaries in the multiply sector.

Let the two-dimensional space objects accommodation

$$S_i\left(x_i, y_i, \theta_i\right),\ i = 1, 2, \ldots, N,$$

with piecewise non-linear boundaries are specified. These objects are undirected and set its sequence of vertices

$$\left\{v_{i1}, v_{i2}, \ldots, v_{im_i}\right\},\ v_{id} = \left(x_{id}\left(\theta_i\right), y_{id}\left(\theta_i\right)\right),$$
$$d = 1, 2, \ldots, m_i,$$

in the local coordinate system and the numbering of tops is made counterclockwise. Each pair of vertices $\left(v_{id}, v_{id+1}\right)$ is connected with curve fragment of 2-nd order:

$$\begin{aligned} &a_{i,dd+1,1}\left(\theta_i\right)x_i^2 + a_{i,dd+1,2}\left(\theta_i\right)x_i y_i + \\ &+a_{i,dd+1,3}\left(\theta_i\right)y_i^2 + a_{i,dd+1,4}\left(\theta_i\right)x_i + \\ &+a_{i,dd+1,5}\left(\theta_i\right)y_i + a_{i,dd+1,6}\left(\theta_i\right) = 0, \end{aligned} \quad (1)$$

where: $a_{i,dd+1,c}\left(\theta_i\right)$, $c = 1, \ldots, 6$ – quadratic form parameters that are describing the fragment boundaries between vertices v_{id} and v_{id+1} of object $S_i\left(x_i, y_i, \theta_i\right)$.

The placement area $S_0\left(l, b\right)$ is a rectangle that is specified in the global coordinate system, and its length is variable (Fig. 1). This rectangle sector includes the sectors of prohibitions $S_{0,r}\left(x_{0,r}, y_{0,r}\right)$, $r = 1, 2, \ldots, N_R$ (e.g. defects of material or placing objects that are at fixed locations) that can be given to similar accommodations to the objects of replacement, but the numbers of vertices is performed clockwise.

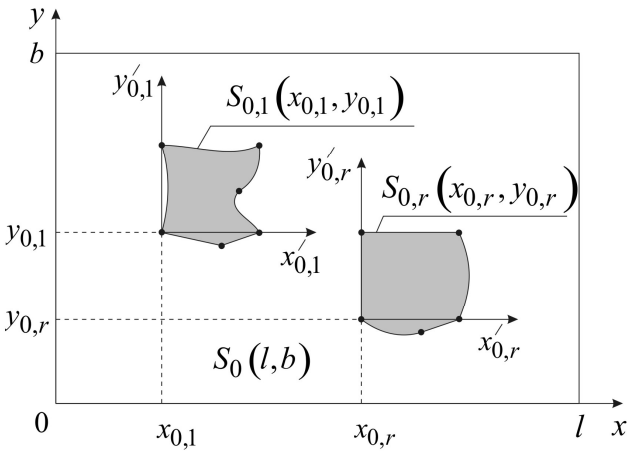

Fig. 1. Multiply placement area

It's necessary to place objects $S_i\left(x_i, y_i, \theta_i\right)$, $i = 1, \ldots, N$, in the multiply area $S_0\left(l, b\right)$ so that length l was minimal and thus the restrictions must be enforced on:

– mutual non-intersection of the objects $S_i\left(x_i, y_i, \theta_i\right)$ and $S_j\left(x_j, y_j, \theta_j\right)$, $i = 1, \ldots, N$, $j = i+1, \ldots, N$,

– non-intersection of the objects $S_i\left(x_i, y_i, \theta_i\right)$ and areas of prohibition $S_{0,r}\left(x_{0,r}, y_{0,r}\right)$, $r = 1, 2, \ldots, N_R$,

– objects belonging $S_i\left(x_i, y_i, \theta_i\right)$ in the area $S_0\left(l, b\right)$.

Formulate a mathematical model of optimal placement of undirected planar objects with piecewise non-linear boundaries in the multiply area:

$$\min_W l\left(x_1, y_1, \theta_1, \ldots, x_N, y_N, \theta_N\right) \quad (2)$$

where W:

$$\Phi_{ij}\left(x_i, y_i, \theta_i, x_j, y_j, \theta_j\right) \geq 0,\ i = 1, \ldots, N-1,$$
$$j = i+1, \ldots, N; \quad (3)$$

$$\Phi_{kr}\left(x_k, y_k, \theta_k, x_{0,r}, y_{0,r}\right) \geq 0,\ k = 1, \ldots, N,$$
$$r = 1, \ldots, N_R; \quad (4)$$

$$\Phi_{icS_0}\left(x_i, y_i, \theta_i, 0, 0\right) \geq 0,\ i = 1, \ldots, N. \quad (5)$$

In the model (2)÷(5) the formulae (2) is the objective function of the problem; restriction (3) – is a condition of

the mutual non-intersection of the objects; the restriction (4) – is a condition of the non-intersection the objects of placement and prohibition areas; the restriction (5) – is a condition of belonging the objects to the placement area, where cS_0 – additions of S_0 to the two-dimensional space.

It should be noted that the conditions of (3) and (4) are, in general, non-linear, and the conditions (5) – linear. All restrictions analytically are submitted by Φ-functions [4], and their total number is $C_N^2 + N(N_R + 1)$. To formalize the restrictions (3)÷(5) the method given in [26] is used.

Geometric interpretation of condition (3) for fixed θ_i and θ_j is shown in Fig. 2

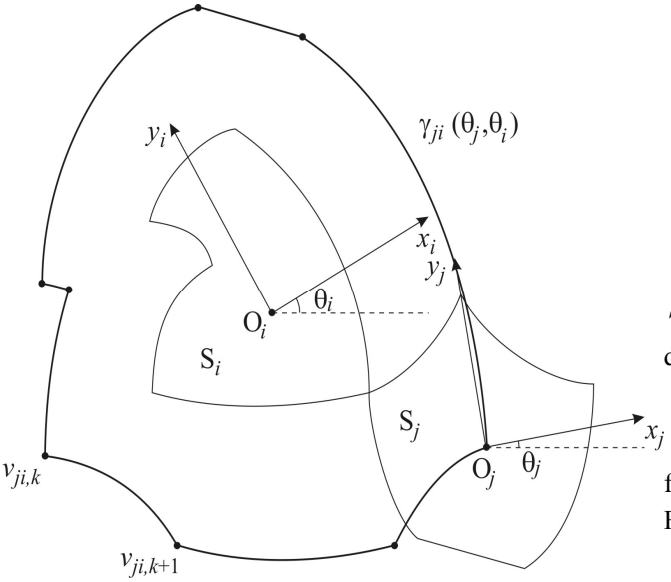

Fig. 2. Geometric interpretation of condition (3)

In general, the condition of the contact the objects $S_j(x_j, y_j, \theta_j)$ and $S_i(x_i, y_i, \theta_i)$, has the form:

$$\begin{aligned} &a_{ji,kk+1,1}(\theta_j,\theta_i)x^2 + a_{ji,kk+1,2}(\theta_j,\theta_i)xy + \\ &+a_{ji,kk+1,3}(\theta_j,\theta_i)y^2 + a_{ji,kk+1,4}(\theta_j,\theta_i)x + \\ &+a_{ji,kk+1,5}(\theta_j,\theta_i)y + a_{ji,kk+1,6}(\theta_j,\theta_i) = 0; \end{aligned} \quad (6)$$

where: $a_{ji,kk+1,t}(\theta_j,\theta_i)$, $t = 1,\ldots,6$ – are quadratic form parameters describing the piece between k and $(k+1)$ vertices of the contact contour $\gamma_{ji}(\theta_j,\theta_i)$ of the objects $S_j(x_j, y_j, \theta_j)$ and $S_i(x_i, y_i, \theta_i)$, $j = 1,\ldots,N$, $i = 1,\ldots,N$, $j \neq i$.

It should be noted that the geometrical interpretation of the condition (4) is similar to (3) with one exception: the numbering of the vertices contact contour is made counterclockwise.

Fig. 3 shows a geometric interpretation of the condition (5) for fixed θ_i (placement area for illustration of the condition is simply connected).

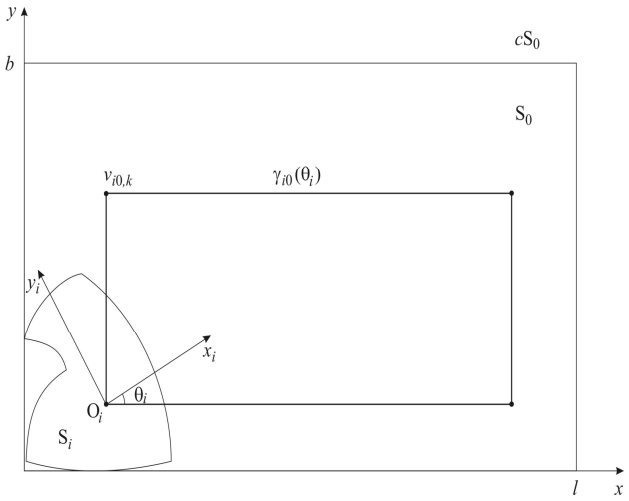

Fig. 3. Geometric interpretation conditions (5)

Thus, the condition of the contact the object $S_i(x_i, y_i, \theta_i)$ and addition of the area S_0 to the two-dimensional space is written as:

$$a_{i0,k}(\theta_i)x + b_{i0,k}(\theta_i)y + c_{i0,k}(\theta_i) = 0; \quad k = 1,\ldots,4 \,. \quad (7)$$

To search of global extremum of the objective function (2) construct a tree of solutions that is shown in Fig. 4.

Each level of the tree corresponds the independent variable of this problem, whose number is $3N+1$. At the appropriate level solutions trees are written in pieces of contact contours of geometric objects. For example, for the level of tree, that is corresponding the independent variable x_1, are written in equation, that consist of this variable.

The complete change of tree branches that is shown in Fig. 4, will determine the global extremum of the objective function (2). For permissible values of the objective function of the problem is necessary to solve a system of $3N+1$ equations (both linear and nonlinear), and a fragment of contour $\gamma_{ji,k}(\theta_j,\theta_i)$ is described by the equation of type (6) and contour $\gamma_{i0,k}(\theta_i)$ is described by the equation of type (7). Unacceptable branches of the solutions tree are cut off by means of the relevant rules.

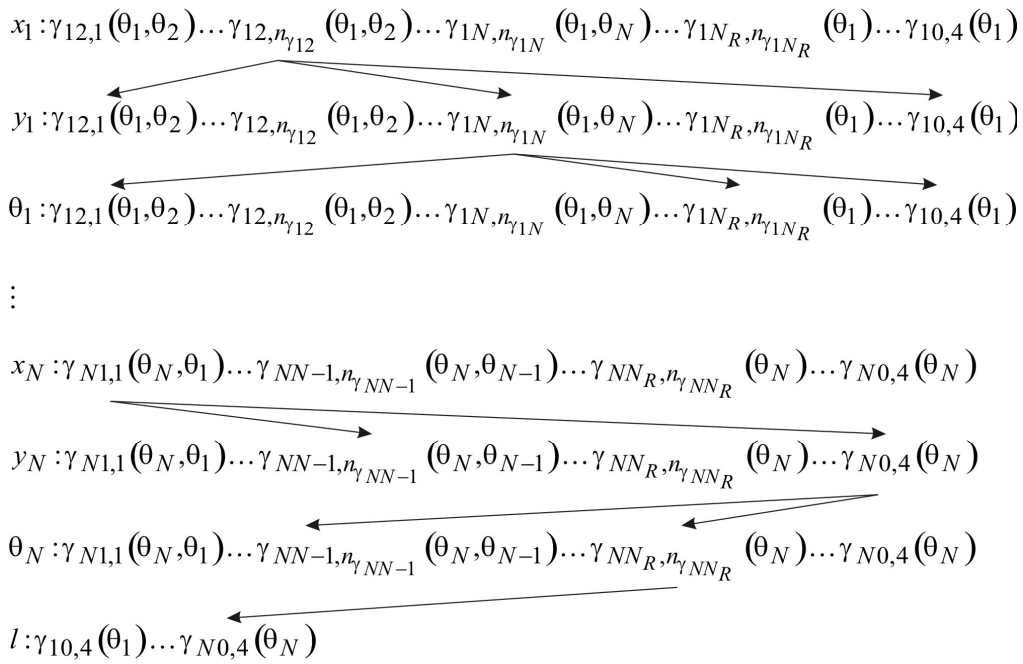

Fig. 4. Solution tree

The upper bound of the complexity (the number of equations system to be solved to determine the parameters of appropriate placement of geometric objects) of the developed modified method of branches and borders is as follows:

$$O_1 = N \cdot \prod_{i=1}^{N} \left(\sum_{\substack{j=1,\\ j\neq i}}^{N} n_{\gamma_{ij}} + \sum_{r=1}^{N_R} n_{\gamma_{ir}} + 4 \right)^3; \qquad (8)$$

where: N – is the number of placement objects; $n_{\gamma_{ij}}$ – is the number of contact contour pieces for objects $S_i(x_i, y_i, \theta_i)$ and $S_j(x_j, y_j, \theta_j)$; $n_{\gamma_{ir}}$ – is the number of contact contour pieces for objects $S_i(x_i, y_i, \theta_i)$ and $S_{0,r}(x_{0,r}, y_{0,r})$

The disadvantage of the modified branch and bound method is that the conclusion of the global extremum of the objective function (2) can be done only after a search of all the branches of the solutions tree, which is an excessive (8) number of. This leads to the fact that to apply this method for solving practical tasks is almost impossible. To overcome these drawbacks propose we suggest a method, which is based on simulated annealing method. This method is an algorithmic analog of physical process of controlled cooling and uses the ordered random search for new states of the system with a lower temperature [27].

During slow controlled cooling of the molten material, called annealing, the crystallization of the melt is accompanied by a reduction of its global power E, but the situation in which it can grow for a while (especially when heating the melt to prevent too rapid cooling) are implied. Thanks to the admissibility of a short-term increase in energy levels, there is a possible way out of the trap of local minimum energy that are arising in the implementation process. Only lowering the temperature T to absolute zero makes it impossible for any independent power increase of the melt.

Therefore, to develop a modified simulated annealing method must be defined with:

– the function of the energy E system,

– the function that describes the decrease of the temperature T over time,

– the function (rule) that creates a new state of the system.

In this case, the objective function of the task (2) will be the energy of the system, that is:

$$E = l(X), \qquad (9)$$

where: $X = \{x_1, y_1, \theta_1, \ldots, x_N, y_N, \theta_N\}$ – is the current state of the system.

As for the choice of function that describes the decrease of temperature T over time, historically the first simulated annealing scheme was Boltzmann's scheme in which the temperature change is:

$$T = \frac{T_0}{\ln(1+t)}, \qquad (10)$$

where: T_0 – is initial temperature; t – is time, $t > 0$.

For this scheme is proved that for sufficiently large values T_0 and the number of steps the finding a global minimum of the functions is guaranteed (9) [28] The disadvantage of Boltzmann's annealing is slow decreasing of the temperature T. The solving of this problem is possible by replacing the law of change of temperature (10), such as the following:

$$T_m = q \cdot T_{m-1}, \; m = 1, 2, \ldots \qquad (11)$$

where: the temperature coefficient q is chosen as usual within 0,7÷0,99. This scheme of simulated annealing allows to save the computing resources, but, while the

finding a global minimum of the functions is not guaranteed (9).

As for the formation of a new state of system, then, the first, the random permutation of numbers of the placement objects is performed $\{i_1, i_2, \ldots, i_N\} \in \{1, \ldots, N\}$ and is determined by the current state of the system $X = \{x_1, y_1, \theta_1, \ldots, x_N, y_N, \theta_N\}$ through the consistent placement of objects according to permutation their numbers and taking into account the constraints (3)÷(5). Fig. 5 shows an example of placing an object $S_{i_2}\left(x_{i_2}, y_{i_2}, \theta_{i_2}\right)$ with fixed value θ_{i_2}.

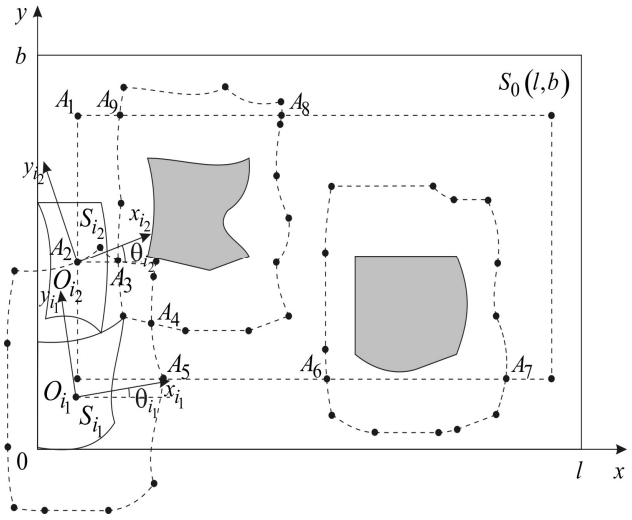

Fig. 5. Placement of object $S_{i_2}\left(x_{i_2}, y_{i_2}, \theta_{i_2}\right)$

Thus, in this case admissible points for placing the beginning of the local coordinate system of the object $S_{i_2}\left(x_{i_2}, y_{i_2}, \theta_{i_2}\right)$ is points $A_1, \ldots, A_9$, which are determined by means of second-order equations (both linear and nonlinear). The data of the system of equations are recorded by the corresponding transformation of inequalities (3)÷(5) to equalities. Obviously, in terms of impact on the value of the objective function (9) for the points A_1 and A_2 are equivalent to placement of the beginning of the local coordinate system of the object $S_{i_2}\left(x_{i_2}, y_{i_2}, \theta_{i_2}\right)$. However, based on the technological requirements we choose the point A_2. Likewise the placement of other objects is implemented $S_{i_j}\left(x_{i_j}, y_{i_j}, \theta_{i_j}\right)$, $j = 3, \ldots, N$, with the calculated objective function value $l(X)$ for the current state of the system.

For the formation of a new state of the system

$$X^* = \left\{x_1^*, y_1^*, \theta_1^*, \ldots, x_N^*, y_N^*, \theta_N^*\right\}$$

is possible, for example, to make the permutation of numbers of any two objects and carry out their placement according the new reshuffle considering the restrictions (3)÷(5). Further growth of energy system is computed:

$$\Delta E = l\left(X^*\right) - l(X).$$

If $\Delta E < 0$, then the system moves from state X to the state X^*. Otherwise, the transition to the state X^* is made with a probability $p\left(\frac{\Delta E}{T}\right)$, which is calculated:

$$p\left(\frac{\Delta E}{T}\right) = e^{-\frac{\Delta E}{T}}. \qquad (12)$$

Therefore, choosing the initial T_0 and final T_e temperature value T, that decreases over time, the optimization of the objective function of (9) is carried, with each successive generation of the system is subject to the limitations of (3) ÷ (5).

Obviously, to solve practical problems of optimal placement of the undirected planar geometrical objects with piecewise non-linear boundaries in the multiply area should be used the modified simulated annealing method, the complexity of which can be obtained using expressions (10) or (11) and is several orders of magnitude less than (8).

CONCLUSIONS

In this paper the problem statement is formulated and the mathematical model is created. The modified branch and bound method and modified method of simulated annealing to minimize the objective function for the problem of optimal placement undirected planar geometrical objects with piecewise non-linear boundaries in the multiply area are developed. It was shown that to solve practical problems it is advisable to use a modified simulated annealing method. Further research will be aimed at developing algorithmic and software to computer implementation of methods that are designed to optimize the placement of the planar undirected geometrical objects with piecewise non-linear boundaries of the multiply area.

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Analysis of the costs and cost-efficiency of regeneration of modern fuel injection systems in CI engines

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Abstract. This paper presents the analysis of costs and cost-efficiency of the repair of modern fuel injection systems in compression-ignition engines. The requirements for modern Diesel engines are low emission of toxic substances into the atmosphere and low fuel consumption. In order to meet the rigorous standards, the Common Rail fuel injection system has been implemented. By increasing fuel injection pressure to 200 MPa and introducing multi-stage dosing, engine designers have improved the process of air-fuel mixture combustion and engine ecological and economic parameters. The price for these changes is an accelerated wear of fuel injection equipment in modern CI engines.

Regular fuel filter replacement and periodical cleaning of the systems would minimise the risk of damage. Unfortunately, most users do not comply with vehicle servicing times, and come to car repair shops only when a failure occurs, but then it is too late and the repair costs are high.

Key words: Common Rail system, injection pump, fuel injector, high pressure system, low pressure system, Diesel engine.

INTRODUCTION

Accumulator fuel injection systems, called Common Rail (CR) systems, have been introduced in the late 1990s due to ecological and economic reasons. Due to an appropriate organisation of the combustion process in an engine, CI engines with CR system have met more and more rigorous environmental standards and have been consuming less fuel [1].

The use of modern vehicles with CI engines in which a Common Rail fuel injection system has been installed requires certain procedures to be complied with. These procedures are to protect fuel injection equipment from premature wear and tear. The most important factor affecting the service life of all fuel injection system elements is the quality of fuel. Fuel quality refers not only to the type of diesel fuel that is being poured into a fuel tank but also all operations which affect its physicochemical properties after refuelling [2, 3].

PRESENTATION OF THE COSTS ASSOCIATED WITH REGENERATION OF FUEL INJECTION SYSTEMS

The process of testing a vehicle with compression-ignition engine begins with computer diagnostics. During the tests, current parameters of the running engine and possible errors stored in the controller's memory are being read. The test of overflow values should be performed for a vehicle during the operation of engine and fuel injectors. If a failure in fuel injection system is suspected, fuel injectors should be dismounted and tested on a test bench. Furthermore, the pressures at the end of compression stroke in all cylinders should be measured. If the pressures at the end of compression stroke are normal and fuel injectors do not work properly, a decision should be made what needs to be done in order to avoid the excessive costs of vehicle repair. Table 1 presents all the costs of computer diagnostics and possible repair of the Common Rail fuel injection system [18]. If reparable fuel injectors are mounted in a vehicle, they should be disassembled into individual components and analysed under a microscope. During the testing, attention should be paid to the general condition of individual components (corrosion, degree of fouling, presence of metal filings shavings.), also, the condition of the plunger and barrel assembly components and internal seals should be checked. Sometimes it is enough to clean fuel injectors, replace seals, assemble and adjust the volume of fuel injection doses for the engine to start working properly. If there are metal filings shavings and the components of the plunger and barrel assembly are damaged, a complete repair of fuel injection system should be performed [6, 7, 17].

A complete repair of fuel injection system consists of the following steps:

- regeneration of fuel injectors,
- regeneration of fuel injection pump,
- disassembly and cleaning of CR accumulator,
- disassembly and cleaning of high pressure lines,
- disassembly, checking and cleaning of pressure sensor, high-pressure valve, and delivery valve,
- cleaning of low-pressure lines and elements,
- disassembly and cleaning of fuel tank or replacement of fuel tank, if recommended.

A complete repair of fuel injection system makes sense if the above-mentioned steps are met. If any of these steps has been omitted, there is no use to perform

the whole procedure. Table 1 presents all the costs of the above operations together with computer diagnostics.

The cost estimate should also include the costs of replacing fuel filter and other possible operations. When analysing the costs of computer diagnostics and repair of accumulator fuel injection systems, it can be concluded that if a vehicle of a total value of approximately PLN 10 thousand is tested, it is more cost-effective to scrap it or sell it for parts because the overall costs are too high.

Table. 1. An example of cost estimate for a complete repair of the Common Rail fuel injection system

Operation	Cost [PLN]
Computer diagnostics of engine system (initial diagnostics, together with fuel injection system)	200
Regeneration of fuel injectors	750 (per unit)
Regeneration of fuel injection pump	1500
Disassembly and cleaning of CR accumulator	50
Disassembly and cleaning of low pressure lines	50
Disassembly, checking and cleaning of pressure sensor, high-pressure valve and delivery valve	100
Cleaning of low pressure lines and elements	100
Disassembly and cleaning of fuel tank or replacement of fuel tank, if recommended	500
Total	5500

Figure 1 presents a diagnostic procedure which is performed during the testing of accumulator fuel injection system. A complete procedure, consisting in the total disassembly of fuel supply system elements, cleaning and regeneration of worn components, is cost-effective only in newer vehicles of a higher market value. The advantage of a complete repair is a guarantee given by an authorised car repair shop for the performed service. However, in case of older vehicles of low market value, it is not cost-effective to carry out the whole procedure due to excessive costs. If the repair cost exceeds 70% of the vehicle value, it is uneconomic to repair it. Therefore, the author has proposed a procedure that is aimed at detecting the fault and eliminate it at the minimum cost.

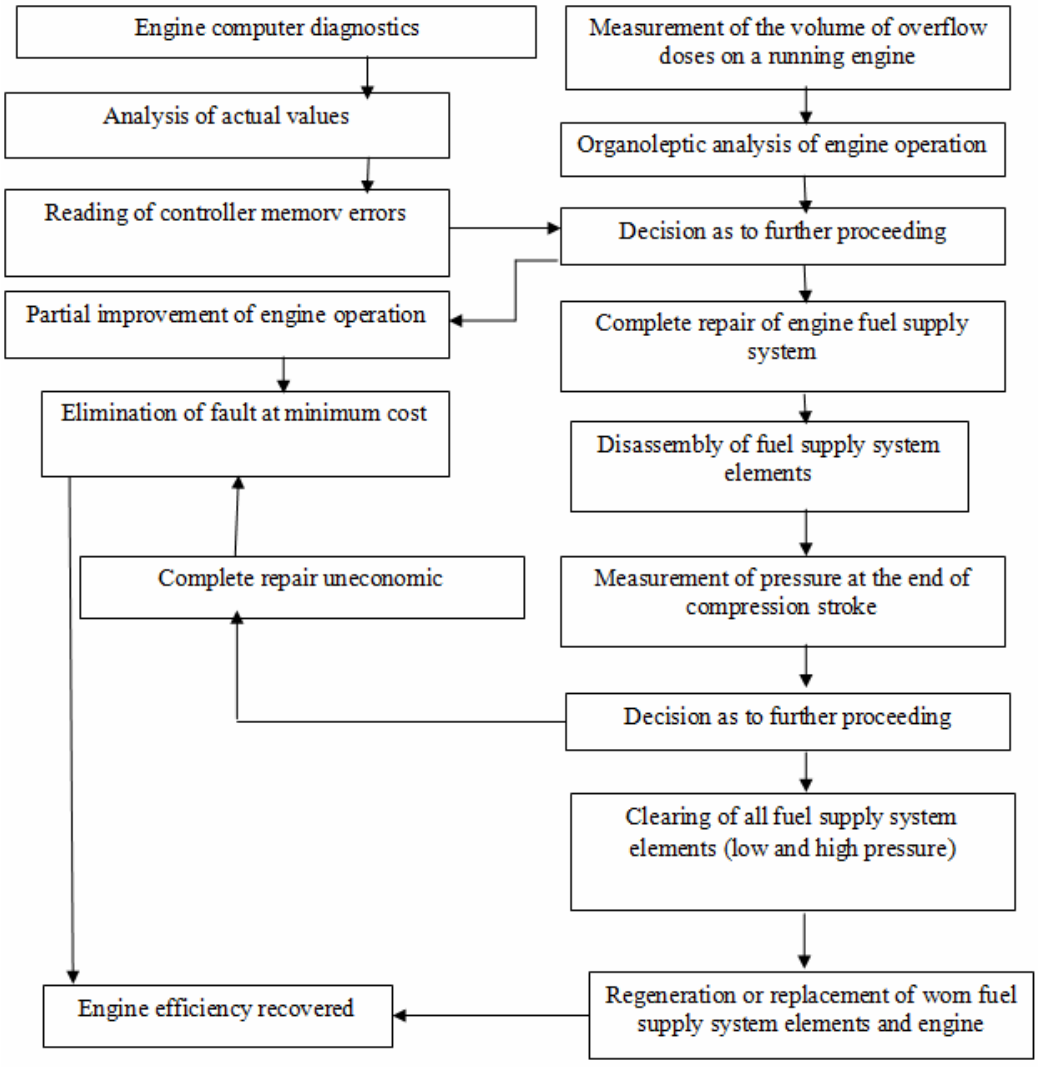

Fig. 1. Diagnostic and repair procedures for a modern Diesel engine

PRESENTATION OF HIGH-PRESSURE SYSTEM TESTING PROCEDURE

After initial diagnostics which has shown a fault in the high-pressure system, the following elements should be dismounted from the engine and tested on a test bench: fuel injectors, pressure and delivery regulators and the pressure sensor [8]. In the first place, pressure and delivery regulators and the pressure sensor are tested, next the test of fuel injectors is performed and finally the fuel injection pump test is done. If the fuel injection pump is worn and it ejects metal filings shavings into the systems, they are visible on the regulator and sensor components. When testing fuel injectors, attention should be paid to the volume of fuel injection and overflow doses, as well as to whether fuel injectors are tight [9]. Electrical parameters, such as resistance, coil inductance or crystal capacitance, should be measured with an appropriate meter, as well as the possibility of short-circuit to earth occurrence is being checked. It is also possible to check pressure regulators by connecting them to an appropriate test bench and testing whether they operate during actuation. If a fuel injection pump is tested, it is not recommended to mount it on a test bench and to carry out the test without prior disassembly and microscopic examination. A fuel injection pump can be a source of metal filings shavings; if a fouled pump is mounted on the test bench, all metal filings shavings enter into the system.

Table 2 presents an example testing protocol of a Bosch solenoid-controlled fuel injector, catalogue No. 0445110025, on a Bosch EPS 200 injector test bench.

Table. 2. Protocol of fuel injector testing on a Bosch EPS 200 injector test bench

Type of test	Test parameters			Fuel injection dose [mm^3/H]		Return fuel dose [mm^3/H]	
	Injection timing [μs]	Pressure MPa	Time of measurement [s]	Set values	Actual values	Set values	Actual values
Leak test	0	140	200	0	0	35^{+}_35	27.34
VL	800	135	90	51.8^{+}_4	62.97	47^{+}_30	148.5
EM	500	80	90	$18.4^{+}\_2.5$	24.07		
LL	675	25	90	$4.9^{+}\_1.6$	9.34		
VE	160	80	90	$1.5^{+}\_1.2$	1.87		

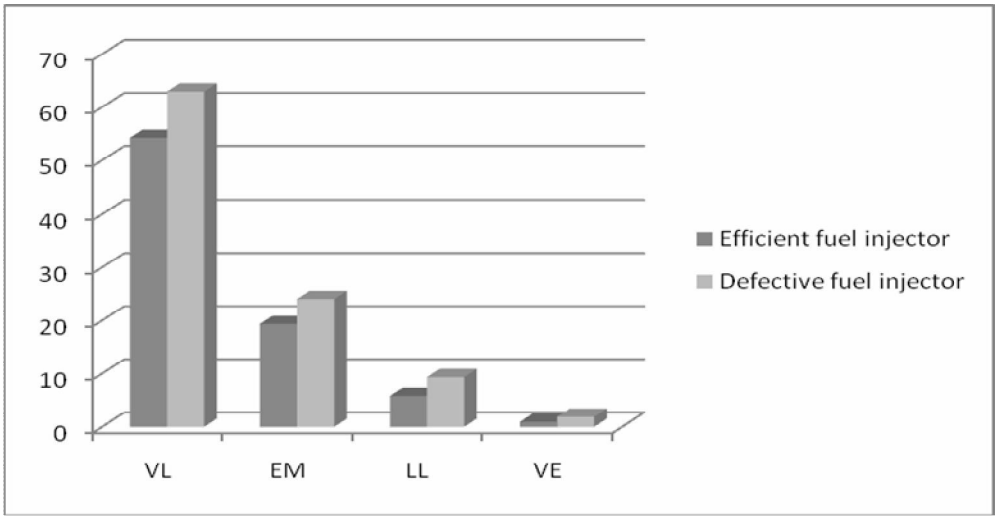

Fig. 2. Graphic depiction of the volume of fuel injection doses for an efficient fuel injector and a defective fuel injector

Each fuel injector is tested for different operating parameters. Leak test consists in the testing of a fuel injector in terms of its internal leakage at maximum working pressure. Only fuel return dose is tested. This testing shows whether the components of the plunger and barrel assembly and internal seals are not worn. In addition, they are observed for external leakage. During the test of full load quantity (VL), fuel injection and overflow doses are tested. The next step of testing is to test the emission quantity (EM). It is the dose of half load. The LL quantity is the dose of idling, while the VE quantity is the pilot injection dose [14].

The tests showed that the fuel injector had too high fuel injection doses, except pilot injection dose, as well as too high overflow volumes. The next step is to disassemble fuel injector into individual components and

to test them under a microscope. The microscopic testing is aimed at checking the technical condition of the components of the plunger and barrel assemblies, testing the condition of internal seals, as well as testing the general condition of fuel injectors for fouling, corrosion or metal filings shavings coming from a high pressure pump [4, 5]. Figure 3 presents the fuel from the high-pressure rail in which metal filings shavings are to be observed.

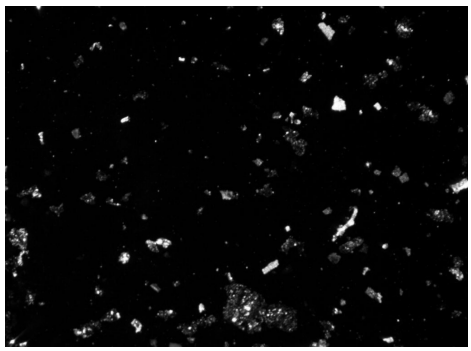

Fig. 3. Fuel from the high-pressure rail under a microscope

Metal filings shavings come from a high-pressure pump. Figure 4 presents a pressure regulator.

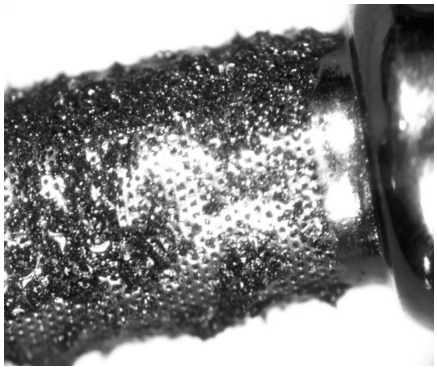

Fig. 4. Pressure regulator with visible metal filings shavings under a microscope

Metal filings shavings accumulate in the whole fuel supply system. Starting from the fuel injection pump, through the CR rail, pressure sensor and regulators, they enter into the low pressure system, pass through the fuel filter and accumulate in it [15].

The source of metal filings shavings is the roughing pump installed on the fuel injection pump and the raceway of main shaft that drives the high pressure section into the fuel injection pump. Figure 5 presents the interior of fuel force-feeding pump.

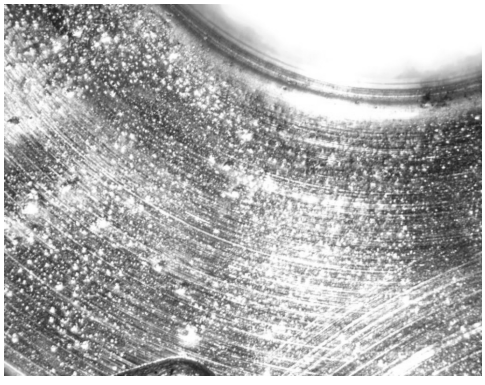

Fig. 5. Interior of fuel force-feeding pump

On the raceway of gear wheels, metal filings shavings visible in Figure 4 develop as a result of friction. Figure 6 presents a fragment of main shaft raceway in a fuel injection pump.

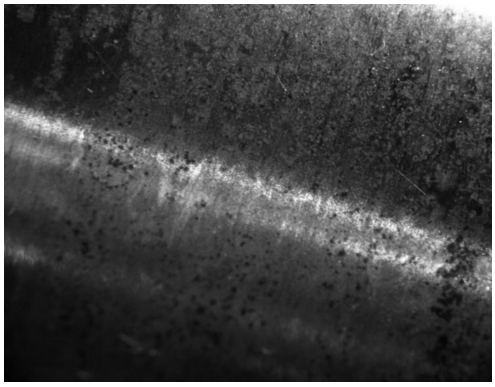

Fig. 6. Raceway of the main shaft of fuel injection pump

The plungers of high pressure section are driven into a fuel injection pump. As a result of temperature, friction and poor fuel quality, seizures as well as corrosion occur locally on the surface [20]. The result of these phenomena is different types of fuel supply system fouling and metal filings shavings. Figure 7 presents the surface of a high pressure section plunger.

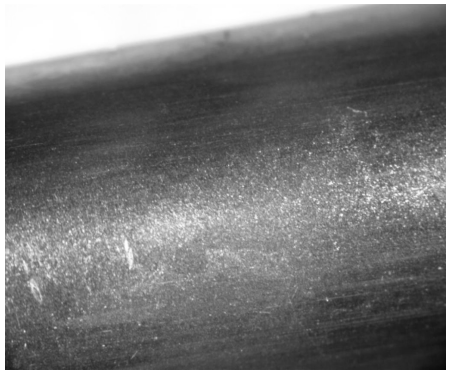

Fig. 7. Surface of a high pressure section plunger

The fouling and metal filings shavings deface the plunger surface. The effect of wear is lower fuel delivery volumes and lower efficiency of fuel injection pump [13].

Figure 8 presents the characteristics of fuel delivery for efficient and worn fuel injection pumps. Figure 9 presents the efficiency characteristics of efficient and worn fuel injection pumps.

If the efficiency of fuel injection pump is lower than 80%, it should be disassembled and tested.

The fuel fouling and metal filings shavings migrate with fuel into fuel injectors. The job of fuel injector is to spray and distribute an adequate fuel quantity in the engine's combustion chamber. If the elements responsible for proper operation have been fouled, damaged or they have undergone accelerated wear, fuel injection doses will be changed and, as a result, the engine will stop working properly.

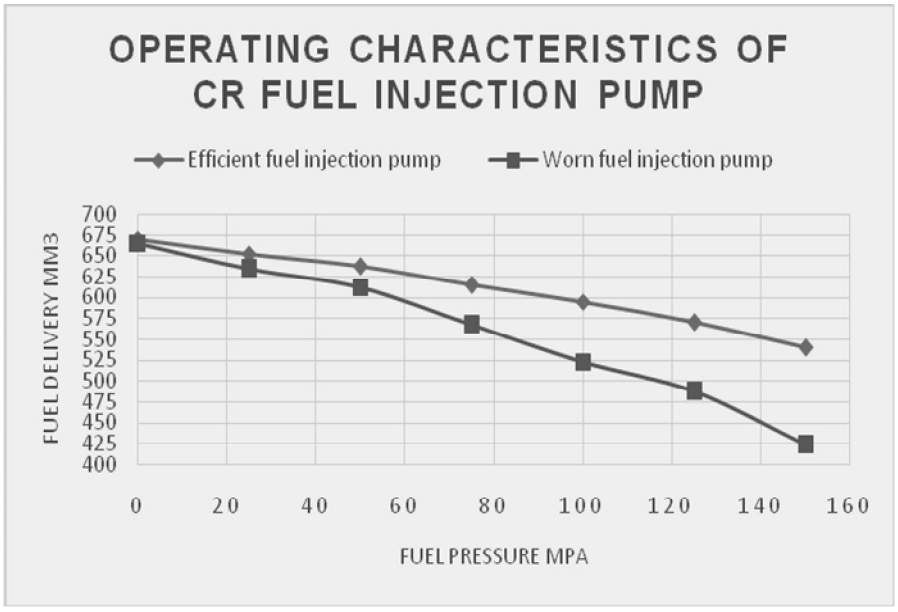

Fig. 8. The operating characteristics of fuel delivery of a fuel injection pump

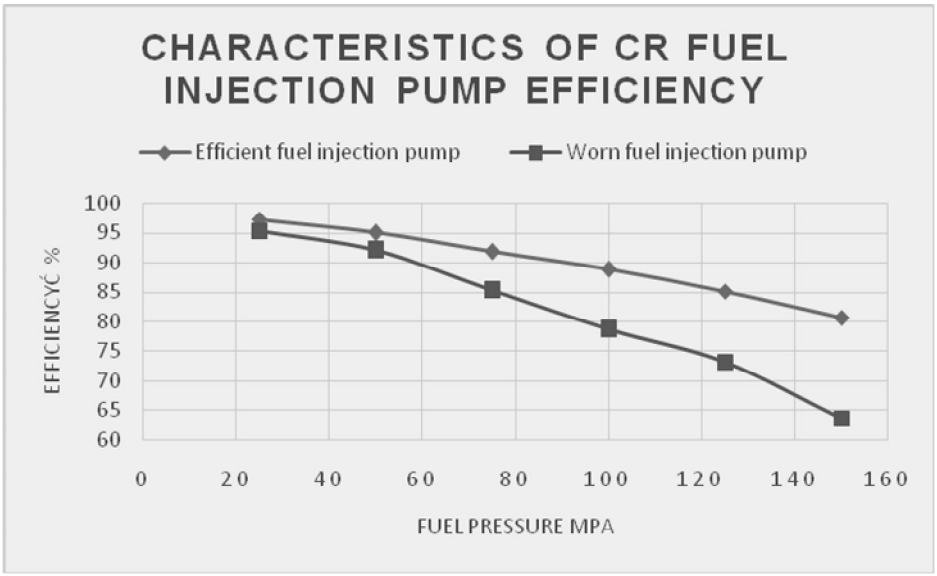

Fig. 9. The characteristics of fuel injection pump efficiency

If this occurs, the following should be carried out:

- regenerate fuel injectors,
- regenerate fuel injection pump,
- clean the CR rail, pressure regulators, pressure sensor and high pressure lines,
- clean the low pressure system together with the fuel tank,
- replace the fuel filter.

The high price of regeneration of modern fuel injection systems is due to the fact that the whole system should be completely regenerated to carry out the repair process in accordance with all the procedures so that a guarantee can be given for the performed service [16]. Unfortunately, this process is time-consuming and costly due to the prices of spare parts and work time. Most vehicle users want to have the repair made as cheaply as possible; therefore, the method has been developed by which a fault is detected and eliminated during computer diagnostics. Most often, this method repairs the effect of the fault and not its cause, but it is cheap and so popular with customers [10, 11].

When analysing the above-described case, only the cleaning and regulation procedure is conducted after the testing of fuel injectors and their disassembly [19]. Next, the pressure regulator, pressure sensor, CR rail and high pressure lines are cleaned. The fuel injection pump is left as it is. Its efficiency is approximately 78% at 100 MPa. Then, the system is assembled, the fuel filter replaced and the final computer diagnostics performed. If the engine operates properly, the repair process is to be finished. A vehicle has been repaired but the reason of failure has not been removed. It is difficult to estimate how long the engine will efficiently operate. This may be 20 thousand kilometres, or perhaps 1000 kilometres. Customers usually choose this method despite no guarantee for the

performed service due to its price. The total cost of this repair is approximately PLN 1000. When compared to the standard procedure at approximately PLN 5500, this is a big difference [12].

CONCLUSIONS

The analysis has shown that the performance of complete regeneration of fuel injection systems is only cost-effective in the case of vehicles of high market value. Usually, these are higher-class vehicles or new ones, in which the failure occurred due to the owner's fault (use of poor quality fuel). The repair is uneconomic when the repair cost exceeds approximately 70% of the vehicle value. The objective of the proposed method is to maximally reduce the repair costs. This method only eliminates the effects of failure and makes the engine efficient again. The main reason of modern CI engine troubles is poor fuel quality and lack of compliance with the operating procedures by users. Regular fuel filter replacement and periodical cleaning of the systems would minimise the risk of damage. Unfortunately, most users do not comply with vehicle servicing times, and come to car repair shops only when a failure occurs, but then it is too late and the repair costs are high.

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Using the finite element method in the modeling of layered composite delamination

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*Abstract***.** The article presents issues associated with an analysis of the process of delamination of fibrous composite using the Finite Element Method. Research encompassed three computer modelling sessions for delamination of the material for three different values of distance between the test force application point and the middle of the laminate. The results, encompassing the force value and displacement, were then compared to identify the correlation between these variables and the distance from the force application point. The model correctness was also verified by comparing the value of forces modelled with the real values, obtained during an experiment.

On the basis of the results obtained with regard to the size of the force applied, it was concluded that the numerical model represented well the mathematical model presented by Comanho. The negative result errors were due to the increased sensitivity of the software to the laminate fracture phenomenon, occurring during the experiment. Thanks to good representation of the model, it can be used interchangeably with numerical calculations

*Key words***:** delamination, composite, analysis, Finite Element Method.

INTRODUCTION

The purpose of modelling is to develop mathematical models to describe the examined physical phenomena [2, 17, 19, 23]. The Finite Element Method (FEM) has become very popular in this regard [3, 4, 21, 22]. This article describes application of the Finite Element Method for modelling of layered composite (the phenomenon of delamination) [5, 10, 14, 27, 29]. Its objective is to analyze delamination along with the crack initiating such delamination [11, 13, 15, 31].

Modelling of delamination of layered composite was performed using the parameters and results of laboratory tests described in the article [7].

The actual laminate, used in the experiment, is a two-layered composite, placed on the base supporting both ends of the laminate. On the top there is a beam attached to the composite in two locations: in the middle and near the end, in which delamination is taking place. The beam is subject to the force of leverage of the value of F_{lp}. This value shifts the entire load applied to the composite, resulting in delamination of the material or lack of such delamination. The objective of this modelling is to obtain the maximum value of force $F_{lp.}$The actual model geometry is presented in Figure 1.

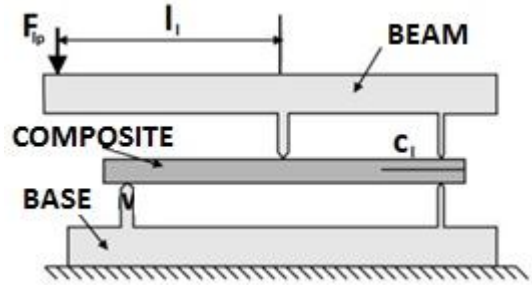

Fig. 1. The actual laminate geometry [Own elaboration on the basis of 7]

Leverage force was applied at the distance of l_l from the middle of the laminate. This distance influences the impact of individual fixtures of the beam on the composite. Depending on application of force F_{lp} to the beam, the ratio of the action of the force of the fixture in the middle of the laminate (the force acting down) and the forces at the end (the force acting up) of the laminate changes.

Simultaneous action of the two forces results in two types of loads: bending and stretching, which results in emergence of normal and shear stresses [1, 8, 24, 26, 32]. Normal stress emerges as the force acts at the end of the beam and it leads to delamination of the material. Shear stress results from impact in the middle of the beam.

Displacement due to development of a crack along the normal direction is referred to as mode I, and in the shear direction – mode II. Tests were conducted for the mixed mode, taking into account mode I and mode II. The emergence of the two modes depends on the above-mentioned action of leverage force. Correlation between the two modes in relation to displacement δ is presented in Figure 2.

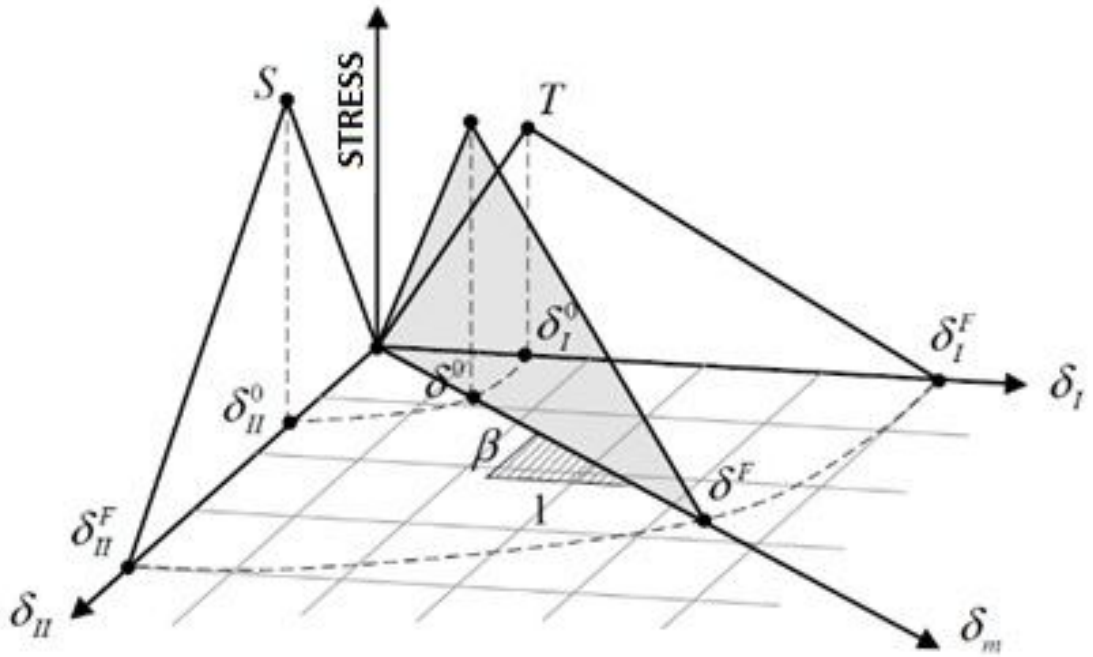

Fig. 2. Stress-displacement chart for the mixed mode, taking into account mode I and mode II [20]

The mixed mode coefficient β, visible in Figure 2, defines the share of individual modes in the process. By changing the values of this coefficient, as well as the values of variables depending on β, three different modelling processes were obtained:

1. Modelling 1 for β=0,2;
2. Modelling 2 for β=0,5;
3. Modelling 3 for β=0,8.

All displacements with index *I* are applicable to mode I: δ_I, δ_{I0}, δ_{If}, while displacements with index *II* – to mode II: δ_{II}, δ_{II0}, δ_{IIf}. The remaining displacements are assigned to the mixed mode. For the purposes of this study, in order to facilitate recording of the calculations, instead of symbol δ, symbol *u* was applied.

Tests were conducted using simplified models, disregarding the leverage force. The models consist of two layers of laminate, where the length of one layer is 102 mm, its width is 25.4 mm and thickness – 1.56 mm, which, for two layers, gives the result of 3.12 mm. T geometry of the modelled laminate is presented in Figure 3. In addition, Figure 3 presents the length of the crack, which emerged in the middle of the laminate thickness. Supports were placed on both ends of the beam.

In the middle of the top side of the beam, there is the conventional leverage that shifts the load. The leverage is also fixed to the end, and it rotates around the area of contact towards the middle of the beam. The force id displaced towards the opposite free end, which allows for the application of mode I and II loads, simultaneously. In the model, the leverage was disregarded and replaced with direct forces. There are two forces acting on the model: tensile force F_e, applied at the end of the beam and compressive force F_m, applied in the middle of the beam.

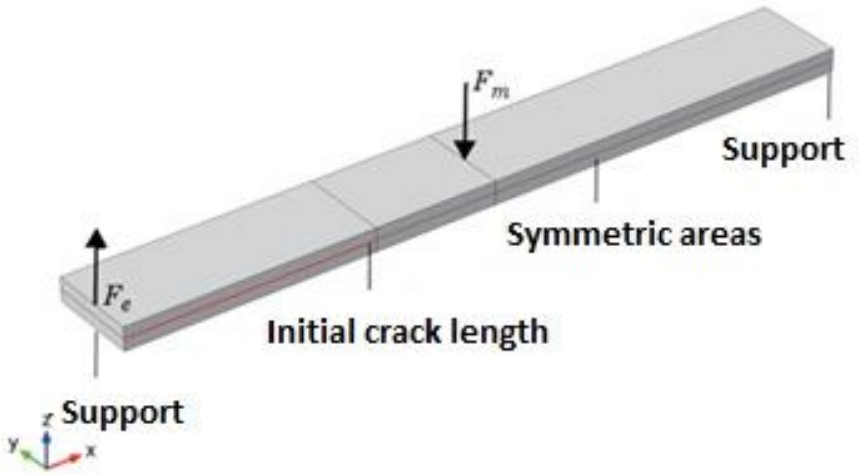

Fig. 3. Geometry of the laminate modelled [Own elaboration]

The initial length of delamination of samples *cl* (Fig.1) depending on coefficient β and resistance to cracking G_c, obtained in the experiment are presented in Table 1.

Table 1. Sample delamination length and resistance to cracking [7]

Mixed mode coefficient β	0,2	0,5	0,8
Resistance to cracking G_c (kJ/m^2)	1,103	1,131	1,376
Delamination length cl (mm)	33,7	34,1	31,4

The material of which the laminate is made is fibrous carbon epoxy composite AS4/PEEK, where AS4 is the fiber, connected using epoxy resin PEEK [12]. The characteristics of this material are presented in Table 2.

Model development stages

13 main stages of the model development were distinguished, where the first 11 are responsible for the model development and the last two – for calculations and results [6, 16,28, 30, 33]. Modelling was conducted using the COMSOL software.

1. Introduction – specification of the modelling type.

Two types of physical phenomena were added, which served as the basis for laminate modelling: Solid Mechanics – for modelling of solids, andBoundary ODEs and DAEs – introduction of differential equations.

2. Parameters – specification of the main parameters of the model.

Table 2. Characteristics of composite AS4/PEEK [7]

Feature	Symbol	Value
Young's module	E_X	122,7 GPa
	E_Y=E_Z	10,1 GPa
Poisson's ratio	ν_{YZ}	0,45
	ν_{XY}, ν_{XZ}	0,25
Kirchoff's module	G_{YZ}	3,7 GPa
	G_{XY}=G_{XZ}	5,5 GPa
Density	g	1570 kg/m^3
Maximum tensile stress	N_s	80 MPa
Maximum shear stress	S_s	100 MPa
Connection rigidity	K_p	106 N/mm^3
Fracture energy - mode I	G_{Ic}	969 J/m^2
Fracture energy - mode II	G_{IIc}	1719 J/m^2

Figure 4 presents the basic parameters for the model being developed. Most of them are common for all the three models. Values that vary are marked by the red frame and they include: initial fracture length *cl*, mixed mode coefficient β, distance from loading point *ll* and medium load coefficient *lr*.

Parameters

Name	Expression	Value	Description
lb	102[mm]	0.102 m	Length
wb	25.4[mm]	0.0254 m	Width
hb	2*1.56[mm]	0.00312 m	Thickness
cl	34.1[mm]	0.0341 m	Initial fracture length
Kp	1e6[N/mm^3]	1.0000E15 N/m^3	Connection rigidity
N_s	80[MPa]	8.0000E7 Pa	Maximum tensile stress
S_s	100[MPa]	1.0000E8 Pa	Maximum shear stress
u_I_0	N_s/Kp	8.0000E-8 m	Displacement initiating
u_II_0	S_s/Kp	1.0000E-7 m	Displacement initiating failure for mode I
GIc	0.969[kJ/m^2]	969 J/m^2	Displacement iitiating failure for mode II
GIIc	1.719[kJ/m^2]	1719 J/m^2	Failure energy for mode I
u_I_f	2*GIc/N_s	2.4225E-5 m	Failure energy for mode II
u_II_f	2*GIIc/S_s	3.4380E-5 m	Displacement resulting in breaking of connection for mode I
eta	2.284	2.284	Displacement resulting in breaking of connection for mode II
disp	0	0	Benzeggagh and Kenane (BK) fracture criterion
b	0.5	0.5	Displacement parameter
ll	lb/2*(0.5*sqrt(3*(1-b)/b)+1)/(3-0.5*sqrt(3*(1-b)/b))	0.044596 m	Mixed mode coefficient
lr	8*((6*b+sqrt(3*b*(1-b)))/(3+9*b+8*sqrt(3*b*(1-b))))	2.1436	Distance from load point
			Average load coefficient

Fig. 4. Basic model parameters for β = 0,5 inCOMSOL [Own elaboration]

3. Model geometry – development of the model on the basis of the parameters specified.

The geometric model was built of two identical layers, adjacent to one another along the largest plane (Table 3). However, in order to define the model property and facilitate identification of the required load points, the laminate was made of three double blocks. Moreover, the laminate was built of one half of its width *wb/2*, which allowed for the application of the forces exactly in the middle of the actual laminate, and in the case of the model – on one of the sides.

Table 3. Dimensions of individual blocks [Own elaboration]

No.	Specification	Block I	Block II	Block III
1	Length	cl	lb/2-cl	lb/2
2	Width	wb/2	wb/2	wb/2
3	Thickness	hb	hb	hb
4	Layers	Layer 1- hb/2	Layer 1- hb/2	Layer 1- hb/2

4. Definition of the Cohesive Zone Model – specification of the areas, on which CZM was used (the place of connection of the two layers), and its parameters; specification of variables for the load point originating from leverage;

5. Material – selection of the type of material and specification of its parameters;

6. Definition of the Thin Elastic Layer – specification of forces acting in the Thin Elastic Layer; introduction of the model symmetry.

The first stage of the specification of the model mechanics consists of defining the *Thin Elastic Layer*. For this purpose, the *Thin Elastic Layer* was selected from the *Physics* toolbar. This layer is used for cohesive areas, defined in the previous points. The parameter indicated was the *Force per area as function of extension* F_A. In the calculation software, loads acting on each axis were entered, calculated as the product of cohesive displacement present at a given axis and cohesive rigidity. If u_l<0,along axis Z, instead of cohesive rigidity, rigidity of the entire material K_p was applied.

7. Load definition – specification of forces acting on the model.

The next step was specification of the forces acting on the model ($F_e$and F_m), associated with leverage (Table 4).

Table 4. Defining of loads F_e and F_m [Own elaboration]

	tensile F_e	shear F_m
x	0	0
y	0	0
z	force	-lr*force

8. Expected displacement – blocking of displacement in undesirable directions.

The operation, which enforces specific displacement or prevents displacement of the model in undesirable direction, is *Prescribed Displacement* in the *Physics* section. The last operation, performed in the section *Solid Mechanics*, is specification of the global equation for the general force used earlier to define the loads and the load point force (Figure 5).

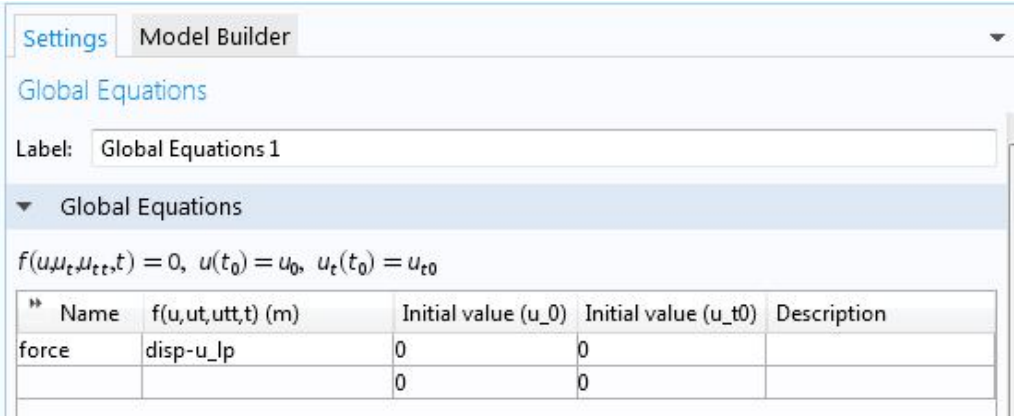

Fig. 5. Specification of *force* in COMSOL [Own elaboration]

9. Boundary ODEs and DAEs – entering of differential equations in the model; introduction of discretization in the cohesive areas; specification of displacement.

10. Model discretization – application of mesh to the model.

All operations associated with discretization of the model were performed in the *Mesh* section, automatically added to the *Model Builder* tree.

The system generated the following values:

- Maximum component size 0,00204 m,
- Minimum component size 0,0000204 m,
- Maximum increase rate for component 1,3,
- Curve coefficient 0,2,
- Narrowness resolution 1.

The above values are applicable to distribution of components along the X axis. The maximum and minimum component size depends on the length of the laminate and it is subsequently 50 times smaller for the maximum size and 5000 times smaller for the minimum size.

The graphic model with all the discretization changes made is presented in Figure 6.

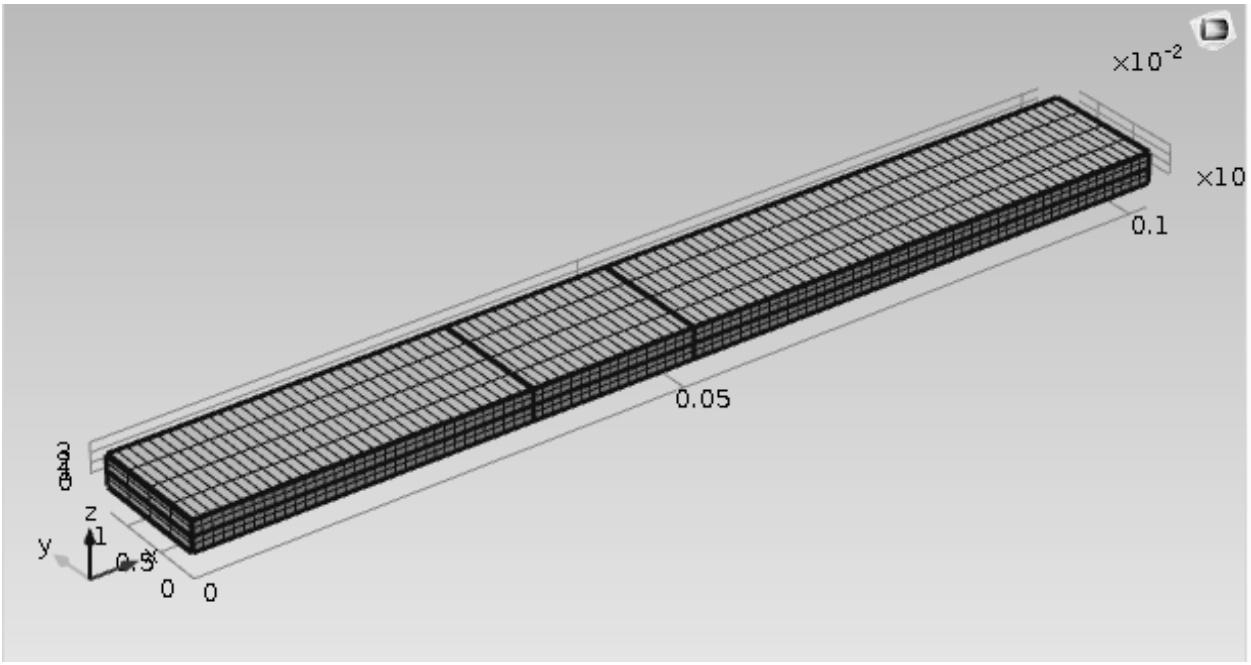

Fig. 6. The model mesh distribution in COMSOL [Own elaboration]

11. Test type – introduction of the calculation algorithm.

This is the last stage before the commencement of computer calculations. The objective is to configure and enable the tracking of maximum displacement in the mixed mode. Test specification started by defining the *Stationary* used earlier – it is responsible for the selection of the model geometry type (linear or non-linear) and the size of displacement between layers. In the *Stationary* options, nonlinearity of geometry was included, which requires marking of the option *Include geometric nonlinearity*. Discretization changed the model analyzed from linear to discrete, hence the selection of the above option. *Auxiliary Sweep* was also selected, which is an auxiliary calculation algorithm, used, when there are no geometric changes in the model. The parameter, which is to be used in the calculation algorithm, is interlayer displacement (*disp*).

12. Computer-aided calculations.

Three different calculations were conducted for three different mixed mode coefficients β, for which duration times and the number of degrees of freedom solved are provided in Table 5.

Table 5. Calculation times for three different experiments [Own elaboration]

	β = 0,2	β = 0,5	β = 0,8
Calculation time (min)	24 min 11 s	33 min 10 s	47 in 29 s

13. Generating of charts.

The chart generated presented a simulation of delamination and deformation of laminate, and the second chart presented laminate deformation on a two-color scale. Moreover, a linear chart was generated, presenting the *Load – displacement curve* (Figure 7).

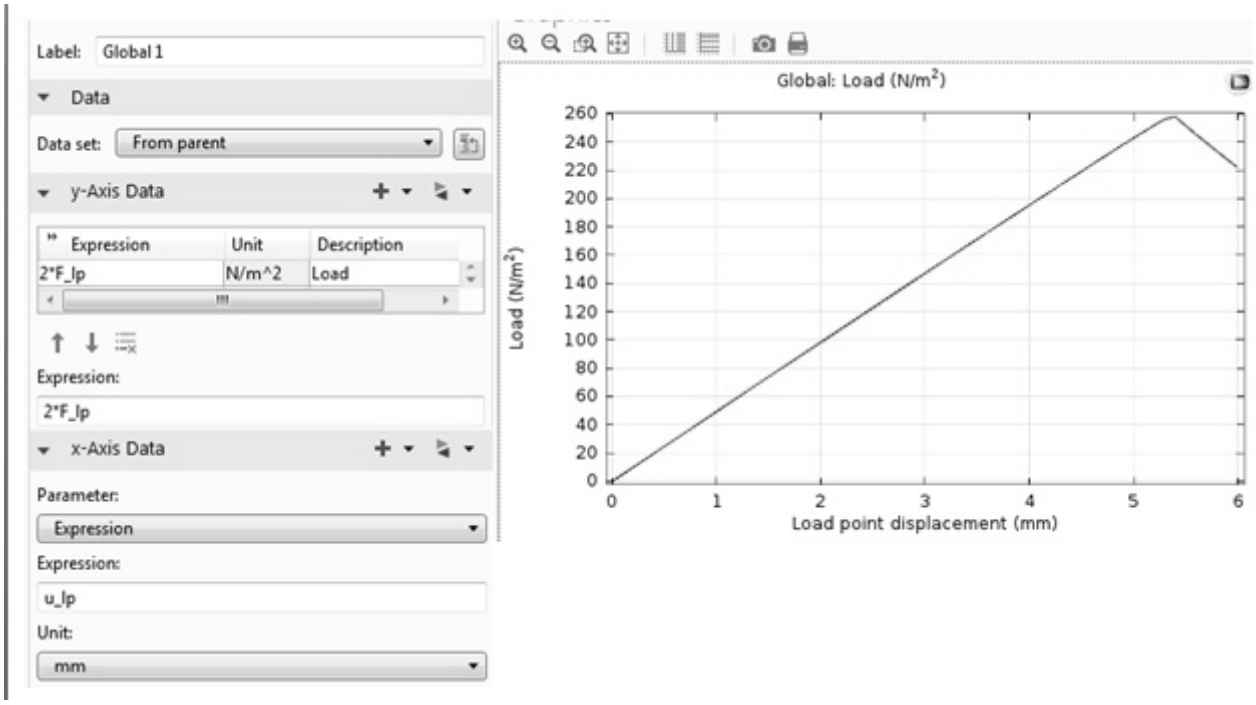

Fig. 6. The model mesh distribution in COMSOL [Own elaboration]

The chart from Figure 7 presents the load force value, which is the purpose of the calculations. It can be read from the chart or generated. From the *Results* toolbar, *Global Evaluation* was selected. The searched value of *2*F_lp* was entered and marked as *Maximum*. In this manner, the maximum value of the beam load force, which does not lead to fracture of the laminate, was identified.

Test results

The experiments conducted varied in terms of the value of the mixed mode coefficient β.

Table 6 presents coefficients with values, which were different for different models. In the right column of the table, information on how a given value was obtained can be found.

Table 6. Coefficients of varying value for individual experiments [Own elaboration]

Feature	Symbol	Exp. 1	Exp. 2	Exp. 3	Mode of obtaining of value
Mixed mode coefficient	β	0,2	0,5	0,8	By experiment
Distance from load point	l_l	0,1098	0,0446 m	0,0285 m	Formula based calculations
Average load coefficient	l_r	1,4641	2,1436	2,7913	Formula based calculations
Initial fracture length	c_l	0,0337	0,0341	0,0314 m	By experiment

The last stage in the model development was associated with generation of charts on the basis of results obtained during calculations. For each of the three experiments, varying in terms of the mixed mode coefficient β,3 different charts were obtained:

1. The model stress chart;
2. The model deformation chart;
3. The displacement shift curve chart;

and the constant initiating laminate delamination;

4. The load force value.

The displacement shift curve chart

The charts provided below (Figure 8, Figure 9, Figure 10) illustrate the correlation between the load force F_{lp} and leverage displacement. In both cases, as the load force increases, the leverage moves down, and this displacement is growing proportionally. The force value is growing linearly until the delamination of the laminate. From this point on, the force value starts to decrease non-linearly. This is due to the fact that the further part of the process is past the most difficult stage, which is complete delamination of the laminate from the place of fracture in the direction of the point of application of force F_e.

The charts presented, as well as Table 7, indicate that the delamination took place the fastest in experiment 3, and the beam was shifted by 5 mm in relation to its original position. In this case, the force applied was displaced at the smallest distance from the middle l_l = 0,028 m. The delamination was the latest – after 10 mm, in experiment 1. In this case, the distance between the force applied and the middle of the model was 0,110 m.

Table 7. Load and load point displacement values for individual experiments [Own elaboration]

		Experiment 1	Experiment 2	Experiment 3
Maximum load	F_{lp}	58,64 N	257,87 N	473,17 N
Displacement for maximum load	u_{lp}	0,01 m	0,0054 m	0,005 m
Load point distance	l_l	0,10989 m	0,044596 m	0,028471 m

A similar phenomenon can be observed in the case of the force applied. The highest values were observed for experiment 3 (473,17 N), and the lowest – for experiment 1 (58,64 N) (Table 8). The difference in values between the two experiments is as much as 8-fold.

Summing up, as the distance between the load point and the middle of the laminate increases, so does the displacement of the load, while the force to be applied to delaminate the composite material decreases.

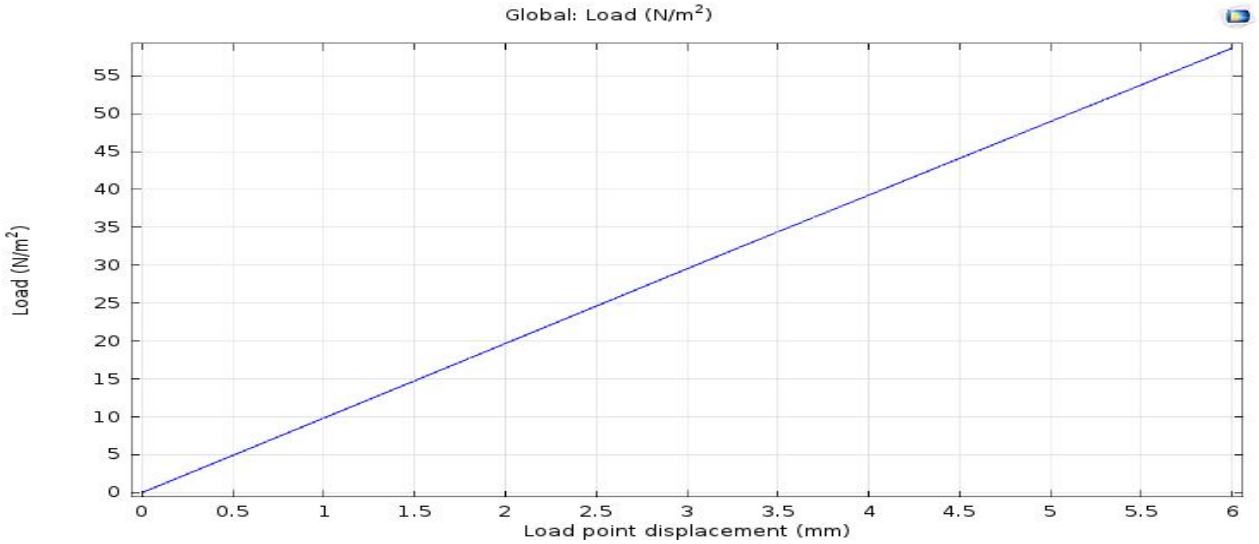

Fig.8. The displacement shift curve chart for β=0,2 in COMSOL [Own elaboration]

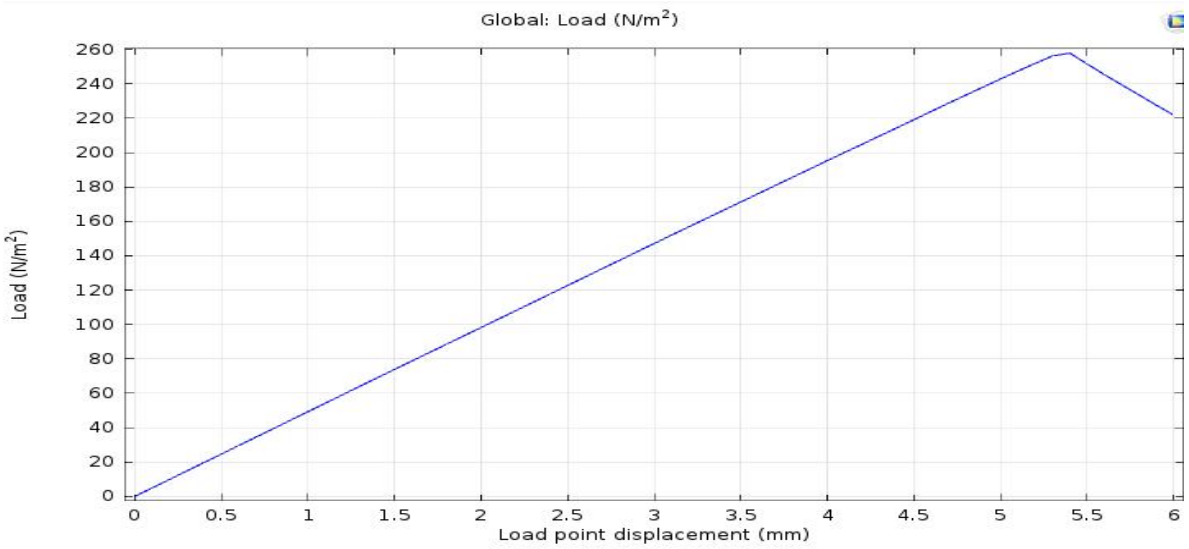

Fig. 9. The displacement shift curve chart for β=0,5 in COMSOL [Own elaboration]

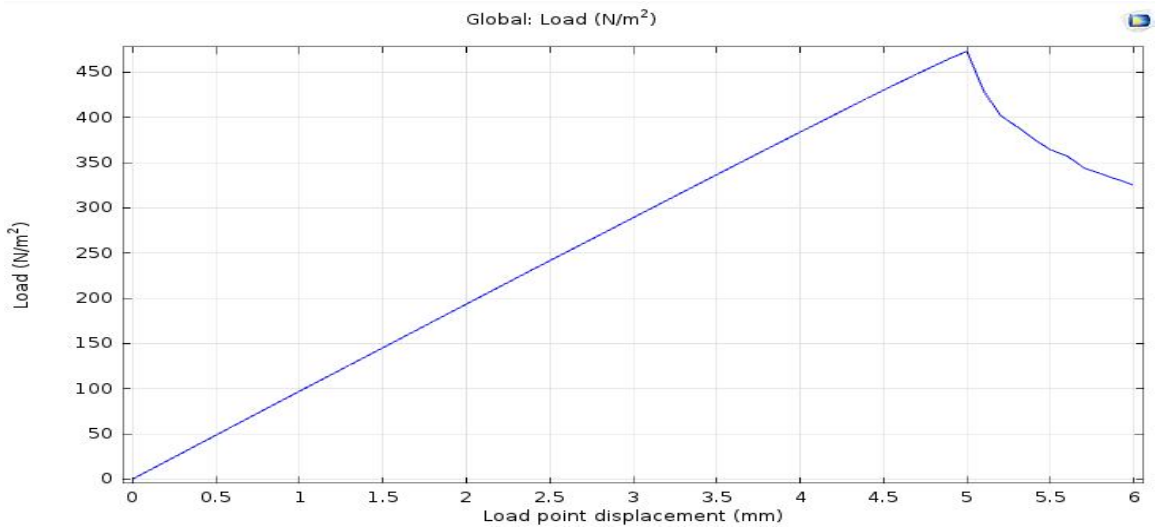

Fig.10. The displacement shift curve chart for β=0,8 in COMSOL [Own elaboration]

Data for the model were obtained on the basis of a real experiment, which was conducted for the composite of the same dimensions, the same properties and with the same load system [7]. Values of the maximum load to be applied to the beam were obtained and presented in Table 8 along with the values modelled. 8.

Table 8.Real and modelled load values [Own elaboration on the basis of 7]

	Experiment 1	Experiment 2	Experiment 3
Real	99,90 N	274,50 N	502,00 N
Modelled	97,73 N	257,87 N	473,17 N
Error	-2,17 %	-6,06 %	-5,74 %

The results obtained in the modelling are similar to those obtained in the real experiment. However, in every case their value is somewhat lower. This is due to the fact that in computer modelling more attention was paid to the initiation of fracture prior to delamination, by introduction of the Cohesive Zone Model.

The model stress charts

The stress charts (Figure 11, Figure 12, Figure 13) were developed on the basis of displacement u_{lp} for the maximum load value. In order to model a well-visible delamination, 10-fold displacement was applied. This resulted in a substantial increase in the distance between the top layer and the bottom layer.

The most visible bending of the beam was observed in experiment 3 (Figure 13), and the smallest – in experiment 1 (Figure 11). Differences in material bending are caused by different force values, described for the previous charts. The higher the force value, the greater the model stress value.

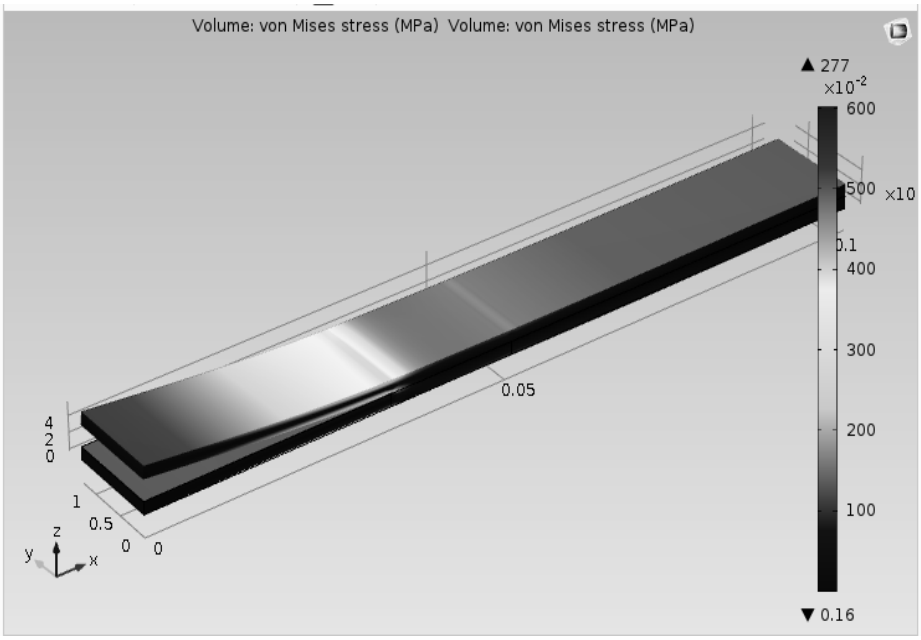

Fig.11. The model stress chart for β=0,2 in COMSOL [Own elaboration]

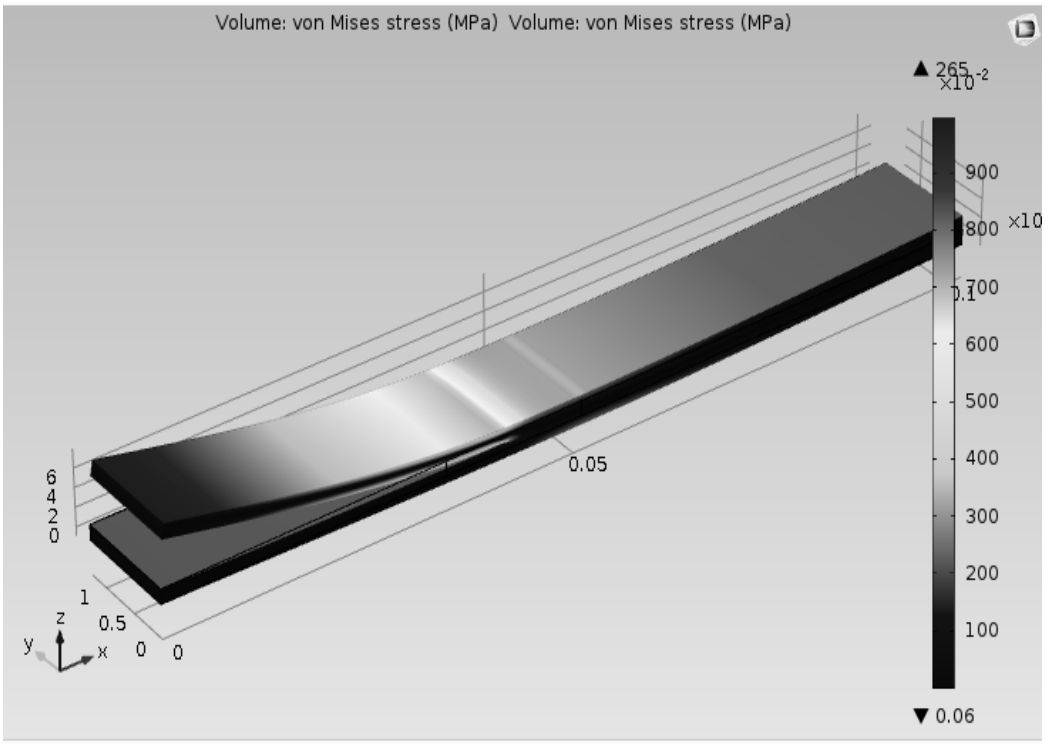

Fig.12. The model stress chart for β=0,5 in COMSOL [Own elaboration]

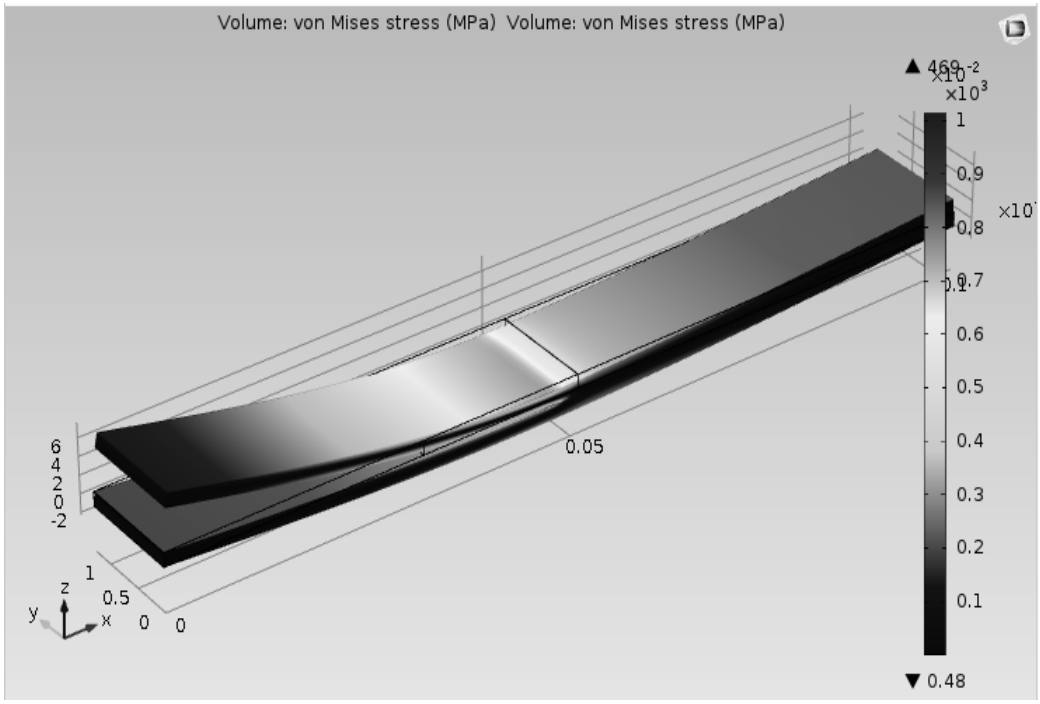

Fig.13. The model stress chart for β=0,8 in COMSOL [Own elaboration]

The model deformation chart

The size of the area subject to delamination is illustrated much better by the model deformation charts (Figure 14, Figure 15, Figure 16).

Maximum delamination, which may take place, is the delamination of one half of the laminate. In the middle, the downforce prevents further delamination.

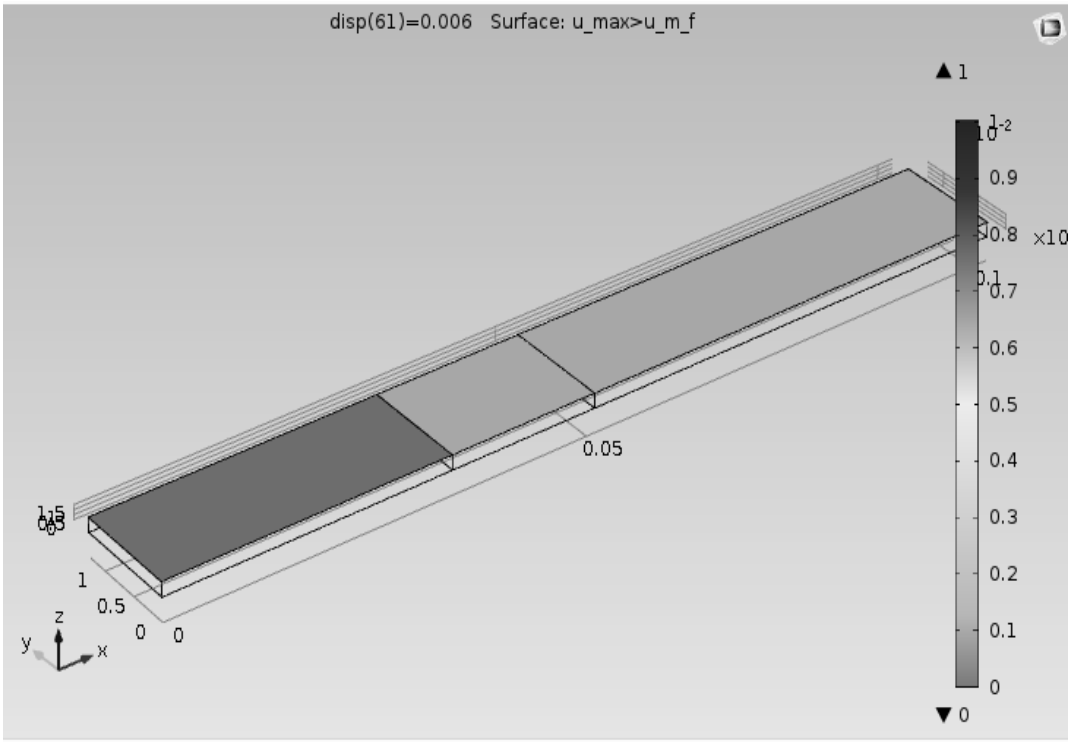

Fig. 14. The model deformation chart for β=0,2 in COMSOL [Own elaboration]

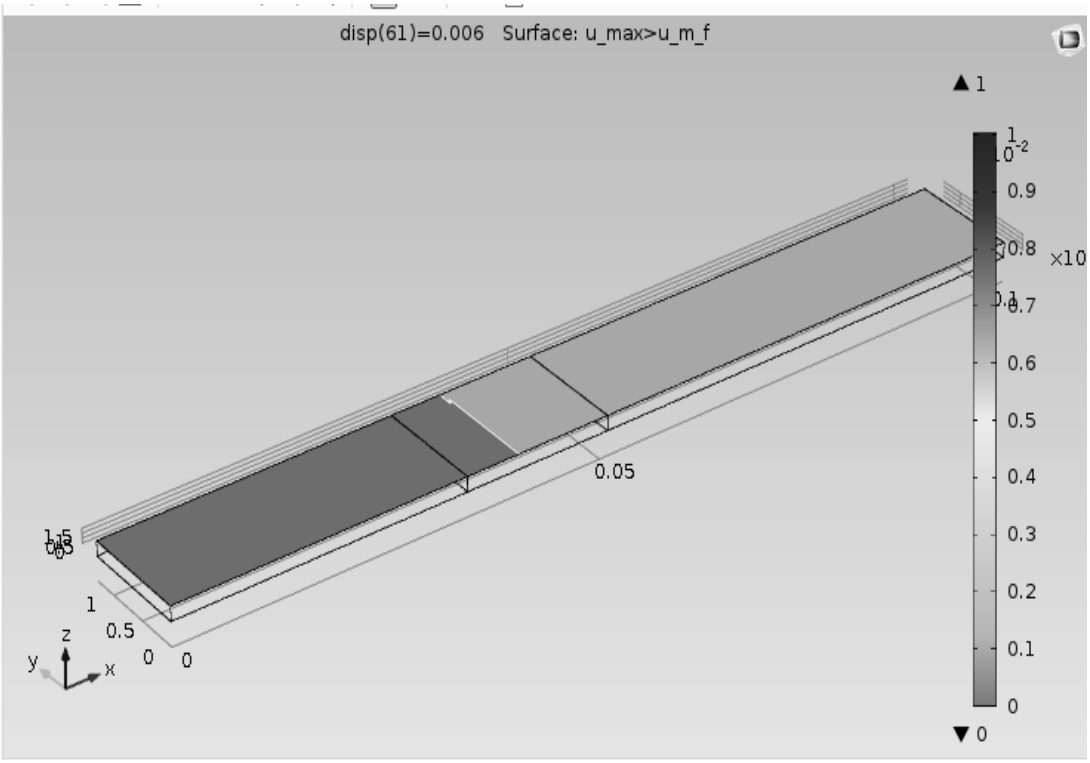

Fig. 15. The model deformation chart for β=0,5 in COMSOL [Own elaboration]

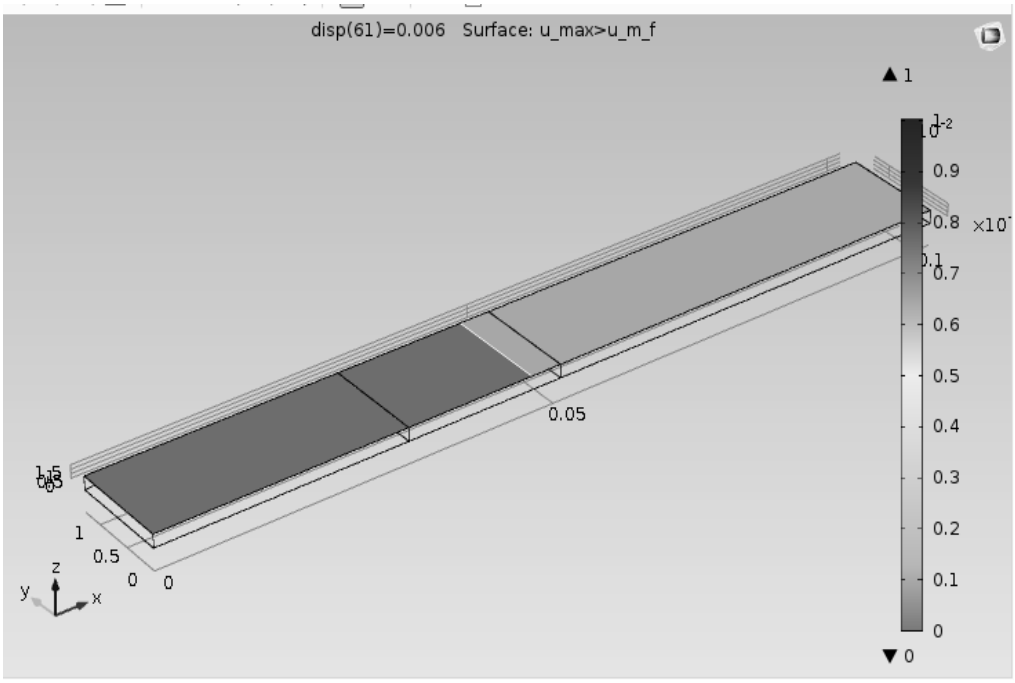

Fig. 16. The model deformation chart for β=0,8 in COMSOL [Own elaboration]

On the basis of the presented results it can be stated that the greater the distance between the force applied and the middle of the composite, the faster (upon lesser displacement of leverage downward) delamination takes place (as the force increases).

CONCLUSIONS

The modelling process presented in this work has allowed for the presentation of delamination of material AS4/PEEK depending on the value of the load force applied.

The delamination modelling has led to the following conclusions:

1. The experiments conducted have made it possible to conclude that it is possible to present the delamination of a layered composite using the Finite Element Method [9, 18, 25, 34];
2. As the distance between the force applied and the middle of the beam grows, the demand for delaminating force decreases, and displacement of the load point increases. This is due to the application of the leverage phenomenon in the model.
3. The size of the delaminated area depends on the size of the force, and thus on the distance between the force and the middle point of the laminate. As the force applied increases, the delamination area increases. Greater force leads to faster delamination from the fracture point up to the end of the laminate, and thus the process of increasing of delamination in the opposite direction is also initiated earlier.
4. On the basis of the results obtained with regard to the size of the force applied, it was concluded that the numerical model represented well the mathematical model presented by Comanho. The negative result errors were due to the increased sensitivity of the software to the laminate fracture phenomenon, occurring during the experiment. Thanks to good representation of the model, it can be used interchangeably with numerical calculations.

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Basic concepts of dynamic recurrent neural networks development

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Abstract. In this work formulated relevance, set out an analytical review of existing approaches to the research recurrent neural networks (RNN) and defined precondition appearance a new direction in the field neuroinformatics – reservoir computing. Shows generalized classification neural network (NN) and briefly described main types dynamics and modes RNN. Described topology, structure and features of the model NN with different nonlinear functions and with possible areas of progress. Characterized and systematized well-known learning methods RNN and conducted their classification by categories. Determined the place RNN with unsteady dynamics of other classes RNN. Deals with the main parameters and terminology, which used to describe models RNN. Briefly described practical implementation recurrent neural networks in different areas natural sciences and humanities, and outlines and systematized main deficiencies and the advantages of using different RNN.

The systematization of known recurrent neural networks and methods of their study is performed and on this basis the generalized classification of neural networks was proposed.

Key words: recurrent neural network, dynamic system, learning algorithms, reservoir computing, unsteady dynamics.

INTRODUCTION

Recurrent Neural Network (RNN) is a neural network (NN) where connections between units form a directed cycle. It is a dynamic system, its current state is

determined not only by input messages, but is dependent on the previous state of the network and due to this RNN has unlimited memory. As contrasted with neural networks they keep in memory input information about the delay for an indefinite period of time. Therefore, it is necessary to analyze the possibility of the research results of dynamic systems invoke in such related fields of science as physics, the theory of nonlinear dynamical systems, chaos theory and so on for the RNN synthesis and dealing with the issues of training.

SETTING

The typical structure of the neural network is shown on Fig. 1 below by authors. In our study the attention is focused on recurrent neural systems or, in other words, reaction-coupled networks. But the study will not be full in case there will be no short summary about the known issues of neural network.

Most researchers [2, 13] emphasize two ways of NN learning. They are divided into a network supervised learning and online unsupervised learning. NN supervised learning is hold by using such pairs as input and target vectors. The output vector is set, output of network is calculated and the result is compared with the corresponding target vector. Then in order to minimize errors weight coefficients of the input vector are changed in a certain algorithm. The vectors of learning set are

formed consequently: errors calculation and further coefficient changes for each input vector is performed until the error reaches the needed value throughout the training structure.

NN unsupervised learning does not require a target vector for its outputs. Learning set consists only of input vectors. Learning algorithm modifies network weight coefficients so that only outgoing vectors are in the output.

Also scientists [1, 5] allocate the so-called separation by way of presenting examples: providing single examples and "page" examples. NN state change occurs after each input presentation in the first method. In the second method based on preliminary analysis submission set examples are carried out simultaneously.

Also, researchers [8, 11] distinguishe NN by neuron model features, for example, neurons with different nonlinear functions.

RECURRENT NEURAL NETWORK STRUCTURE

Depending on the structure RNN are divided into fully connected and local connected. Considering a fully connected RNN each neuron is linked to any other neuron network. As for RNN local connections each neuron is adjecent just to other neurons. These relationships are formed deterministically or randomly. Neurons of RNN local connections are more independent.

RNN with a small number of items has structure with one-, two- and three-dimensional latitude in a discrete state space. The state of the network is characterized by the values of the neurons outputs. Remote control systems (RCS) are use for their mathematical description. If the number of items is large, the discrete space state is switched to a continuous one and RNN structure is simulated by uninterrupted environment with distributed parameters. The dynamics of these infinite-dimensional space systems are described with the help of the following

special wave equations: partial differential equations or integral-differential equations.

Various methods are used in order to analyze the RNN structure, including method which is based on graph theory. It involves calculating various indicators, such as the reachability matrix, routes, cycles, routes, clustered index etc. It is possible to estimate the interaction of elements approximately in RNN using these indicators.

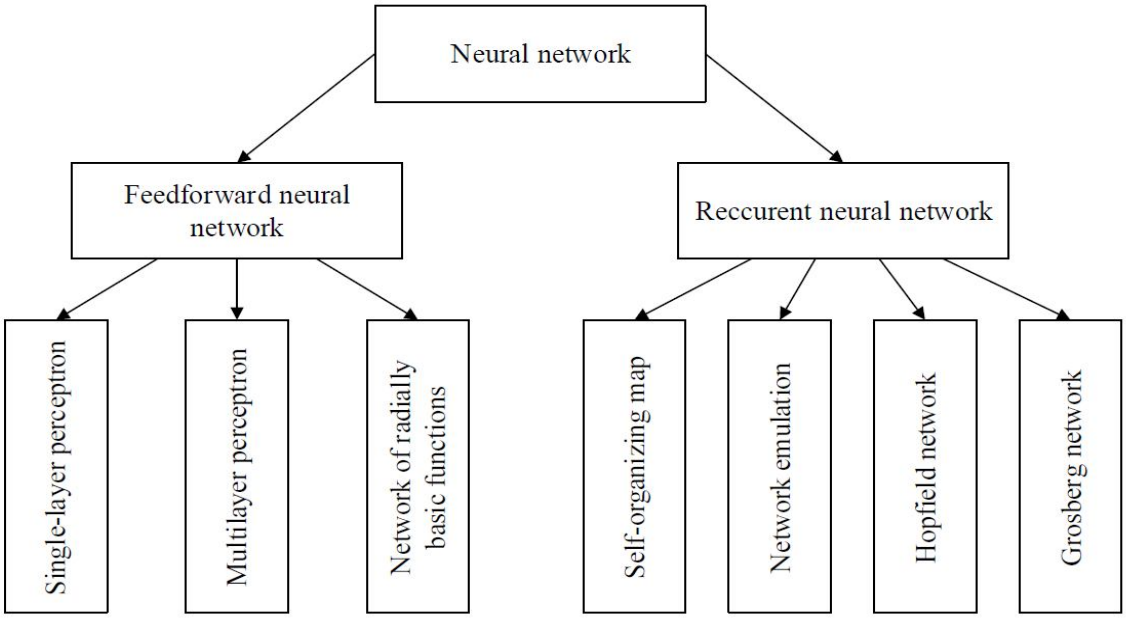

Fig.1. Recurrent neural network classification

In the space of discrete outputs values of RNN changing network conditions can be described by a system of difference or differential equations (1-2):

$$X[t+1] = g_1(X[t], U[t]); \quad (1)$$

$$\frac{dX}{dt} = g_2(X, U)); \quad (2)$$

where: X = (x1, x2, ..., xn) is a system state; n - the dimension of the system; x1 - the value of RNN i exit; U is input effects; g_1 and g_2 - function and image accordingly that describe the system state dependence to the previous state and the input (determine the evolution of the system over time).

Depending on the type of g_1 and g_2RNN will belong to a different class of dynamical systems, which classification overlaps with the dynamic classification of RNN described above. One of the major classification feature of RNN belonging to the class of linear or nonlinear dynamic systems is linearity or non-linearity of the functions g_1 and g_2.

The analysis of RCS can be made depending on the purpose and characteristics of dynamic systems (linear / non-linear, continuous / discrete). The authors propose to use following for analysis:

1) physical principles of dynamic systems (analysis of energy conversion);

2) variational principles for remote control system;

3) formal groups and invariant theory;

4) geometric approach;

5) analysis of the existence and periodic motions stability.

THE ANALYSIS OF RNN DYNAMIC. RNN WITH DISCRETE STATE SPACE

Stability. RNN belong to dynamic systems that can be stable (unstable) in small and large. Stability in the large guarantee stability in the whole state space and stability in the small guarantee stability only at certain points.

Normally, stability in large can be identified only for a small class of RNN (e.g.: Hopfield NN). A stability in small demonstrates only the behavior of the system in equilibrium points. Therefore numerous special characteristics are develped that help to judge the stability of the system in its phase trajectory.

The main types of dynamic. There are three main dynamic types of RNN depending on stability:

- stable dynamics: RNN for a limited time goes to the stable state of equilibrium (in this mode when the input signal is changed the transition from one state to another is possible),
- oscillating dynamics: RNN condition that describes a closed circular trajectory - limiting cycle; on the one hand we can assume that the limit cycle encodes some information, on the other hand there are variations, while information is transferred to the phase relationships,
- unstable dynamics: RNN trajectories with close initial conditions diverge over time; if the growth of the system is not limited, it tends to infinity, otherwise chaotic dynamics is set when the system changes spontaneously.

It should be noted that there is chaotic dynamics where the state changes of RNN are unpredictable, and

the process is stochastic by the casual observer. In terms of physics the system "is in itself" and response weakly to input signals. In a chaotic mode the piece of information contained in RNN is quite large, but it is very difficult to get it. Researchers [15-18] study the behavior of dynamic systems in chaotic conditions in many laboratories. They offer options for this dynamic interpreting. Such type of dynamics is unstable in small but steady in large and in some cases the dynamics can be seen as vibrational.

Different dynamic RNN regimes can be considered as separate stages of solving a particular problem. For example, the author distinguish the following regimes: a chaotic regime, which corresponds to the initial solutions finding, i.e.: the choice between various hypotheses; oscillatory regime reflects the processes of switching attention from one solution to another; stable regime fulfills requirements of found solution.

RNN dynamics depends both on the structure and the properties of the components. There are cases when RNN is not stable though its elements are robust and vice versa – RNN is stable, and its elements are not stable. However, studies of NN stable regimes usually form NN with persistent elements to study the vibrational regimes with oscillating elements and, finally, to study the chaotic regimes with chaotic oscillators.

The authors propose an analytical study of simple systems (of second- and third-order) dynamics using the theory of bifurcations and catastrophes. It is the level of neuron (the synapse). These theories do not work at RNN level. Therefore, in general, for arbitrary RNN structures the only possible way of its dynamics analyze is computing simulation, which implementation is to calculate the mode performance of the network. There are the following theories on the basis of determining these parameters: the theory of probability and mathematical statistics, theory of stochastic processes, information theory, theory of deterministic chaos, fractal and sync theory.

Transient and steady regime. The authors provide RNN dynamic as the sum of two components: sustainable and transition ones. The transient component is asymptotically reduced to zero, and after that there is only steady component. Both transient and steady components (regimes) are used for image recognition:

- in transient regime after the input image is added its dynamics is superimposed on RNN dynamics – it is possible to recognize the input image on "snapshot" of the resulting dynamics later; in this case, a short-term memory property is used accounting background of input signal change (stimulus),
- in steady regime after the input image is added the system enters the attractor after a while (fixed state, limit cycle or chaotic attractor) that enable recognition of input image.

RNN with steady regimes. Researchers [3-4] offered steady in large RNN. After state change or input signal they move into a state of equilibrium to the points of fixed attractor after a while. One of the most famous members of RNN is Hopfield network (HN). It is fully connected RNN with symmetric matrix of communications.

At the macro level HN is described by the special function of energy (Lyapunov function). In the process of HN function its energy decreases until HN go into the state of corresponding attractor. HN got two main implications: associative memory and optimization. HN induced a new trend in RNN research – attraktor NN [15, 19]. Scientists [12] have been proposed various modifications, that eliminate its main disadvantages, i.e: increase memory, reduce the number of false attractors – chimeras and increase speed. In the simplest case learning algorithm varied and, as a consequence, connectivity between neurons is changed as well. In some approaches the status of each neuron is not described by a single number but vector. Also more complex nonlinear models of neurons and connections are used (terminal attractor, synergetic computer of Haken). The principle of NN remained the same as in Haken NN in all cases.

Overall, despite the large number of RNN models with stable regimes, they are not widely spread but became a convenient model for the study of HN. Finally, some researchers [16] critisized attractor idea and predictable dynamics:

- key calculations are performed by chaotic dynamics in human mind and convergence means permanent state of peace,
- RNN with point attractor can not handle dynamic image.

RNN with vibrational regimes or oscillating NN. NN oscillator (NNO) are networks which state varies with time for periodic or close to the periodic law. Sometimes they are called neural attractors of "limit cycle" type. In terms of biology at the heart of NNO hypothesis about the relationship of the perception phenomenon and oscillatory neuronal activity is laid.

All NNO models differ in the following main parameters: type of oscillator elements; type of connections; structure.

The authors offer to use detailed models of biological neurons (Hodgkin-Huxley), simplified models of biological neurons (Hindmarsh-Rose, Fittshyu-Nagumo, Izhikevicha) model of "integration and excitement", models of neurons populations (Wilson-Forged) and models of physical oscillators that have no relation to the biological neuron (generator van der Pol, oscillator phase) as oscillators. The main requirement for oscillator is that it forms oscillating activity at the output. One of the key properties of NNO elements is their frequency. In NNO all elements can be of single frequency or be divided into groups with different frequencies.

The type of connections depends on the oscillator model. If it is the model of biological neuron, the connections are made through chemical synapses, if not, then through electrical ones. Depending on the oscillator model the electrical connection can be linear or nonlinear. Connections can have features of self-supervision (internal dynamics) and plasticity (self-learning).

The most important feature that distinguishes one oscillatory NN model from others is its structure. It includes the following components:

- the topology (connectivity) – fully connected, with local connectons, with weak connections, etc .,
- the balance of excitatory and inhibiting connections (oscillators), the presence of global inhibitor,
- distribution of power relations and delays (homogeneous and heterogeneous).

The research divide ONN into two groups: the mathematical study of ONN synchronization phenomena and orthonormal basis (OB) application for building the models of olfactory, visual cortex and motor systems, as well as memory and attention.

Within the first group the problem of the neural structures of complex spatial-temporal inhomogeneous structures (flat and spiral waves, solitons) formation is considered.

As for another group the application of OB is considered for modeling the various functions of the brain. Many scientific works are related to the research of OB [7]. Some of them [9] concerns the question of the complex dynamic modes origin, the chaotic one.

RNN with chaotic regimes. Chaos is a basic form of collective neuronal activity for all processes and functions of perception. It acts as a controlled noise sources to provide continuous access to previous memorized images and storing new ones. Chaos allows the system to be always active, it provides the system from awake or come to a steady state whenever the input influence changes.

Most researchers [10] agree that regime of orderly chaos is the best one in terms of storage and information handling. On the one hand, this regime has all the advantages of chaos and on the other hand, it can be controlled.

Much attention is paid to the orderly operation regime arrays to form such clusters as chaotic synchronization. This regime is between the two extreme regimes – full order and full chaos. It allows you to use the beneficial properties of chaotic systems to meet the clustering challenges.

RNN with continuous state space. RNN with a very large number of neurons is not considered as a discrete system in space, but as a continuous media. In this case, the wave equations are used to describe it. They determine the dynamics of neural fields u (r, t), that is formed by environment. The field u (r, t) characterizes the activity of RNN at t time at point with r coordinates. For connectivity is used a special communication function w (r), which determines the dependence of communication from a distance, for example, the function of "Mexican hat".

The dynamics of RNN environment is explored using a special method, i.e.: the Turing instability analysis. The wave equation of environment has one state of balance, a quiescent state. Then equation is lineared in the vicinity of this condition and parameters that characterize the type of dynamics are calculated. At a certain selection parameters (weight function, activation function) dynamics may be unstable. Such instability is called the Turing instability. This instability leads to the formation of inhomogeneous stationary structures called dissipative structures or Turing patterns. Dissipative one means that the structure is due to dissipative processes of energy dissipation in an open system.

The type and form of Turing patterns depend primarily on the number of measurement environment. The appearance of periodic global sustainable structures that are called bump or continuous attractors is specific for one-dimensional environment. Under certain conditions such complex in environments dynamic regimes as wave transmission can arise. They may alternate with state of rest, and may exist permanently in the form of solitons. In two-dimensional environments there are spiral waves.

Researchers [18] give the hypothesis that waves can not propagate indefinitely and quickly fade in real biological systems because of the heterogeneity and symmetry break. In general, the processes that occur in the environment can be detected in discrete lattice, but this requires a corresponding dimension to a discrete version.

NN LEARNING. CLASSICAL APPROACHES TO RNN LEARNING

One of the most important properties of NN is the possibility of learning. Under learning is understood the process of setting parameters by simulating neural environment where it is placed. Type of training depends on the method of these parameters setting. To train a neural network signals that change the arbitrary parameters of NN from the environment must appear. They entail different neural response to incoming signals. RNN learning is generally classified as NP-complete problem, even for NN with one hidden layer. For a number of cases (RNN structure and simple learning case) study has polynomial complexity. The following statement is applied to RNN: "harder machine is studying – more complex is learning algorithm". As the RNN is much more complex than conventional NN direct distribution, the algorithms and their learning algorithms are more complicated than for the previous one .

Authors emphasize several different groups of approaches for RNN study:

- Attraktor RNN, where the needed attractors can be coded by means of weight coefficients setting on the basis of Heba rules.
- The usage of supervised learning algorithms based on optimization techniques of the algorithm type of inverse error propagation; the examples are following: Back Propagation Through Time, BPTT, Real-Time Recurrent Learning, RTRL, Recurrent Back Propagation, RBP, algorithms that use Kalman filtering. Since this algorithms optimization functionality is formed as the sum of errors on some time interval and same parameters are set on every step, there are problems with the convergence of methods, working time and computational cost.
- The usage of supervised learning algorithm considering RNN as part of recurrent one, feedback signals are treated as separate inputs, i.e.: contextual neurons. As a result, job training is simplified and reduced to conventional NN direct distribution learning algorithms. This type of training includes Elmana NN, Jordan NN and others.
- The unsupervised learning algorithms usage (Kohonen teaching rule, synaptic plasticity of NN impulse).
- The lack of training in the classical sense, changing system parameters (implicit learning) - setting weight coefficients of random values. In this case, the learning function is assigned to a special device - scanner that deals with the classification of RNN dynamics. The

principle is underlying the new NN paradigm, i.e.: reservoir computing.

The authors singled out another version of the training without explicit training by changing the weight coefficient of RNN. It is a new paradigm of learning where the way to communicate with the environment is represented as a change of phase portraits RNN behavior and the formation of dynamics in response to some effect (it can be compared with short-term memory in NN direct distribution in response to input impact) . The new paradigm of training is related to the new approach in the calculation - reservoir computing (RC).

RESERVOIR COMPUTING

The complexity and inefficiency of the known learning RNN algorithms make us look for new approaches and strategies for the use of their computing capabilities. The authors identify one of these approaches as reservoir computing (PB, Reservoir Computing, RC). The basic idea of these calculations is to use RNN reservoir dynamics with rich and powerful computing capabilities. The reservoir is formed randomly. His transfer to the appropriate dynamic regime of operation (status) is submitting the relevant continuous signal in input. The reservoir is formed in such way that for similar input signals this condition is similar but for different ones it is different as well. The output of reservoir is connected to such special devices as readers that solve the problem of classification, prediction, clustering, and so on for reservoir state. Reservoir integrates the dynamic of the input image in its condition and its readers recognize the input image.

RC necessity is justified by the fact that static and dynamic models of NN are limited. The use of these models makes it difficult to solve the problem of images recognition. Therefore, the problem of RNN training led to new approaches. Consequently RC has appeared combining the rich dynamics of RNN and the power of NN static training.

The authors offered several options for implementing reservoir computing:

- Backpropagation-Decorrelation, BPDC where BPDC learning algorithm is used that is simplifying of RTRL algorithm. If the whole RNN is studying in RTRL, the BPDC is constructed in such a way that only reading modules are training,
- Liquid State Machine, LSM, the reservoir is impulse RNN [17],
- Evolino – EVOlution of systems with Linear Output – reservoir is made up of special neurons that simulate continued short-term memory, the output layer is linear [20],
- Temporal RNN – biological reservoirs that are real cortical NN,
- Other reservoirs that reflect the work of purely analytical as well as really optical, biological, physical, and other quantum dynamical system.
- The authors distinguish three basic ways to form the reservoirs:
- to use general guidelines for creating 'good' reservoirs that do not depend on the type of problem and is solved by choosing topology, connectivity, coupling force, delays,
- adaptation reservoir – unsupervised learning is using examples of input: globally reservoir is formed in such way that it is in the right dynamic mode for a given input and has the necessary properties (for example, division); at the local level – self-organization of reservoir using rules of synaptic plasticity in the process of applying the input,
- reservoir supervised study, using examples of input and corresponding output data. In this case, a lot of reservoirs with different parameters is generated for a particular problem, the quality of recognition for each reservoir is assessed and the best of them is chosen. Basically reservoir computing has universal reservoir computing capabilities in terms of approximation of arbitrary nonlinear dynamical systems with fading memory. If you add back coupling from the reader to the reservoir, the possibility of system approximation with constant memory appears, particularly Turing machines. Readers are simple static training machines: weighted straight-line regression, adalina (with training in real time by the method of the smallest quadrats), perceptron, k nearest neighbors, reference vector machines, static NN.

We provide an example for understanding the idea of dynamical systems class on the basis of remote control (RC) and degree of its difficulty: in order to describe module neural networks that consists of 125 neurons in the presence of noise component and dynamic synapses, 250 correlate nonlinear stochastic RC for neurons and approximately 400 difference equations of the third order for synapses are needed.

The use of existing indicators of dynamic systems (for example, Kolmogorov entropy, fractal dimension, synchronization indices etc.) to determine the regimes of RNN even for simple cases of chaotic neural networks it is ineffective because of the specific use of dynamic regimes for solving data handling tasks. Therefore, methods of cybernetic physics and methods of new sections of nonlinear dynamics should be used for the analysis of complex RNN.

IMPLEMENTATION AREA OF RECURRENT NEURAL NETWORKS

Recurrent Neural Networks have practical use in the following areas:

1. Economics and Business: market prediction, loan default risk assessment, prediction of bankruptcy, evaluation of property value, dentifying of under- and overvalued companies, commodity and cash flow optimization, automatic reading and recognition of cheques and documents, security of plastic cards transactions.

2. Medicine: establishing diagnosis, medical images processing, patienthood monitoring, the factor analysis of treatment effectiveness, clarification of instrument readings from noise.

3. Avionics: radar signal detection, adaptive piloting of heavily damaged aircraft, unmanned drone.

4. Communication: compression of videos, fast coding-decoding, optimization of cellular networks and packets routing plan.

5. Internet: associative information search, information filtering, spam blocking, targeted advertise and marketing for e-commerce.

6. Automatic production: production process optimization, products quality control, monitoring and visualization of multidimensional data control, accidents prevention, robotics technology.

7. Politological and sociological technologies: forecasting of election results, analysis of opinion polls, predicting of ratings dynamics, identifying the important factors, objective electorate clustering, research and visualization of social population dynamics.

8. Safety and security systems: fingerprint, voice, signature identification, voice recognition in the crowd, car numbers recognition, analysis of airspace images, monitoring of information flows in computer networks and detection of intrusion and fraud.

9. Information input and processing: recognition and processing of hand-written payment, financial and accounting documents.

10. Geologic exploration: seismic data analysis, associative search techniques of mineral products, estimate of field resources.

CONCLUSION

The paper presents an analytical review of modern approaches to the study of recurrent neural networks. The systematization of known recurrent neural networks and methods of their study is performed and on this basis the generalized classification of neural networks was proposed.

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Basic concepts of evolution in agents calculating and agents system

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Abstract. The basics concepts of evolution in agents calculating are discovered in this work and are showed their directions and applications. Before explaining what is agent and its description, there were given a bit of its history and the difference between agents and programs. Were given basic types of agents on examples and figures.

The main task of agents is to require a large number of interactions for which most mathematical modeling methods are unsuitable. Were analyzed agent systems architecture and a description of their main parts. Principles of work with mobile and intelligent agents are considered. Furthermore, were exemplify the reasons and situations of use either intelligent agents or mobile agents. Also, their examples were showed on different examples and figures. Technology and application tools which uses in the process are represented.

Analysis of JADE-technology are carried out. On the market today there are analogues of JADE, but most of the systems are relatively new and require many improvements, some are under development prototypes. Also, were given description of main tools and features of JADE. It will help a lot in elaboration of agents.

Advantages and disadvantages of using agent approach are showed for creating system of data processing and they show their versatility compared with other systems.

Key words: system, technology, agents, agents computing, mobile agents, method, web-application, processing, analysis.

INTRODUCTION

Today there is a significant development of computer technology, including the Internet "cloud" computing and GRID-technologies. We often work in open systems, systems that have the ability to update the software (software).

However, most of the web-technologies that provide access to many sources of information described in natural language and therefore is not structured. Working with such systems is interactive and simulation tasks require a large number of interactions for which most mathematical modeling methods are unsuitable [1, 5].

To overcome these problems recently, using agents technology. While the use of agent paradigm allows the use of artificial intelligence methodology and theory of distributed computing.

This paradigm is based on the abstraction "agent" - a component of software that has the properties of reactivity, autonomy, pro-activity and social ability.

TOPICALITY OF PROBLEM

To better understand the agents calculation, you must first understand what the agent is. Agent - a computer program that enters into relation with the mediation of the user or another program. The word "agent" (from Lat. Agere - do) - the agreement on implementation of the actions of someone's name. Such action is meant by the right to decide what is appropriate. The idea is that agents are activated independently and not launched specifically for the task.

The main agent attributes include [3]:

- independent activation itself,
- ability to be suspended on the host and perceive context,
- able to obtain the status of implementation on the host for the initial conditions,
- optional user experience,
- to refer to other problems, including communication.

The work of researchers are analyzed by the authors and are proposed some concepts that characterize the properties of the definition "agent" [2]:

- vitality (the code is never-ceasing and self-organized),
- autonomy (the agent has the option for choosing the tasks prioritization, focus on the behavior and decisions without human intervention),
- social behavior (using defined relationships and actions, agents may involve additional components for common tasks to work on),
- reactivity (agents respond appropriately to the context with which work).

Agents are not tied to one user or to a computer, they have the ability to migrate and maintain a user interface and execution context. They may terminate their own employment and replenished with new components and maintain its internal state during migration. They make effective use of easy to use powerful software for better data and software of the system. This type of software program called migration (migratory applications) or mobile agents. Their use is effective and reasonable mechanism for the quality of the information space. Therefore, the study of the properties and organization of mobile agents and defines the purpose of our study [10].

DIFFERENCE BETWEEN AGENTS AND PROGRAMS

The works of Franklin and Gausser are researched by the authors, which discusses four key concepts on which agents are different from voluntary programs: reaction to environment, autonomy, target orientation and vitality (Fig.1).

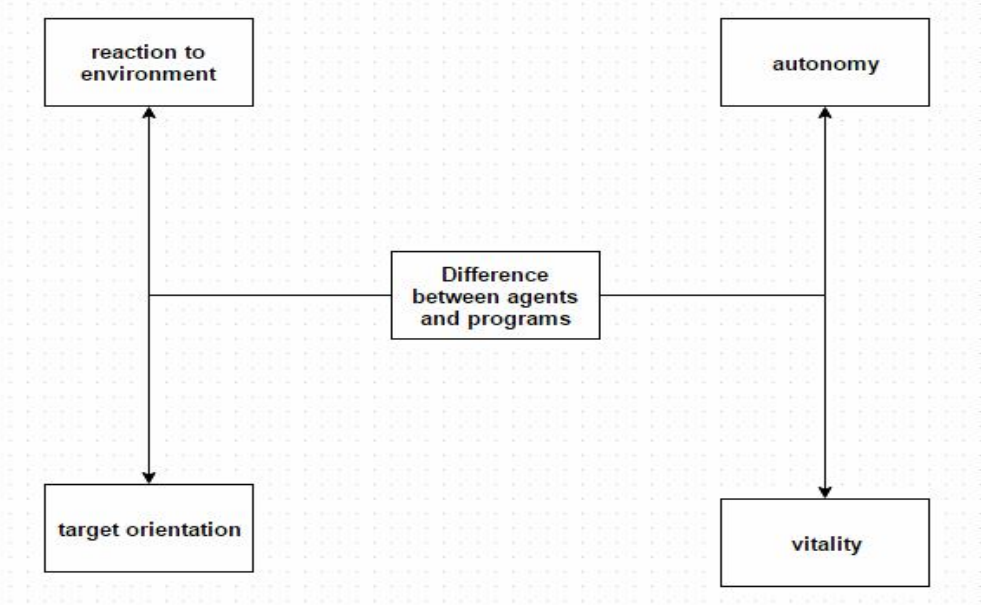

Fig.1. Difference between agents and programs

Also, similar and derivative agent concepts are exemplified by the authors(Fig.2):

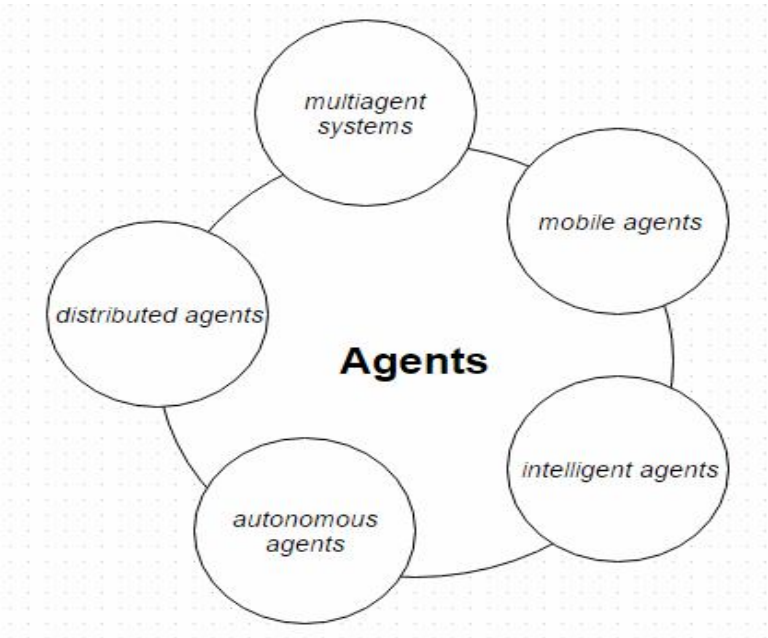

Fig.2. Related and derivative agent concepts

Example of agents concepts listed in Figure 2, allow the isolate their one common trait. They work to achieve a common goal - an efficient, organized, cooperative operation of the system as a whole. Because intelligent agents have partial artificial intelligence, such as learning and reasoning. Autonomous agents - agents that can change the ways of achieving their goals. Distributed agents - agents that perform tasks running on different computers. Multi-system - a distributed agents which can not work and achieve their goals on their own, but only in cooperation with other agents. Mobile agents - are agents that can move their work to other processors.

Property agents and objects are discovered by authors, which mistakenly considered to the same concept. The differences in these definitions are directed by the authors [8]:

- agents are more autonomous than objects,
- agent behavior is more flexible,
- agents have reactivity, proactivity and social behavior,

- agents are both single-threaded and multi-threaded.

Also there is a difference between the agents from expert programs [10]:

- expert systems have no connection with the environment,
- expert systems have not reactive and proactive behavior,
- expert systems do not have the social behavior.

Among the variety of types of agents, the authors paid interest to the intelligent and mobile agents because of the pace of research and development on this subject is growing every day.

EXAMPLES OF INTELLIGENT AGENTS

Researches that are carried out by the authors, allow to distinguish four types of intelligent agents, which results in his writings Stephen Haag (Fig. 3):

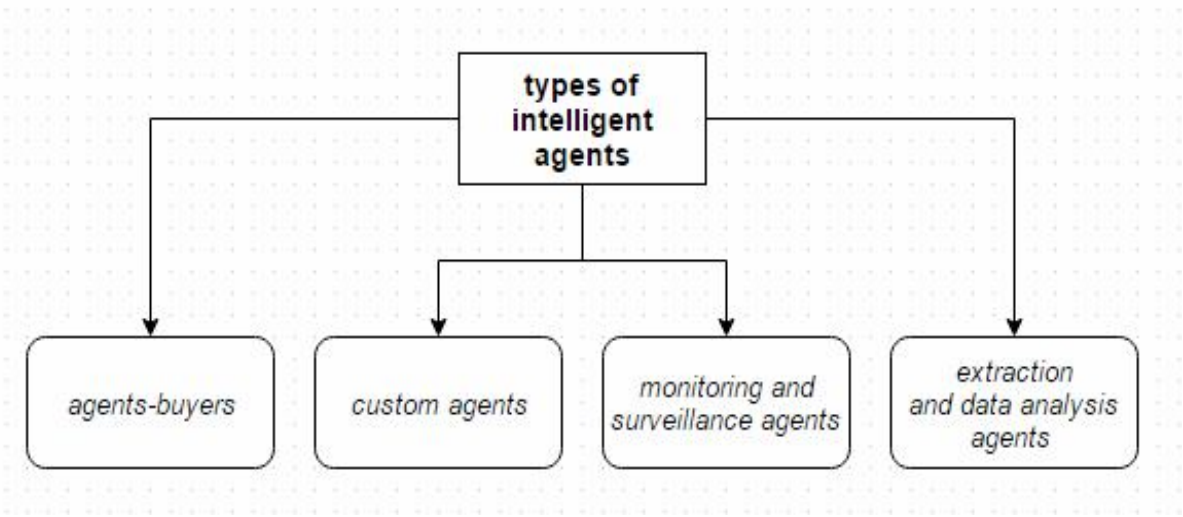

Fig.3. Examples of intelligent agents(by Stephen Haag)

On Fig.3 agents-buyers (or trading bots) analyze network resources (Internet) to obtain various kinds of information about products and services. They effectively works with products like CDs, books, various electronic components or consumer goods.

Unlike previous custom agents (personal boats or personal agents) - is intelligent agents that act directly on the user. These include intelligent agents at a time perform or will perform in the future necessary task. The challenge of this type of agents are shown in Fig.4. Task list user agents can facilitate maintenance of various programs and consumer information services to facilitate their using software.

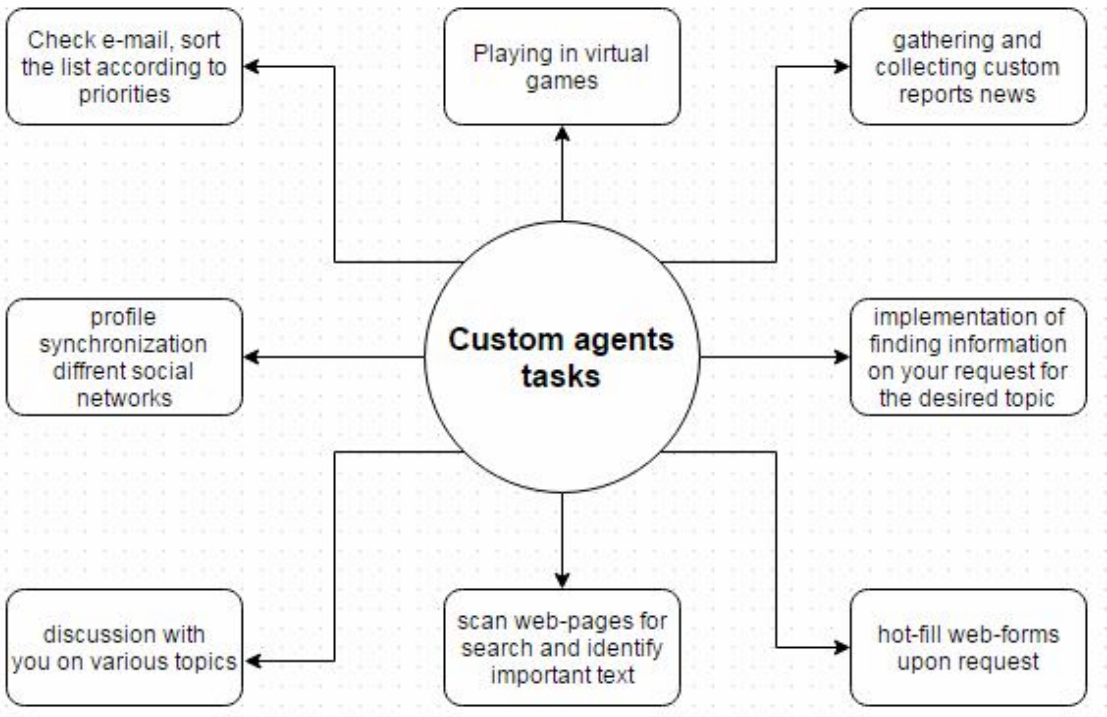

Fig.4. Custom agents tasks

Another type of agents (Fig. 4) are agents for monitoring and surveillance. They are priority for their use in monitoring the objects and data on equipment, usually in computer systems. This type of agents can track inventory levels of resources any corporation, monitor competitors' prices, analyze and synthesize stock manipulation by inside information and rumors etc.

For example Microsoft Monitoring Agent. Microsoft Monitoring Agent is a new agent that replaces the Operations Manager agent and integrates APM .NET features in System Center with full-featured IntelliTrace collector of the development environment Microsoft Visual Studio. This allows complete collection of trace profiling applications. Microsoft Monitoring Agent is able to collect trace on request, or you can leave it running for application monitoring and collecting trace. There is provided an opportunity to limit the disk space that the agent uses to store collected data. When the amount of data reaches the limit, the agent overwrites old data in the right places replacing new [6, 12].

Last in Fig. 3 shows the agent monitoring and surveillance. This structure agents used for decision support systems during tactical operations. These agents carry out an analysis of assets (ammunition, weapons, personnel, vehicles, etc.) and get a job (order) of the top-level agents. This type of agent reaches the goal with their assets, costs are minimized. They operate information technology to monitor and search for trends or patterns for a wide range of information flow. You can sort the existing information in accordance with the submitted search criteria.

Extraction and analysis data agents operating with data store accumulated information. This storage combines a huge range of information flows for subsequent analysis. This review process is a data repository for the purpose of isolating the necessary information [4].

Classification is the most widely used data mining, without which there are keywords in information flows. Agents for the extraction and analysis allow for changes in trends in key indicators, track the updated information to fill her store. For example, the agent finds decline in cybersport team or player of the same team. Bookmaker companies involved in calculating the coefficients for cybersport matches, based on information received on time, can change their data rates or peer review, which will replace the previous best rates so that revenue was maximized [7].

Researchers show other modern intelligent agents that are less common and can realize the task spam filters, game bots of monitoring servers and bots indexing searching systems. Their variety is provided by the authors in Fig. 5.

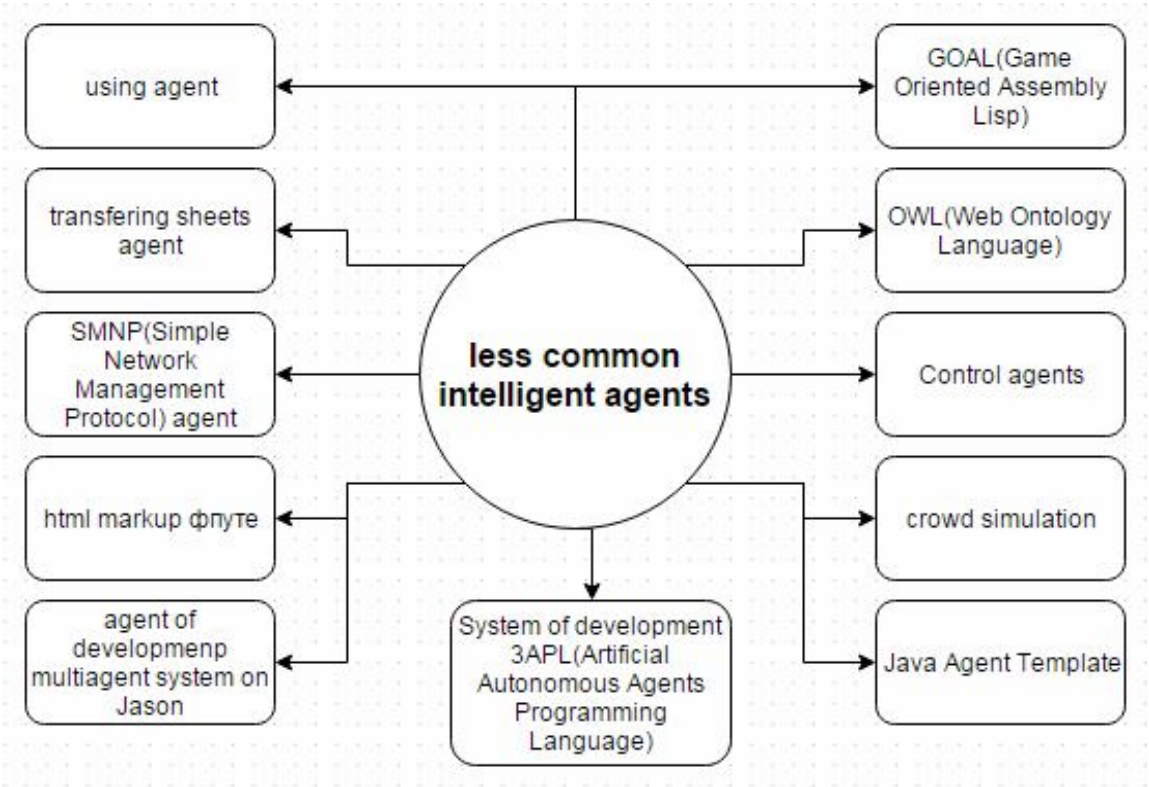

Fig.5. Uncommon intelligent agents

Fig. 5 given the use of an agent (Using agent), which is used for browsers WWW. Another singled out transfer agent to mail that serves electronic mail, for example, MailRu.Agent. This program supports IP-telephony, video calls, sending SMS, and also provides notifications of new messages submitted to the server Mail.Ru. For their use requires an account with domain @ mail.ru, @ inbox.ru, @ list.ru, @ bk.ru, @ mail.ua. Also this program makes it possible to connect to the email account that is tied to the service «Mail.Ru business." The official client supports the ICQ. This agent referred to a collection of settings and rules that do not allow the user to perform their own mail filtering.

SNMP agent (Fig. 5) continuously monitors the network and work of any corporate network, allowing you to keep it in working order.

Next agent, which give off researchers is an agent markup in HTML-format. This intelligent agents in virtual environments are under the authority of the agency DARPA. There are also agents of development multiagents system on Jason platform (Fig. 5). This platform established to develop multiagents systems, advanced by programming language AgentSpeak and uses to program the behavior of individual agents. The system design of artificial autonomous agents include 3 APL abstract programming language for developing, implementing and testing several synthetic autonomous agents using the BDI approach.

The programming language for the development of rational agents GOAL is a high level programming language. Description language for semantic web ontologies OWL. This language allows to describe the classes and relations between them inherent web-documents and applications. OWL is based on earlier languages OIL and DAML + OIL and now recommended by the World Wide Web Consortium.

Management Agents, which are presented in Fig. 5, used in knots of telecommunications networks. The basis of the existing network management scheme is "manager-agent". The agent is the intermediary between the managed resource and the main control program manager. Interacting with a property agent delivers formalized information manager which decides on management.

Crowd simulation is used for providing safety and for three-dimensional graphics. Java Agent Template - template that is designed to create software agents in the system Java (JAT).

MOBILE AGENTS

Recently, mobile agents often discussed in the scientific world and became an interesting topic in the circle of researchers. This trend is growing, contributing authors to revive interest in the subject. After all, mobile agents is a promising area of research that affects development of this area.

The concept of mobile agent was identified in 1994. Then it was a description of the computing environment (Telescript). In this environment, these programs could actually stop the execution and were able to move from one computer to another computer within the same network. Also they could restore your runtime after the "arrival" to the point of destination [6].

Mobile agents have to operate on various platforms and operating systems to realize their full potential. This need arises from the fact that mobile agents that were created in such systems, allowing use scripts and application code represented as bytecode. The interpretation for different operating systems (OS) eliminates the need to recompile agent after the transition to a new computer, provided they stay in the same environment of different machines. These servers are called environmental agents.

The advantages of mobile agents include: simplicity while installing the server database, the flexibility of the service, and the opportunity for local agents interact in real time. Because system of mobile agents can implement process support of cloning processes ensure their permanent memory and do their exchange group in the system.

According to some researchers the only reason for the rejection of mobility is that in the near future will have enough Internet bandwidth to support all traffic. Client-server interaction through the web will be carried out as quickly as interactions within a single machine. So one could argue advantage interaction, which is accessible through mobile agents. Although this is only a theory and assumptions made by separate groups of scientists [5].

On fig. 6 agent movement among multiple platforms are given by the authors. The platform, which is derived agent called home (Home platform), and is usually reliable environment for him. One or more hosts can contain the agent platform that supports several places of agents.

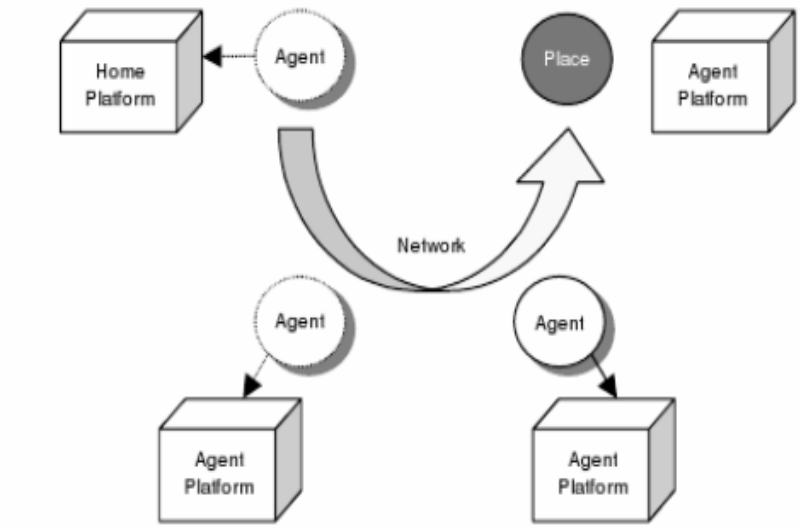

Fig.6. Movement of agent between few platforms

The typical architecture of agent system can consist of following parts (Fig. 7): agent-collector, agent-correlator, the agent analyzer, the agent manager.

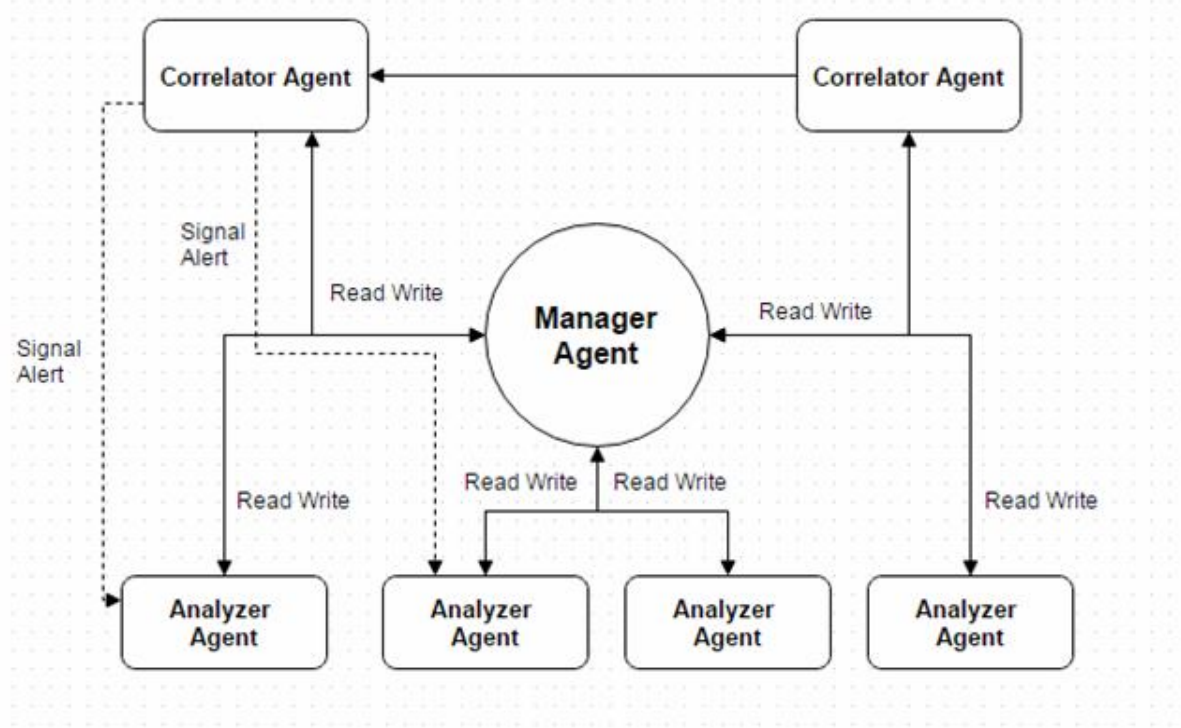

Fig.7. The typical architecture of agent system

Fig. 7 shows the agent-collector that is cloned and distributed throughout the network. Its task is to monitor the network and gather information that takes place on the host to which it relates.

Agent correlator send certain information that call critical to an appropriate agent analyzer, bypassing the agent manager. Default communication protocol is centralized. This means that the agent-collector must send a report to the manager, who will decide whether to send data to the analyzer. This communication model is not suitable for online use, because some important events should be handled by analyzer in the process of entering the system. That's why each correlator uses a set of rules that clearly define the required events, conditions and agents analyzers that includes to them.

Agent analyzer analyzes. There is also a behavioral analyzer that uses a statistical model to determine the "normal" behavior of the system.

Agent Manager receives the information and distributes it among agents analyzers. This process does not allow online communication analysis. For this reason, agents correlators can decide whether they communicate directly with agents analyzers.

On Fig. 7 administrator distributes certain functionality on any number of hosts on the network. Each node can receive any number of collectors agents that monitor all events taking place on the host. All agents collectors report on its findings to the manager who passes it to agents analyzer. Critical events, detected by collector, transmitted immediately to the correlator (critical event - any event that is part of the scenario defined functionality). Correlator takes responsibility to transfer critical events received from the collector to the appropriate agents analyzers. On fig. 7 agent analyzer collects events from the manager and from the correlator and perform analysis using the right method. Then the analyzer reports its findings to the manager and notify the system of detecting anomalies. Agents cooperate with each other because their task is to monitor critical events messages to other agents. Administrator, according to their needs, through an external interface manager may stop by some agents, send them to other locations and resume their activities. Agents can independently decide to redirect themselves. In other words, they can stop their performance, move to another location (host with the appropriate agent platform) and restart its execution. In addition, agents can clone themselves, especially in the case of increasing load on the network [9, 12].

Agents perform actions, but communication - is the only type of action. Putting communication at the same level as the action, the agent may, for example, to carry out a plan that includes both physical actions and communication. To make communication planned should clearly define the impact of the previous conditions for each possible session. Communication has semantic meaning. When the agent - the object of communicative action (that is, when he gets the message), he is able to understand the true value of actions and why it is done (to wit, the intention of the sender). Thus there is a need for the existence of universal semantics and standards. For this, authors give off Jade-technology, which allows you to implement development agents [10].

JADE-TECHNOLOGY

Java Agent Development system - an open source platform, created for the development of multi-agent systems and applications and supports FIPA-standards for intelligent agents. On fig. 8 the components of the system are represented by the authors.

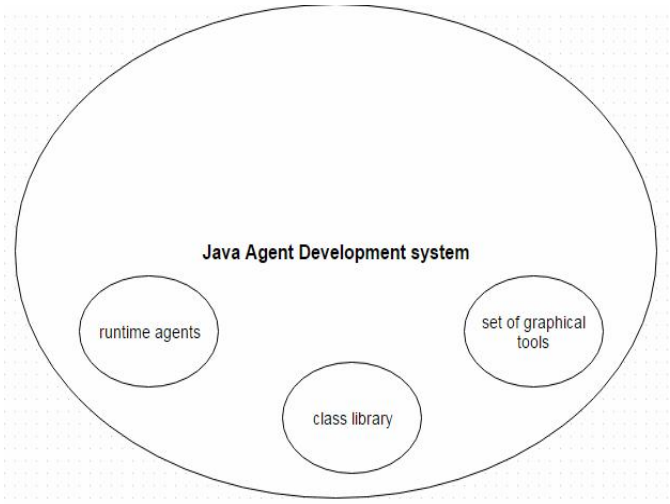

Fig.8. Elements of Java Agent Development system

On fig. 8 one of the elements presented runtime agents in which they are registered and operating under control. Element class library used to develop agents systems. The third - a set of graphical tools designed for management and monitoring of vital functions active agents.

JADE is completely written in the Java programming language using opportunities such as Java RMI, Java CORBA IDL, Java Serialization and Java Reflection API. It simplifies the development of multi-agent systems through the use of FIFA-sheets (Foundation for Intelligent Physical Agents) and through a series of instruments (tools), which support the phase debugging and deployment system. This Agent platform can be distributed among computers with different operating systems. It can be configured remotely via GUI- interface (Graphical User Interface).

The process of configuring the platform is flexible: it can be changed even at runtime. You must move agents from one machine to another. The only requirement is to install this system on a machine Java Run Time 1.2, which communication architecture offers flexible and efficient process messaging. This JADE process creates and manages the flow of all ACL-messages (Access Control List), which are private to each agent. Agents are able to address the queue by using a combination of several modes: blocking, voting, recess and comparison with the standard (this applies to search methods).

The authors analyzed that today the system uses Java RMI, event - notification and IIOP. Also, it is easy to add other protocols. In the JADE system provides the ability to integrate SMTP (Simple Mail Transfer Protocol), HTTP (HyperText Transfer Protocol) and WAP (Wireless Application Protocol). JADE uses a number of companies and academic groups. Among them are such well-known: BT, CNET, NHK, Imperial College, IRST, KPN, University of Helsinky, INRIA, ATOS and many others.

JADES FEATURES

The authors singled out the key features of the JADE systems that are on Fig. 9.

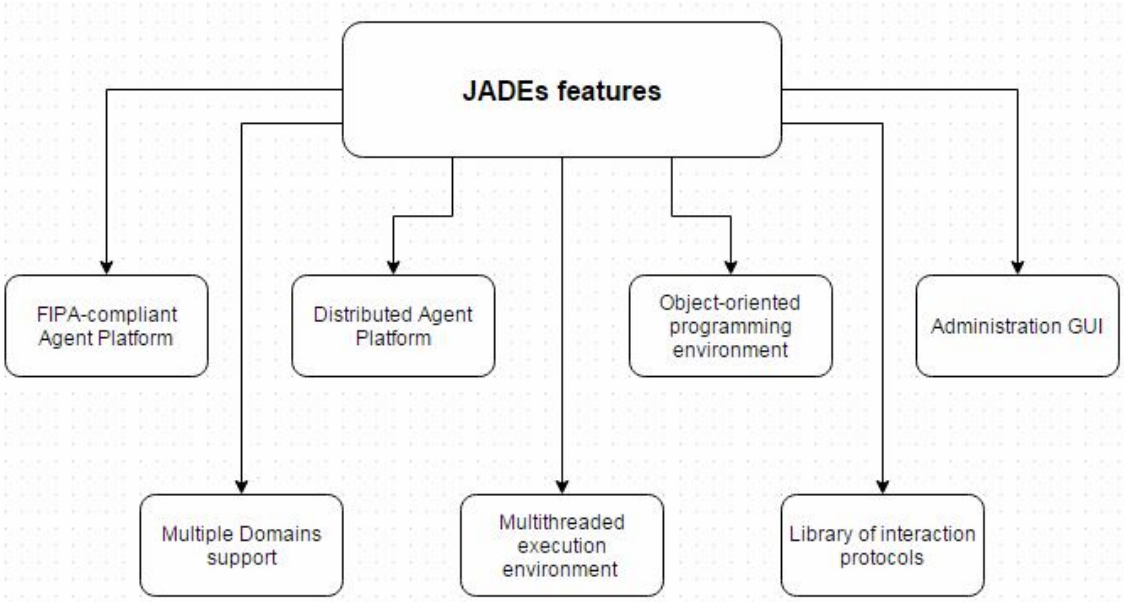

Fig.9. JADEs features

Shown in fig. 9 FIPA-compliant Agent Platform agent platform is based on FIPA-required specifications and include the types of systemic agents: AMS (Agent Management System) and DF (Directory Facilitator). These two types of agents are automatically activated when starting platform.

Distributed Agent Platform - is a distributed agent platform that can use multiple hosts, with each node runs only one Java Virtual Machine. Agents are implementing like Java-flows. Depending on the location of the agent, that sends a message, and the person who receives it, using suitable transport mechanism [6, 13].

Next possibility of JADE, suggested by the authors, is Multiple Domains support, which is based on the FIFA-specification DF-agents. They can unite in a federation, thus Multidomains of implementing agent environment.

Each JADE-agent has its own flow control that is able to work in multithreaded mode. Java Virtual Machine with the possibility Multithreaded execution environment with two-level scheduling conducts scheduling performed agents. Most of the concepts inherent FIPA-specification, have the ability Object-oriented programming environment, represented by Java classes. They form the user interface.

Library of interaction protocols using standard interactive protocols fipa-request and fipa-contract-net. To create an agent that would act in accordance with these protocols, application developers need only implement domain-specific actions. Under the system implemented in parallel JADE all independent of application logic protocol.

GUI. Simple operation management platform can be performed through a graphical interface that displays active agents and agent containers. Using the Administration GUI capabilities to create, destroy, break and resume action agents, create a hierarchy of domains and multi-agent federation DF (facilitators).

Investigation agent calculations following determining a number of advantages and disadvantages. The benefits of agent-based computing include: reducing the load on the network, asynchronous and autonomous program execution, dynamic adaptation, functioning in heterogeneous environments, robust and fault-tolerant behavior. The disadvantages are: problems of protection, limiting performance, a large amount of code, lack of a priori knowledge, methodologies and limited programming and implementation issues. Advantages and disadvantages affect the behavior, performance and system protection, network congestion, and scope of the program code.

CONCLUSION

In this work the basic concepts of agent and agent-based computing systems are adduced in general by the authors. Were analyzed agent systems architecture and a description of their parts, the most popular technologies and platforms for their development, opportunities and tools, as well as their practical application. Illuminated main types of intelligent and mobile agents, their characteristics and advantages and disadvantages. Adduced the basic advantages and disadvantages of agent-based computing. The authors provides a visual accompaniment theoretical material to better understand the article. Examples of real agents used in practice.

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Personified information technology to support the tourist with excursion content in DAISY format

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Abstract. The paper is devoted to a depth analysis of the intellectual processes of dynamic formation of personal audio and video content for mobile information support of a user during his touristic trip. The main goal is to develop methodological approaches that are appropriate to use for designing one of the subsystems of innovative intelligent system "MIAT" (Mobile Information Assistant of Tourists) that will provide formation and processing of audio and video content that is required for individual information technology of user support during realization his excursion. The authors examined the architecture of mobile audio travel guides and algorithmic synchronization tools of their multimedia content components. Travel guidebooks in DAISY format are proposed to use as sources of multimedia content that accompanies the trip or tour. The basic requirements for mobile subsystems of intelligent information systems "MIAT" are formed, so it is responsible for dynamic personalized audio and video support tourists during realization his trip.

Key words: DAISY format, "quantum of knowledge", mobile tourist information technologies, trip support, audio guide, multimedia travel guide, dynamic content, personalized information content, tourist information technology, audio tours, sightseeing content.

INTRODUCTION

Tourism is one of the most profitable and promising sectors of business activity. An integral part of world tourism business is the domestic tourist industry. In spite of all the political and socio-economic problems of recent years, the tourism industry has become the sector of the economy of Ukraine, which is constantly, almost without the involvement of state subsidies stable increasing volumes of tourism product. According to the rating of the World Tourism Organization, Ukraine ranks 8th in the world in the number of tourist visits. The country annually attracts more than 20 million tourists (25.4 mln. In 2008), primarily from Eastern and Western Europe, Canada, USA and Japan. The rapid development of the industry generates a wide range of problems whose solution can significantly extend the range of offered tourist services. Naturally in these circumstances there is a need to create new approaches to ensure modern tourist quality, comprehensive multimedia information on relevant tourist route. A key innovation factor according to the authors is a comprehensive information and technological support for the entire tourist route, not just in its separate points.

In this context, the actual task is creating intellectual information system that provides the functions regarding selection of quality synchronized media content according to the needs of tourists throughout his journey. Problems with solving this task lies in the absence of known methods and tools of dynamic sampling synchronized media content and its voice acting by Ukrainian language TTS or announcer, in web/mobile applications.

Development of intellectual information system of tourist tour support route aimed at a comprehensive and quality meet the information and educational needs of tourists who wish to travel without the services of a guide and individually, not as a part of a tourist group. The benefits of such autonomic trip:

- Freedom to choose the route, time and form of implementation,
- The possibility of a break, change or deviation from the route in random time and independent of its continuation on request,
- Mobile multimedia information support throughout the tour (audio, photo and video materials),
- The possibility of re-listening / viewing information materials regarding the relevant excursions,
- Savings in financial guide services and assembly of travel agencies.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Analysis of travel software mobile guides functionality

Mobile algorithmic audio guide – it is an application for mobile user devices that combines the functions of the information guide and an audio guide and is focuses on the information-technological support during realization touristic excursions. In addition to descriptions of historical and architectural excursion monuments in audio and text formats, to get specified type of program and algorithmic applications often contain much additional background information (hours and cost of visiting attractions of important infrastructure objects, dynamic photo video materials). Mobile algorithmic application, which is the audio guide using satellite navigation technology GPS, can automatically enable relevant asset story when approaching it as a tour or an ordinary walk.

In addition, using the same technology as a mobile information technology guide can show tourist's location on the map. Thus, mobile audio guide allows you to not only listen to information materials on the tour and stories about individual objects at the time of review and search infrastructure objects, but also accurately and correctly positioning a route in an unfamiliar city.

Mobile software tourist guides are one of the most popular tourist information technology applications class today. This tendency is due to the following factors:

- rapid development of the tourism industry,
- formation of significant stable demand for quality and affordable tourist services,
- advent of affordable mobile hardware with a wide range of functionality (smartphones, tablets, etc.),
- development of information technology territorial positioning and reliable user navigation.

The authors conducted a scrupulous analysis of advanced mobile software and algorithmic applications, which are tourist audio guides.

A striking example of this class is PocketGuide - mobile tourist audio guide that can accompany tourist information in many popular cities in the world [3]. Database (DB) system contains information on over 150 historical monuments of major cities and tourist destinations.

The application uses location information received from the user using the technology of GPS. When tourist approaches to a particular place of interest, application begins to voice information. Audio tours that are listed in the PocketGuide database leading from local expert guides and include not only general tourist information, but also interesting information regarding the certain objects. In addition, the system contains a selection of audio materials related thematic hiking area intended for those tourists who prefer individual, not mass popular traditional tourist routes (see. Fig. 1).

Separately it is necessary highlight that the application provides the user recommendations for dining, and allows you to create interesting travel blog with photos/video files, formed during its implementation.

However, the system has some drawbacks. Not all functionality specified intellectual information system is available in the public domain. Free information support tours made only online at the same time the user is given the opportunity to purchase the audio tour at the planning stage travel, and later during its implementation to obtain the necessary information without Internet connection. Also specified application supports only one database of Ukrainian city - Kyiv, so it is not technological to travel in the rest of Ukraine.

Fig. 1. The user interface of PocketGuide system

Another popular application is the mobile audio guide - a project that built through cooperation of Internet users who collectively form the appropriate database/knowledge [4]. The aim of the mentioned program is to provide free audio guide service in every corner of the planet, but tours created exclusively for users of the system through the website application. Most tours voiced in English and Spanish.

During the trip AudioViator locates tourist-user and provide advice accessible audio information about places nearby. This application informative accompanies popular tours in the museum and exhibition hall and contains information about each exhibit in text, audio and photo format of files.

At the same time disadvantage of this system is unprofessional presentation of information on relevant stages, so there is quite a high probability that the information is incomplete and not reliable.

A similar public information technology service platform is izi.TRAVEL [5]. In 2011, a team of innovators from the Netherlands, together with investors from Switzerland, set a goal - to give all travelers a new tool to obtain a feeling of closeness to monuments and sites of historical and cultural heritage of civilization, creating a global, open and free system for users worldwide. In essence, the mobile information service izi.TRAVEL is a platform for creating and distributing audio tours and stories about tourist sites in audio format. The authors emphasize the service because the location and publish audio guides using the said platform is quite an effective marketing tool. Users have the opportunity to create city tours that can lead visitors to interesting appropriate exhibits, while it has some drawbacks – the information to assess interest and popularity of a tourist attraction can be quite subjective.

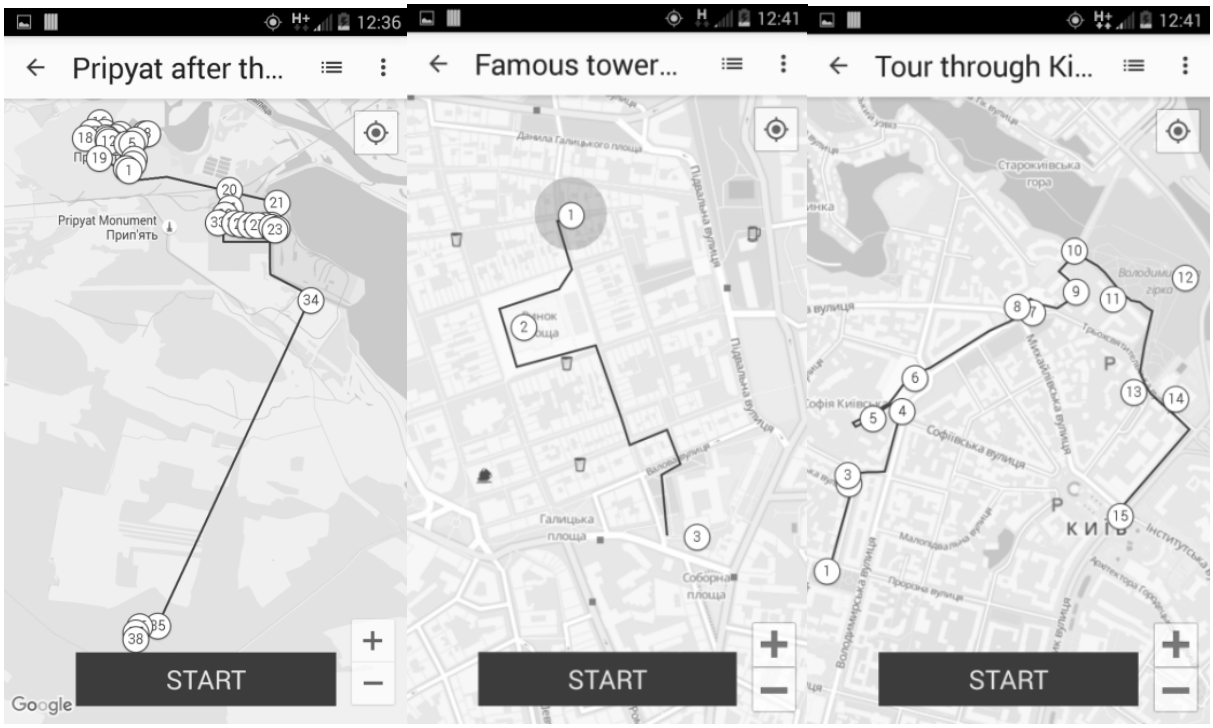

Fig. 2. Izi.TRAVEL audio tours in territory of Ukraine

The information system database contains tourist different type information content - quizzes and multimedia files (photos and video materials) designed to meet the demanding needs of the user and increasing its interest.

Among the tours, which are recorded in the izi.TRAVEL database is (see. Fig. 2):

- «Famous tower clocks», which is available in Ukrainian, English and Russian languages, the tour lasts 40 minutes and includes 3 stops,
- «Tour through Kiev», which is available in English, lasts 40 minutes and includes 15 stops,
- «Pripyat after Chernobyl disaster», which is available in English. The tour lasts 6 hours and involves 38 stops.

Quite popular tourist audio guide is a mobile application 1000Guides [6]. Like most of this class, 1000Guides combines the functionality of simple text guide, navigator and, of course, the audio guide system also incorporates dictionary and phrasebook. The feature of the system is the possibility of tourist routes forming by choosing just those points of interest that are interested in a particular user.

The system supports two modes of operation:

- Standby - sounding information takes place in the tourist arrival to the appropriate facility,
- Excursion mode - specified mode requires consecutive passage user points planned by route. The system generates messages for correcting direction of the user.

Information in text and video submissions supplements audio information. Information about the user's location formed by using GPS and GLONASS technologies. The system requires no Internet connection.

As a drawback the system has relatively small in volume database that contains travel guides for 12 major European cities, but among the positives it is convenient and additions. System's content is paid.

Table 1 shows the comparison of up-to-date popular audio-guides that were described in the article.

Table 1. Comparison of popular mobile touriat audio-guides

Mobile Audio-guide	PocketGuide	AudioViator	izi.TRAVEL	1000 Guides
General interactive map	+	+	+	+
Detailed map of tourist objects	-	+	-	-
Planed tours	-	+	+	-
Self tour forming	+	-	-	+
Professional content	+	-	-	+
Multimedia content	+	+	+	+
Tours among Ukraine	Kyiv	-	Lviv, Kyiv, Pripyat	-
Locating and navigating	+	+	+	+
Offline mode	+	+	+	+

OBJECTIVES

The problems of automated generation of semantic support the user tourist route are particularly in a synchronization presentation of multimedia tourist information (audio and video) and they exacerbated by the absence of a number of scientifically based integrated approaches to design of appropriate databases and knowledge, imperfection of preparing and classification data methods and lack of program and algorithmic tools for automated content creation and presentation. [1]

One of the key issues in this regard is the issue of sounding (listening) text materials that represent the major tour information.

In the US and some economically developed countries of Europe developed high quality speech synthesis application and screen readers. These technologies are almost impossible to transfer in the Ukrainian-environment without a deep transformation due to the nature in the voice sounding originality grammar and phonetics and sentences constructing rules.

Ukrainian language synthesis (announcer reading texts) is considered in the context of presentation and play multimedia texts, which include pictures and video files.

Known algorithmic methods do not provide a comprehensive system solution to the problem of forming synchronized multimedia database / knowledge containing information about the tourist route and do not provide effective tools for the development of an automated system for generating multimedia information support for the user to travel the route in real time.

Improving known and developing new methods of media presentation, processing and synchronization for their effective use in tourist trips is relevant scientific research and technological practical task [2].

The main purpose of the article is to analyze approaches which should be used for the design of one of the subsystems of innovative intellectual information system "MIAT" (Mobile Information Assistant tourists) that will provide formation and processing of audio and video content required for the individual personalized information technology support the user during realization it tourist excursions, and a generalized representation of the results of the author's research.

To reach those goals it is necessary to solve the following problems:

- analyze the main characteristics of current mobile software and algorithmic applications of audio guides,
- analyze possibilities for personalized DAISY format forming audio and video content of information excursions support,
- define the basic functional requirements to support rich media subsystem in the system MIAT.

THE MAIN RESULTS OF THE RESEARCH

Features of usage of DAISY standart

The analysis of the processes of forming the content according to travel routes for tourists support, that is organized by the authors, confirms the validity of choosing DAISY format (Digital Accessible Information System - available digital information system) as books that "talk" to use as a source of information in intelligent information system "MIAT".

DAISY is an open international standard for access to multimedia content. The main its developer is DAISY Consortium, which interacted with a number of professional and community organizations and formed the conceptual basis of standards in close cooperation with leading employees of a number of libraries, researchers and users. The main target group, which was led by scientific and technological innovation, consist of those with low vision and users with other disabilities. DAISY book is an multimedia content synchronizator of text, audio and graphics with advanced features of flexible navigation in it.

The core of DAISY technology is an effective synchronization tool for text, graphics and audio, that is based on the recommendations of the W3C, according to the needs of people who need to provide high-quality special way to access information.

The most common specification of DAISY version is known as ANSI / NISO Z39.86-2005 (R2012) [10] and ANSI / NISO Z39.98-2012 [11]. More than 70 participating countries that issue and disseminate books "speak" in the DAISY Consortium are registered.

DAISY formats became widespread in use when developing a specialized software and algorithmic applications for people with vision problems and content for them. The rates of the use of the format are rapidly increasing in library funds of foreign countries. Synchronized Multimedia Library is a key technology of the near future in this direction.

Among the most common problems of the Ukrainian market of publication and distribution of books that "talk" is inadequate legislation on copyright in the book meager circulation and a small assortment of books, lack of specialized equipment and recording studios.

The analysis of functionality of DAISY standard, suggests that it can be used for quality assurance wide range of requirements inherent in the process of creating a database / knowledge containing multimedia information on tourist excursions and walking trails, as it provides creating audio content using flexible mechanisms of navigation. Users can listen to a book linearly, and navigation tools make it possible to navigate through the sections, subsections, paragraphs and pages. The standard provides the ability to bookmark specific locations in the text to re-listen them.

The navigation map imposes in certain way in the audio book, so the "reader" can not only listen to the text, but to work with him to make bookmarks, notes and quickly accessed to information. DAISY books in general can be structured or unstructured. The decision to adopt such structures makes the library government or publisher who produces it.

The books DAISY standard technique used backup MP3 files, which can contain up to 90 hours of audio that tapped as the special reproducing devices and the computer on which you installed the software.

DAISY format specification uses numerous cross-references between text files XHTML, audios MP3, SMIL file synchronization and navigation control NCX. Extensible Hypertext Markup Language (XHTML) - is extensible hypertext markup language based on XML and opportunities for language similar to HTML.

The file structure of DAISY book includes content files (text and audio), synchronize files and content Book navigation controls, which are responsible for imposing the navigation scheme on the book. [12]

DAISY book can contain audio files, text files and images, or a combination thereof. [13] All books DAISY standard using a common set of file types, although some files are optional .

Almost all types of files based on XML [14]. Here are the most important types of files that are part of the DAISY book, a batch file, text file content, image file, audio, file synchronization, navigation file management, Resource file, file presentation style, file changes.

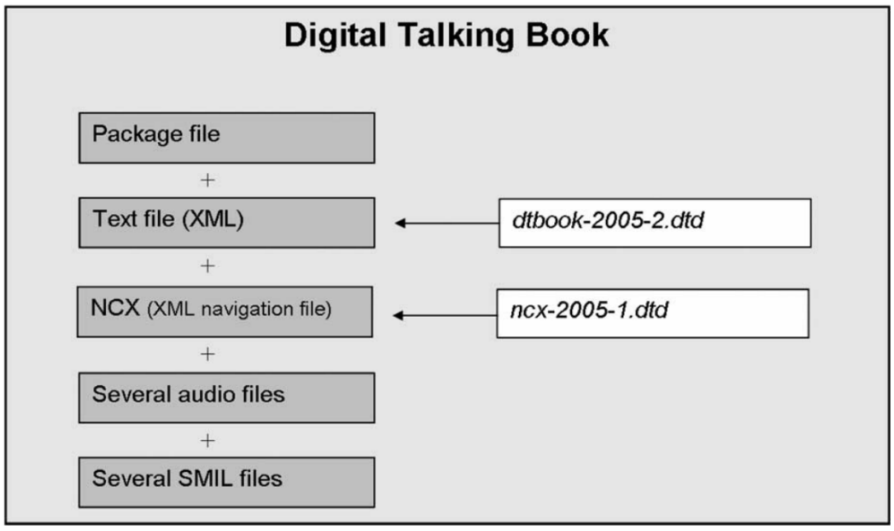

Fig. 3. The structure of a DAISY book

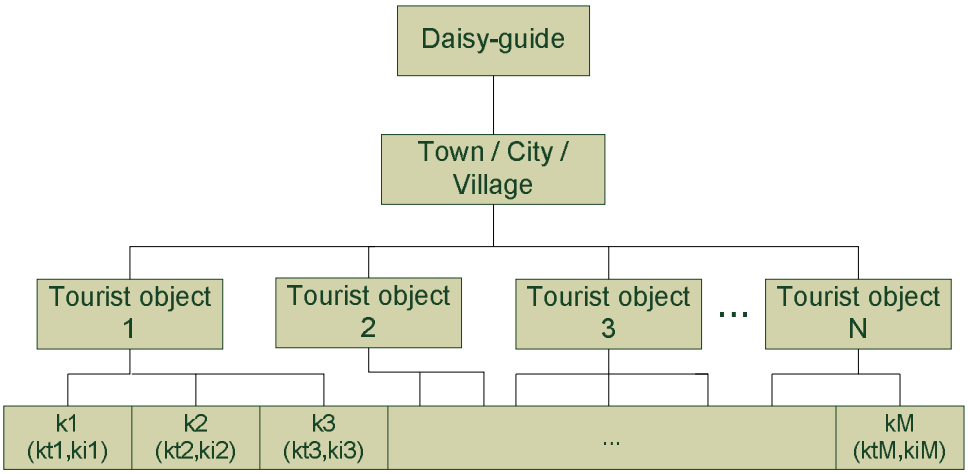

Fig. 4. The structure of DAISY-guide

Table 2 presents the possible types and file extensions that can be used in the manifest package.

Table 2. Types and Expansions of files that are used in DAISY books

Type	MIME Media file type	Expansions
MPEG-4 AAC	audio/mpeg4-generic	.MP4
MPEG-1/2 Layer III (MP3)	audio/mpeg	.MP3
Linear PCM - RIFF WAVE	audio/x-wav	.WAV
JPEG	image/jpeg	.JPG
PNG	image/png	.PNG
Scalable Vector Graphics, SVG	image/svg+xml	.SVG
Cascading Style Sheets, CSS	text/css	.CSS
SMIL	application/smil	.SMIL
Package file	text/xml	.OPF
DTD	application/xml-dtd	[no requirement]
Navigation Control File, NCX	application/x-dtbncx+xml	.NCX
Textual content files, dtbook	application/x-dtbook+xml	.XML
Resources files	application/x-dtbresource+xml	.RES

Technology presentation audio books previous generations much inferior technologies using DAISY format, because in this digital book can record six levels of hierarchy, which in turn makes it easier to navigate and helps to find the right section, subsection, page or even a word in the text. Undoubtedly, this is a convenient information technology to solve the problem on the formation of multimedia content database / knowledge that will contain information to provide information technology support users of various tourist routes.

Functioning features of subsystem "Multimedia guide" of system MIAT

One of up-to-date problems that face developers of intelligent system "Mobile tourist information assistant" [15] is a dynamic individual issues of formation personalized multimedia content for mobile tourist information support at the time of their tour.

Derivative objective of the study is to design information technology and algorithmic tool for intellectual formation and dynamic multimedia tour of content submitted in the application of user's mobile device (Smartphone or tablet). The originality of the proposed approach is the intellectual dynamic formation of individual personalized audio and video content for mobile information technology user support during the realization of a tourist trip. Dynamic formation of the tour content is an operational automated selection of tourist information according to the wishes of the tourist, his route of the trip. The originality of the proposed approach is that the guided tour is formed by the user in real time, taking into account the individual needs of a particular user.

Personified character is the provision opportunities to the tourist for forming independent tour route, taking into account individual needs, preferences and interests and selection of target points according to his personal interests. Mobility of filling the audio content to support sightseeing tour is to provide opportunities for tourist to get sightseeing information anywhere and at any time according to the head of information technology slogan "EVERYTHING! HERE! IMMEDIATELY! This technological mandatory requirement is the availability of Internet connection of a custom gadget.

Intelligence, primarily, is designed to provide to solve a task of automated synchronization process of multimedia content (display optional text description of the excursions of parallel support audio and video playback associate) for passing tourist route. The methods developed by the authors are intended to provide automated dynamic personalized formation of different multimedia content designed for mobile information support of the user with regard to his individual needs, wishes, velocity and the total duration of the tour as one of the basic functions of intelligent system "Mobile Information Assistant tourists" [16].

"Quantum of knowledge" are certain paragraphs of DAISY books that contain detailed structured information about tourist sights, such as architectural monuments, museums, galleries, castles, palaces, monuments, etc. (see. Fig. 4). The information given in the DAISY-guide (tourist guidebook in DAISY format), accompanied by the additional information associated with the location of various tourist sites. Each tourist sites meet several "quantum of knowledge" that differ in length of play, the type of data presentation and options according to specifications profiles. Data describing the "quantum of knowledge" are three identical dimension arrays: k – array "quanta of knowledge" about tourist sights, (kt) – an array of values corresponding durations of play of "quanta of knowledge" and (ki) – array, which recorded compliance "quanta of knowledge" individual characteristics of users.

The size of the individual tourist DAISY-guide – is limited, it may contain a set of "quantum of knowledge", the total playing time does not exceed 90 hours. In this regard, there is need for the formation of databases that will consist of several DAISY-guides, which typically

contain multimedia information about tourist sites are located in a separate village or place the interests of a particular profile. Technologically determined that a DAISY-guide contains information about the maximum number of the most interesting sightseeing points (monuments, separate buildings, squares or parks) within one city, for example c. Lviv.

Research task is formulated as follows:

Given:

- array of tourist sites, the user will visit,
- start and end point of the route,
- the procedure of visiting tour sites,
- the duration of transitions between objects and stop near them,
- Database of DAISY-guides (array "quanta of knowledge" on tourist sites, array with the time length of each "quanta of knowledge", an array of conformity of each "quanta of knowledge" to individual wishes of users)

Develop:

- algorithm for generating of information content to support tours according to user-selected individual tour route its duration and specific requests

The user of mobile software and algorithmic application should be able to choose the key points of the future of the tour route and sequence set for visit.

With the help of Google Maps tool the user selects tourist destination points and the order of their visit, and clarifies exactly what streets he wants to choose to get between tourist places of his guided tour, see. Fig. 5.

Fig. 5. Forming tourist route with the help of Google Maps tool

The main user of this mobile software and algorithmic application is ordinary tourist who, in active interaction with the system, is planning his own tourist route.

System after processing the input data and the formation of the multimedia content of the individual's wishes, the specifics and peculiarities of a particular user, provides information and technological support user on the tourist route in an audio representation and provides support for diverse graphic and video materials.

It is assumed that in addition to ordinary tourists defined system, and enjoy professional guides and experts tourism organizations for planning and development of new routes and excursions and provide quality information services. The original information-technology solutions in this development is a dynamic formation personalized content databases / knowledge system "MIAT" using different multimedia (audio and video) information content while forming a database of knowledge that is supplied in a handy format and follows the international standard DAISY (see. fig. 6, 7).

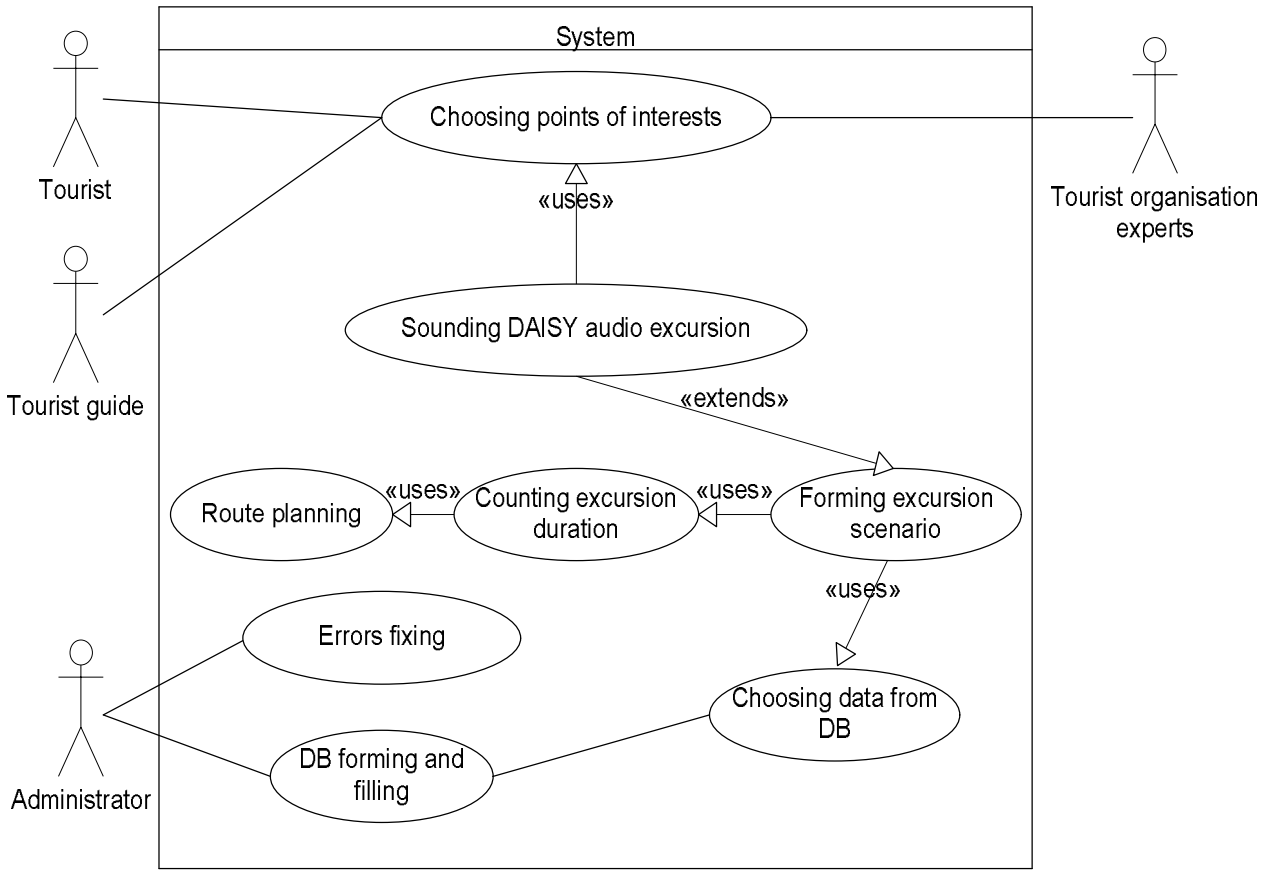

Fig. 6. UML Use-Case diagram. The roles of the user's classes

The process user interaction with the system "MIAT" presented in Figure 7. The user choses key points of the route that he wanted to visit and the approximate duration of stops during the tour.

CONCLUSION

The main purpose of the study is to analyze the approaches that are appropriate to use to design "Multimedia guide" – one of the subsystems of innovative intelligent system "MIAT" (Mobile Information Assistant tourists), which would provide dynamic personalized formation and processing of audio and video content for individual tracking of users during the tourist excursions.

Meticulous analysis of current mobile audio travel guides shows a number of important characteristics of this class of information systems and fundamental flaws in the market system in the public domain.After analyzing the tools of creation and synchronization of components of multimedia content, authors concluded that the DAISY format, that is developed for the submission and processing of audio books has the qualities necessary to create multimedia content information and technological support of the user at the time of his tour.

The designed multimedia subsystem of "MIAT" that is responsible for the dynamic audio and video support of tourist is presented in the article.

The main the target user is an average tourist, but there is also an ability to use the application by tour guides and experts of tourism organizations that want to improve the quality of services they provide. The design of the user interface satisfies the requirements of usability and quality and easy playback of multimedia content.

In general, "Multimedia guide" subsystem structure is quite extensive and high-quality implementation requires the usage of powerful algorithmic software and information technology tools.

In the future, the development of the algorithm of operation of subsystem "Multimedia guide" of system MIAT and its intelligent components is planned. The main functional load of them is to determine the characteristics of the user's profile information, forming personalized routes and provide advice on visiting some tourist sites, taking into account the specific personal wishes of tourists.

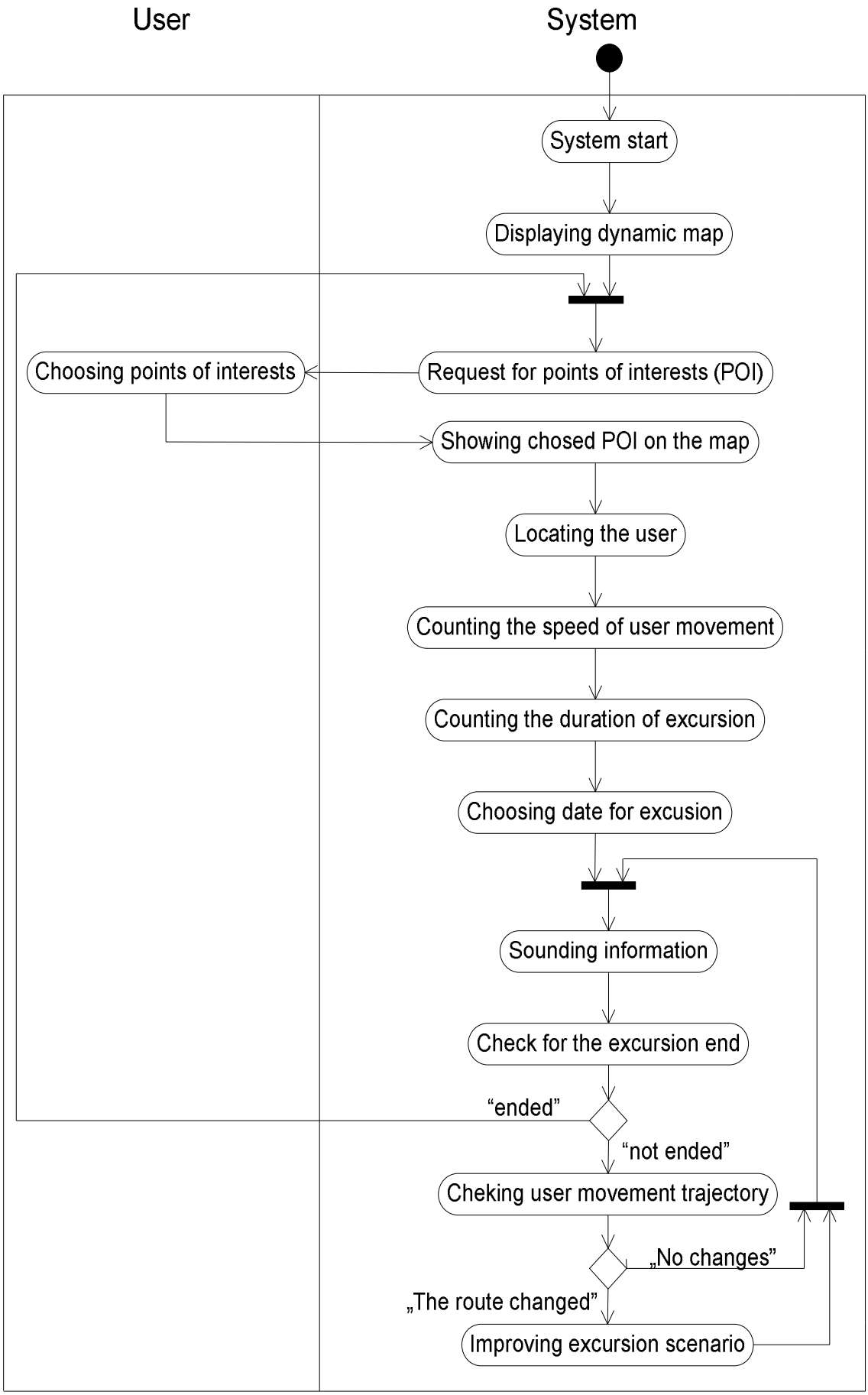

Fig. 7. UML Activity diagram. User interactions with the system

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Informational resources processing intellectual systems with textual commercial content linguistic analysis usage constructional means and tools development

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Abstract. The article content lies in solving the important applied scientific problem of the informational resources processing intellectual systems (IRPISes) with textual commercial content linguistic analysis usage creation. The IRPISes functioning mathematical ensuring was developed. The IRPISes construction means and methods will be developed on the basis of created mathematical models. Such systems have the widespread usage, in particular for the forming, managing and maintenance of the expanding content volume in Internet, running e-business, during the online and offline content realization systems, cloud storage and cloud computing.

The increase in the content volume causes the proper quality and productivity evaluation of the very content author. The increase in the evaluation criterions allows covering the broader aspect range of any author's / moderator's work.

Key words: informational resource, commercial content, content analysis, content monitoring, content search, e-content commerce system.

INTRODUCTION

The active Internet development promotes the increase in operative industrial/strategic operating data and informational services via up-to-date IT e-commerce realization requests. The commercial content is the documented information prepared according to users' requests. For today the e-commerce is the objective reality and long-range business process. Internet is the business environment and commercial content is the most requested product with sales inside and the main content e-commerce processes object. The commercial content can be ordered, registered, paid and got online as goods strait away. The whole commercial content diversity (viz. scientific and publicistic articles, music, books, films, photos, software etc.) is sold via Internet. The well-known corporations to sell electronic content commerce are Google via Play Market, Apple – Apple Store, Amazon – Amazon.com. The informational resources processing in the informational resources processing intellectual systems (IRPISes) allows to receive the hot and objective data about the system operating and for financial market content segment competitive level evaluation; to estimate the level of competitors, their competitiveness onto the content expansion financial market [4, 6, 13-15, 17].

The majority of decisions and researches were performed on the concrete projects' levels. IRPISes are built on the close basis as one-time projects. Modern IRPISes are oriented on the outside the system commercial content realization. The IRPISes designing, creation, implementation and maintenance are impossible without usage of modern commercial methods and informational technologies to form, manage and support the commercial content. The main categories of the informational resource users/characters (customers, working groups managers and administrators) fix the informational resource design and decision making process. IRPIS has obligatory the informational resource with the content catalogue (with the possibility to search) and requisite interface elements for the registration data entering, the order proceeding, payments execution via Internet, delivery request (e-mail / on-line), receiving information about the company and the on-line help. The whole content managing process is recorded in the content maintenance subsystem to form the IRPIS functional statistics and propositions in content popular subjects list for the content forming subsystem [1-2].

MATERIALS AND METHODS

The informational resources working-out technology development is topical because of the factors such as the theoretical arguments insufficiency of the commercial content torrents processing methods and the IRPISes' informational resources processing software unification necessity. The practical factor of the informational

resources processing in IRPISes is related to the solution of such tasks as forming, managing and maintenance of commercial content growing amount in Internet, e-business fast development, growing possibility of the access to Internet, informational goods and services widening, increase in commercial content request. Principles and informational technologies of e-commerce are used for Internet-shops creation (selling of eBooks, software, video, music, movies, pictures), online systems (newspapers, journals, remote education, publishers) and offline content sales (copywriting services, Marketing Services Shop, RSS Subscription Extension), cloud storage and cloud computing. The major global producers of informational resources proceeding means (such as Apple, Google, Intel, Microsoft, Amazon) work in this area. The theoretical factor of informational resources processing in the IRPIS is connected with the commercial content processing IT development. The electronic informational torrents processing mathematical models were explored and developed in the scientific works of D. Lande, V. Furashev, S. Braichevskyi, O. Hryhoriev. G. Zipf proposed the words frequency distribution empiric rule of natural language in a textual content for its analysis. The content life cycle models are worked out in the works of B. Boiko, S. McKeever, E. Rockley. M. Weber, J. Kaiser, B. Glaser, A. Strauss, H. Lasswell, O. Holsti, V. Ivanov, M. Soroka, A. Fedorchuk introduced and developed the content analysis methodology for textual data arrays processing. The methods of textual information intellectual processing proposed in the works of V. Kornieiev, A. Harieiev, S. Vasiutin, V. Raikh. The EMC, IBM. Microsoft, Alfresco, Open Text, Oracle and SAP corporations has developed the Content Management Interoperability Services specifications for the Web-services interface to provide the e-business content managing systems cooperation. From scientific side of view this IT segment is investigated not enough. The every unique project is realized practically from the very beginning and, in fact, based on one's own ideas and decisions. The essential theoretical grounds, researches, deductions, recommendations, generalizations for the IRPISes designing and informational resources processing in such systems are extremely little regarded in the literature. The necessity in the analysis, generalization, and founding of the e-commerce realization and the IRPIS construction existing approaches has arisen. There is the actual task to create the technological means system based on the theoretical foundation of the IRPISes' informational resources processing methods, models and principles built on the 'open systems' principle which allows to control the process of the commercial content realization increase.

The analysis of the mentioned above factors let make the decision about the existing of some contradiction between the quick IT and IRPISes development and expansion on the one hand and comparatively small amount of scientific works towards this topic and their locality on the other. This contradiction causes the problem of the e-commerce innovational development through proper newest progressive IT creation and establishment restrain, which has the negative influence on this market sector growth. The task of the e-commerce informational resources processing scientifically grounded methods elaboration and the creation of the IRPISes creation, expansion and stable development software based on them is actual in the general problem terms. In this work the research to determine the regularities, specifics and dependences of the informational resources processing in the analogical systems (especially for textual commercial content automation processing) was done.

There are the tendencies of the automatic text processing (ATP) usage (Fig. 1) [20-22]:

- The Turing test: the system can be regarded as intellectual when no difference can be seen while talking with it [20-25, 30-31, 39, 41-44],
- The Internet systems (language naturalness) → the information research [4,6,13-15,17,32,46-48].

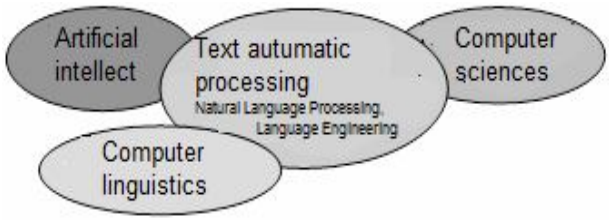


Fig. 1. The automatic text processing

The information research (IR) development fields [20, 27]:

- The fifties – Information Retrieval (IR) [1],
- The nighties – WWW (Google > 8 billion dollars, Yandex > 600 million pages, 2.5 million sites).

The main IR determinations according to [1, 3, 16, 20, 27] (Fig. 2):

- Filing, saving, organization of the information unit and the access to it,
- The focus on the user's informational requests,
- The accentuation on the search of information (not data),

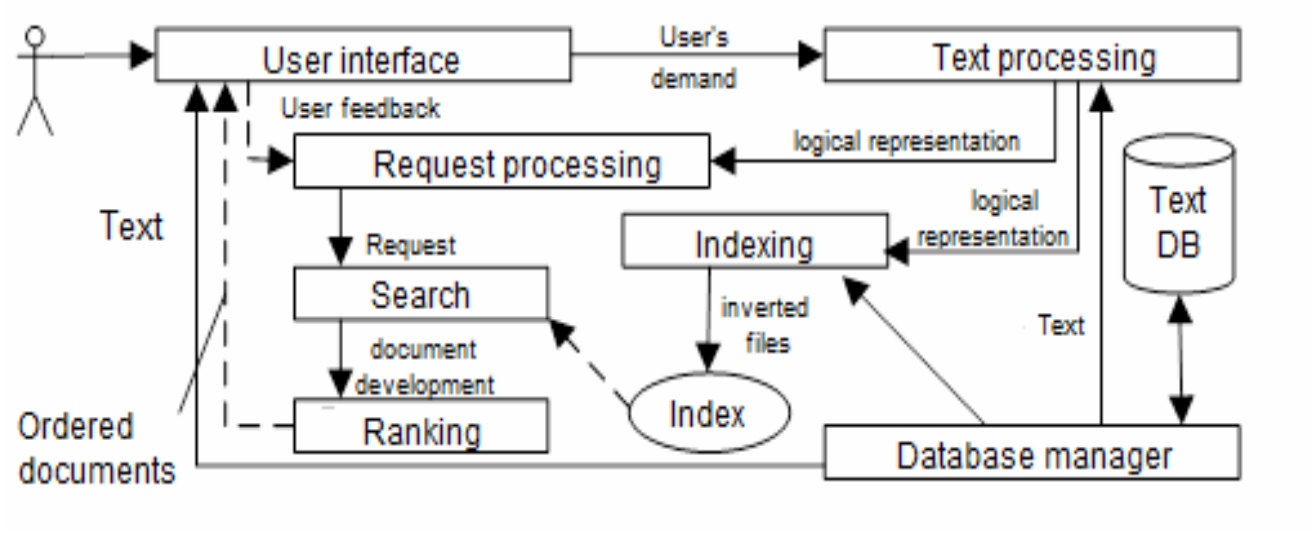


Fig. 2. The IR process

The direct search [20]

S	O	N	I	A	S		D	A	D		I	S		S	M	A	R	T

D	A	D

D	A	D

- Dboyer-Moore with the average complexity O(n/m)

S	O	N	I	A	S		D	A	D		I	S		S	M	A	R	T

D	A	D

D	A	D

D	A	D

D	A	D

- Brute force with the average complexity O(n+m),

The indexation is the process of the document research image creation (logical presentation). Usually it's the inverted index (according to [1,3-4,7-12].

$$\text{Dictionary}\begin{cases}\text{Brutus} & \Rightarrow 2 \to 4 \to 8 \to 16 \to 32 \to 64 \to 128\\ \text{Calpurnia} & \Rightarrow 1 \to 2 \to 3 \to 5 \to 8 \to 13 \to 21\\ \text{Caesar} & \Rightarrow 13 \to 16\end{cases}$$

Postings

The stages of previous ATP [20]:

- The extracting and / or receiving of the text (HTML, PDF…),
- The coding and language determination,
- The fragmentation of words and sentences (tokenization),
- The stop-words abolition,
- The lemmatization (stemming) – bringing the word into the lexicographic form.

Tokenization (the example) [20]:

1. Dates, numbers: 13/03/2014, 1415…;
2. Adverbs: finally, usually, thence, then, e.g.…;
3. The opening speech: in other words, to summarize, apropos…;
4. Prepositions: on the eve of, despite of…;
5. Particles: and yet, as if, like, besides, seems like…;
6. Verbose tokens: Ulan-Ude, New York, Ivan Ivanovych… (collocations);
7. The sentences' scopes: The last winter I.I. Ivanov came to Lviv.

The stop word determination [20]:

- Text = unstructured set of meaningful words ("bag of words"),
- The stop-words are the ancillary word class (prepositions, conjunctions, particles…): ah, aha, wow, yeah, hurrah, aside, along, besides, so, except, instead of, inside, outside, near…

The IR model [20]:

- The documents file method,
- The information request assigning method,
- The propinquity between request and document computation method.

The Boolean IR model [20]:

- The document = the set of words (terms),
- The request = the Boolean expression:

(cat OR dog) and food
Bird ANDNOT soldier

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	1	1	0	0	0	1
Brutus	1	1	0	1	0	0
Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
Mercy	1	0	1	1	1	1
Worser	1	0	1	1	1	0

The Boolean IR model peculiarities [20]:

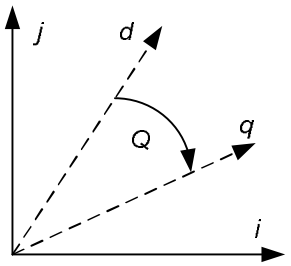
Advantages	Disadvantages
Simplicity	Too 'contrasting' (the document presentation as well as relevance)
Is easy for those who know the logical operators	

The IR vector model [10-12, 18, 20]:

- The document and the request are vectors in the space of words (terms); the importance of the word for the document / request is the vector component,
- The propinquity measure is the cosine of the angle between vectors ($\rightarrow$ ranking)

$$sim(\bar{d},\bar{q}) = \frac{\sum d_i \cdot q_i}{|\bar{d}||\bar{q}|},$$

where: d_i is the i term value in the document, q_i is the i term value in the request [1, 16]:



The term importance is calculated with taking into consideration the next factors [20, 26, 45, 49]:

1. How often does it occur in the document?
2. How often does it occur in the collection?

The $TF \cdot IDF$ approach, where TF - term frequency, IDF - inverse document frequency, so $TF \cdot IDF$ is the basic variant [1, 16].

$$tf_{ij} = \frac{f_{ij}}{\max\limits_k f_{kj}},\ idf_i = \log\frac{N}{n_i},\ w_{ij} = tf_{ij} \cdot idf_i$$

$TF \cdot IDF$, Okapi [20-22].

$$TFIDF_D(l) = \beta + (1-\beta) \cdot tf_D(l) \cdot idf_D(l).$$

- The request processing = the operations with the sets corresponding to words (terms).

The Boolean model example (according to [10-12, 20]):

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	1	1	0	0	0	1
Brutus	1	1	0	1	0	0
Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
Mercy	1	0	1	1	1	1
Worser	1	0	1	1	1	0

$$tf_D(l) \frac{freq_D(l)}{freq_D(l) + 0.5 + 1.5 \cdot \frac{dl_D}{avg\_dl}},$$

$$idf(l) = \frac{\log\left(\frac{|c| + 0.5}{df(l)}\right)}{\log(|c| + 1)},$$

where: avg_dl is the average document length, c is the collection size, $\beta = 0...1$

The vector model peculiarities

Advantages	Disadvantages
Works nice in the "pure" static collections	Can be easily attacked (spam)
Partial coincidences are conceded	Has low efficiency with short texts

Web [4, 6, 13-15, 17]

- Uncontrolled collection,
- Huge amounts,
- Different formats,
- Diversity (language, topics…),
- Competition (spam),
- Clicks,
- Links! (PageRank)

The base for research quality evaluation is the relevance concept (relevance to the information request), viz. the precision $p = a/b$, the recall $r = a/c$ and the F-limit $F = (p+r)/2pr$, where a is the number of relevant results in the reply, b is the number of all results in the reply, c is the number of all relevant results [20, 27].

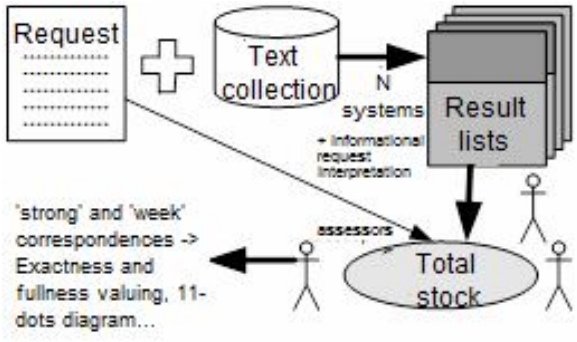


Fig. 3. The 'total boiler' method

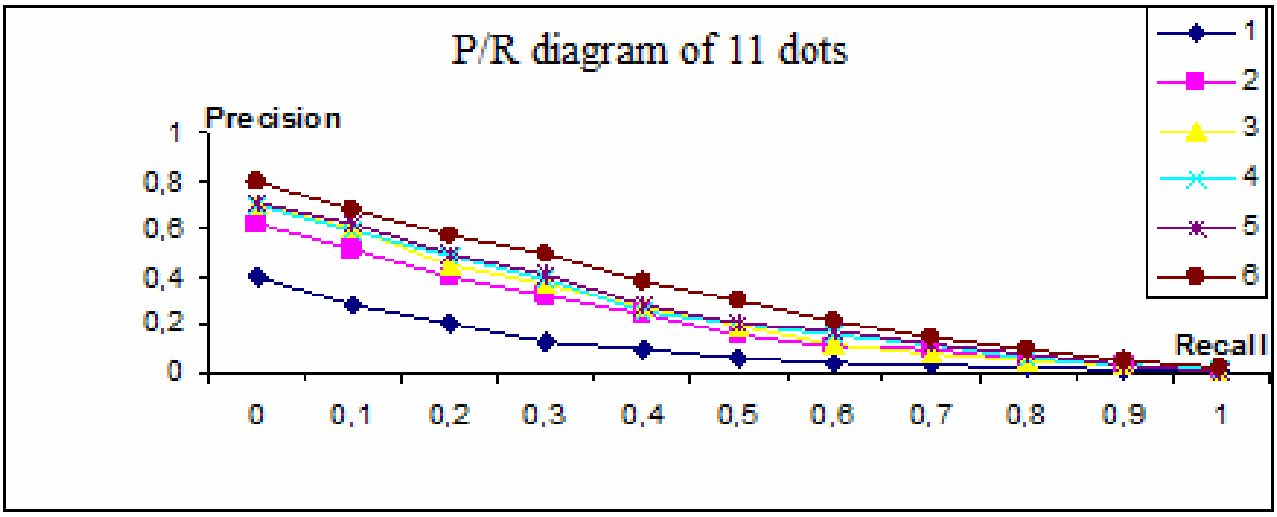


Fig. 4. P/R diagram of 11 dots

RESULTS AND DISCUSSION

The automatic morphological analysis necessity [20, 33-34, 36-38, 50-60]:

- The key words equivalent classes while searching: cat, cats, with cat…,
- The further processing (syntactic analysis, semantic analysis…).

The analysis types [20]:

- Stemming is the stem severance: *wood, wooden, woody, wooded* → *'wood'*, or *system, systematical, systematically, systemize* → *'system'*,
- Unification to the lexicographic form: *dancing* → *to dance, damaged* → *to damage, woods* → *a wood,*
- POS-tagging (part-of-speech): *leaves <N> dancing <V> in <PREP> the <ARTICLE> air <N>,*
- Absolute morphological information: *leaves <N, plural, not-being> dancing <V, present participle> in <PREP> the <ARTICLE, definite> air <N, single, not-being>.*

Stemming is the process of shortening the word to the stem by throwing affixes (like ending and / or suffix) away. The stemming results are similar to the word root finding but still the stemming result may differ from the morphological root of a word. Stemming is used in the morphological analysis and IR. The majority of search systems use the stemming for the slur process, i.e. merging of words into sets (synonyms), which have the similar forms after the stemming. After the stemming process is done the words *active, actively, activity* are led to the form *'activ'*. And the words *loud, loudly, aloud* are processed to the very root *'loud'*. The most active researches in this area were performed by Martin Porter. He had developed the algorithm which became widely popular and in fact became the standard stemming algorithm for the English language only [20].

Search in the table, where all the possible words variants after the stemming are collected [20]. The advantages are the simplicity, quickness and easement of the linguistic exceptions working out. As the disadvantages there may be regarded the search table should contain all the word forms, and, as the result, the algorithm will not work with new words and the table volume may be quite huge. For the languages with the simple morphology e.g. English the research table sizes are quite small, while for Turkish or Ukrainian there exist a huge amount of words with the one root. The table fragment of the *word* → *stemming* model for example for the word *гарний* looks like { *гарна*, *гарне*, *гарний*, *гарним*, *гарними*, *гарних*, *гарні*, *гарній*, *гарнім*, *гарного*, *гарної*, *гарному*, *гарною*, *гарну*} → *гарн*.

The endings and suffixes throwing away is based on the word shortening rules [20], e.g. if the word ends with '*льна*', '*ьна*' is cut off, if it does with '*льне*', '*ьне*' is cut off, if it does with '*льний*', '*ьний*' is cut off, if it does with '*льним*', '*ьним*' is cut off. Those stemming rules number is much smaller than the table with all word forms, thus the algorithm is quite compact and productive. The mentioned rules process correctly the following adjectives with the *word* → *stemming* model, e.g. '*вільна*'→'*віл*', '*мильне*'→'*мил*', '*сильний*'→'*сил*' та '*суспільний*'→ '*суспіл*'. The algorithm may make the mistakes. For example in the word '*пальне*' the wrong form '*пал*' may be instead of *'пальн'*. Taking into consideration the language special features the endings and suffixes throwing away rules set is complex especially for the Slavic languages. As the disadvantages there may be regarded the exceptions (the words which have the variable form) processing. For example words '*криком*' and *'кричу'* should have the *'крик'* form after the stemming process. The algorithm should take this into consideration which causes the rules complications and thus have a negative effect on the productivity.

Lemmatization is based on the word stem finding by the POS tagging (word classes' determination in a sentence) [20]. Then the stemming rules are applied to the word according to its word class belonging. Thus words '*пальне*' (noun) and '*сильне*' (adjective) should be processed with different rules sets. These algorithms offer the high quality and have the minimum mistakes percent if the part of speech discerning rules are correctly listed.

Scholastic algorithms are based on the word stem determination probability [20]. They have the ability *to learn*. The set of logical rules and the search tables are the knowledge base for these algorithms. After the word was processed with the scholastic algorithm there may be several word stem variants within which the algorithm takes the most probable one. For example there is the only one logical rule of the last letters cutting off. The knowledge base is built in the *word→ stemming→ ending* model, e.g. { *популярність → популярн → ість*, *хвилини → хвилин → и*, *добрими → добр → ими* }. The *ending* domain contains the results of the algorithm training based on the knowledge base. For the illustration let's perform the stemming of the word *'львівяни'* using the *word → ends with? → result→ numerical result* model i.e. {*львівяни → ість → по→* 0, *львівяни→и→yes→*1, *львівяни→ими→по→*0}. The only result was got, so the word after the stemming looks like '*львівян*'. But if the word *'відомими'* is processed with this algorithm the result with the *word → ends with? → result→ numerical result* model is ambiguous, i.e. { *відомими → ість→ по→* 0, *відомими → и→ yes→* 1, *відомими → yes→* 1}. The rule complication solves the contradiction because the stemming (within which the a word is shortened more or less) is more preferred.

The hybrid stemming approach combines all the motioned above algorithms. For example the algorithm uses the endings and suffixes throwing away method but on the first stage performs the search in the table. In spite of the search in the table this one contains not all the word forms but only the rule exceptions which are worked out incorrectly by the algorithm that cut off endings [20].

The prefixes cutting off process exists simultaneously with the word's suffix and ending cutting off. Not all prefixes may be disjoined from a word, e.g. the word *'незалежний' ('independent')* will be transformed to the *'залежн' ('dependent')* form, which is the exact antonym. But there are quite a lot of words in which a prefix don't change the main word meaning, e.g. *'проголошую, наголошувати, виголошував'* may be easily shorten to the *'голошу' ('tell')*.

For **the correspondence search** the knowledge base which only contains words' stems is used. In the other words this knowledge base consists of the forms created after the stemming process has been done to the usual words. If we parallel with the search in the table, it's the second column words. The main object of these algorithms is to find the most appropriate word's form in the knowledge base using the inside rules system. The similar length of the word and its stem system may be one of these rules. For example the knowledge base contains two stems '*чорн*' and '*чорняв*'. In comparison with the word '*чорнява*' the first variant has 4 joint symbols ('*чорн*') and the second one does 6 symbols ('*чорняв*'). Thus the algorithm takes the longer variant.

The stemming process within different languages. The first academic works were dedicated only to the English language, but now there are quite a lot of stemming realizations for various languages. The stemming algorithm writing process complexity depends on the peculiarities of the language. For English the stemming is quite a trivial task but for Arabic or Hebrew the task is ten times more difficult. There exist the stemming variants for the Ukrainian language and they are used in the commercial search systems. For this moment the realization of such algorithms isn't free.

Mistakes in the stemming process. Within the stemming algorithms the two types of mistakes are common.

- *Overstemming* – the stemming process which causes the shortening of two different words to the only stem (but this should never happen),
- *Understemming* – the mistake of the contrary matter. Within it words get different stems but they should get the same one.

The stemming algorithms aims to minimize the similar mistakes, but the minimization of one type mistakes may cause an increase of the other ones.

The IRPIS's information source is the set of data with the certain attributes (table 1) which are the objective of the IT operations within their transmutation into content process [2, 5-6, 19-22, 25-29, 32-40, 50-60].

Table 1. The IRPIS's information resources main properties

Name	Property
Heterogeneity	Presence of components with various nature, contents and file format
Coordination	Absence of contradictory and opposite content data
Format accessibility	Accessibility for all users based on the standardized means, methods and interfaces.
Openness	Possibility of the cooperation, data exchange and common usage with any external resources.
Dynamic	Quick actualization according to the system / environment terms
Scalability	Possibility to change the logical / real content volume (values, conceptions and their symbols)
Controllability	Content change / usage identification and the influence of content on the information system (IS) processes.

A result of the one IT usage may be an information resource for the other one. The IT content is the formalized statements and knowledge contained in the IS environment (in spite of the data which exists without any detailed specification of their properties, formalization and normalization methods. One of the significant issues of the IRPIS construction and functioning is the transformation of data different in its nature, content and origin into the centralized coordinated information resource. The data selection from primary sources, its fixation, filtering, transformation into the specific format to form content and set it in the database determine the information resources forming and usage order in a IRPIS (Fig. 5).

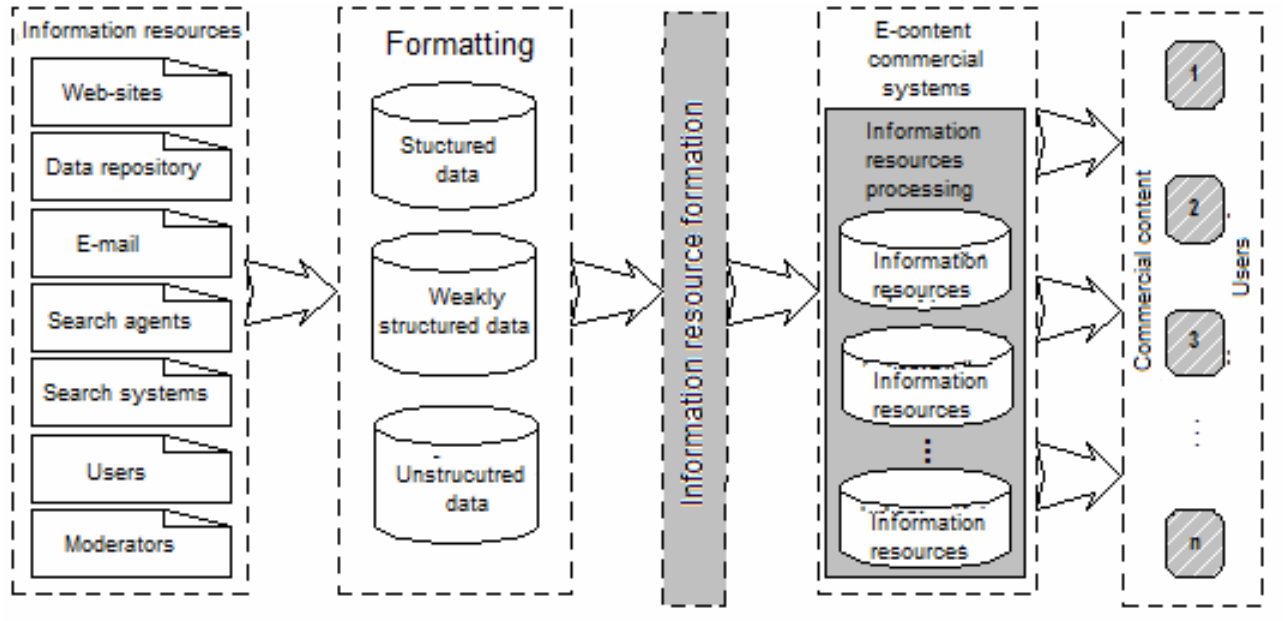


Fig. 5. The information resources forming and usage order in a IRPIS

The main IRPIS framing project task is the information resource architecture development by forming the actual commercial content which is created accordingly to the reaction of users on the commercial activity extension type (Fig. 6).

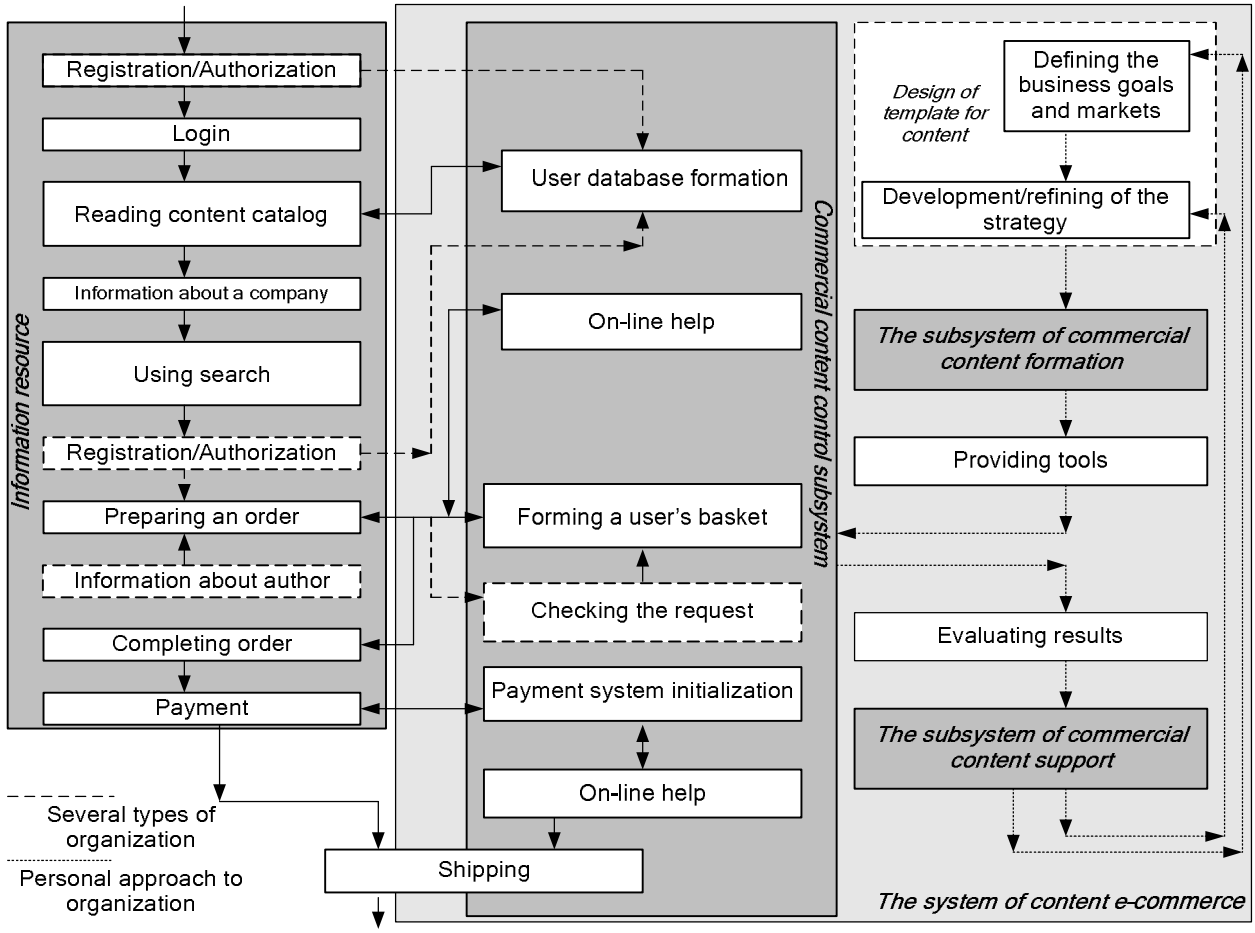


Fig. 6. The scheme of information torrents in e-content commerce systems

Let exist some prescribed initial content sources set n_X with fixed or variable composition. Every information source $Sourse(x_i)$, where x_i is the i-th content from the source under $i=\overline{1,n_X}$, forms some set of values which

contain statements/ knowledge /facts from the IRPIS subject field. The result of any requests to the source $Sourse(x_i)$ performed by IRPIS's technological means is the generating of the values set $X = \{x_1, x_2, ..., x_{n_X}\}$ that is acquired and presented in some fixed form. According to the system technological features, during the generated values selection and fixing process every values set generated by any of the information sources is transformed to the content input $C = \alpha(u_f, x_i, t_p)$ of the fixed format c_r, where $r = \overline{1, n_C}$.

Every set of content is presented the form of structured, weakly structured data or data without any specific structure description and is saved in the commercial content database $DataBase(C)$. For every single set the content structuring requires the forming of the set composition description, ways to combine elements and to normalize them (the set of terms $U = \{u_1, u_2, ..., u_{n_U}\}$ where u_f is the content forming condition under $f = \overline{1, n_U}$). The set of data from a source is the values set combination under certain format and set of terms $\langle X, U \rangle$ while forming the content input without any structure description ($U = \varnothing$). Before being saved the content should pass the verification / validation to confirm its formal / meaning correctness / relevance accordingly to the system requirements. If some material don't meet the specific measures this part of content is excluded from the further usage. The filtered content is formatted and saved and then the corresponding statements and knowledge become available for users via the- IRPIS i.e. $Sourse(x_i) \rightarrow x_i \in X \rightarrow X \rightarrow \langle X, U \rangle \rightarrow \alpha(u_f, x_i, t_p) \rightarrow c_r \rightarrow C \rightarrow DataBase(C) \rightarrow \beta(q_d, c_r, h_k, t_p) \rightarrow \langle C, H \rangle$ where $i = \overline{1, n_X}$, with n_X as the amount of content sources; $Sourse(x_i)$ – the source of i-th content; $x_i \in X$ – the i-th content of the source $Sourse(x_i)$; $X = \{x_1, x_2, ..., x_{n_X}\}$ – the set of data as a result of selection from the source $Sourse(x_i)$; $\langle X_i, U_i \rangle$ – the set of data with the terms set; $\alpha(u_f, x_i, t_p)$ – the content forming operator; c_r – the formed commercial content; C – formed content set; $DataBase(C)$ – the operator that saves commercial content in the database; $\beta(q_d, c_r, h_k, t_p)$ – the content managing operator; $\langle C, H \rangle$ is formed from the commercial content set and the informational resource content controlling terms.

The main stages of the information resource working out process are the content forming, control and maintenance with the following connections *content → content formation → database → content control → information resource / user request → content control → information resource → content maintenance → database*. The information resources working-out process may be presented as

$$S = \left\langle \begin{matrix} X, Q, Formation, H, C, V, \\ Management, Support, Z, T, Y \end{matrix} \right\rangle,$$

where: X is the content stock from various resources, Q is the users' searches set, $Formation$ is the content forming operator, H is the forming and controlling terms set, C is the commercial content set, V is the terms set concerning the content maintenance and the external influence on the system, $Management$ is the content managing operator, $Support$ is the content maintenance operator, Z is the information resource component set, T is the time of information resource processing transactions, Y is the system functioning statistical data set. The commercial content forming operator provides the commercial content transformation into the new state which differs from the previous one by the new content portion that supplements the previous state. The commercial content managing operator provides the commercial content transformation into the new state that differs from the previous one by values of the distinguishing parameters (the actuality, completeness, relevance, authenticity, trustworthiness) which should answer some specific requirements. The commercial content maintenance operator provides the commercial content transformation into the collection of values which are created as the result of the analysis, monitoring and evaluation of the cooperation between a user, search systems and other informational resources that are the decision-making base for the content formation and management. The content formation phase is outlined in the $Formation$ operator like $c_r = Formation(u_f, x_i, t_p)$, with u_f as the set of content formation terms, i.e. $u_f = \{u_1(x_i), \ldots, u_{n_U}(x_i)\}$.

Thus the content is presented in the following way

$$c_r = \left\{ \bigcup_f u_f \left| \begin{matrix} (x_i \in X) \wedge (\exists u_f \in U), \\ U = U_{x_i} \vee U_{\overline{x_i}}, i = \overline{1, m}, f = \overline{1, n} \end{matrix} \right. \right\}$$

The commercial content formation phase is outlined in the *Management* operator like $z_w = Management(q_d, c_r, h_k, t_p)$, where Q is the set of requests, H is the set of content managing terms, i.e. $H = \{h_1(c_{i+1}, q_d), \ldots, h_{n_H}(c_{i+n_H}, q_d)\}$. The content management process is presented as

$$z_w = \left\{ \bigcup_{k=1}^{n_H} h_k(c_{i+1}, q_d) \left| \begin{matrix} (c_{i+k} \in C) \wedge (q_d \in Q) \wedge (h_k \in H_q), \\ H = H_{q_d} \vee H_{\overline{q_d}}, i = \overline{1, n_C}, \\ d = \overline{1, n_Q}, k = \overline{1, n_H} \end{matrix} \right. \right\}$$

The maintenance phase is described in the *Support* operator of the next format

$$y(t_p + \Delta t) = Support(v_l, h_k, c_r, z_w, t_p, \Delta t),$$

where: v_l is the set of content managing terms and influences the environment has on the system i.e. $v_l = (v_1(q_i, h_k, c_r, z_w, t_p), \ldots, v_{n_V}(q_i, h_k, c_r, z_w, t_p))$. The output data is realized in the following way

$$y_j = \left\{ \bigcup_l v_l \left| \begin{array}{l} (\exists q_d \in Q) \wedge (\exists z_w \in Z) \wedge \\ (\forall v_l \in V) \wedge (\forall (c_r \wedge q_d) \in h_k), \\ V = V_{q_d} \vee V_{\overline{q_d}}, d = \overline{1, n_Q}, l = \overline{1, n_V}, \\ w = \overline{1, n_Z}, r = \overline{1, n_C}, k = \overline{1, n_H} \end{array} \right. \right\}.$$

Content formation is the data (from various information sources) processing control supporting measure complex for commercial content framing with the set of additional values such as actuality, authenticity, uniqueness, completeness, accuracy, etc. Content management is the determinant content parameters' (like actuality, completeness, relevance, authenticity, trustworthiness according to prescribed requirements in the criterion set) values supporting complex of measures.

Content maintenance is the complex of measures that provides the IRPIS's functioning in accordance with the prescribed requirements and the following ones. The complex system of related operations, methods and means (Fig. 7) is typical for any full-scale IRPIS. The content formation process may be presented by the following link pattern $Sourse(x_i) \rightarrow x_i \in X \rightarrow X \rightarrow \langle X, U \rangle \rightarrow \alpha_1(Downloading(\langle X, U \rangle), T) \rightarrow \alpha_2(Verification(\langle X, U \rangle), T) \rightarrow \alpha_3(Conversion(\langle X, U \rangle), T) \rightarrow \alpha_4(\langle X, U \rangle, T) \rightarrow \alpha_5(Qualification(\langle X, U \rangle), T) \rightarrow \alpha_6(\langle X, U \rangle, T) \rightarrow \alpha_7(\langle X, U \rangle, T) \rightarrow c_r \in C$,

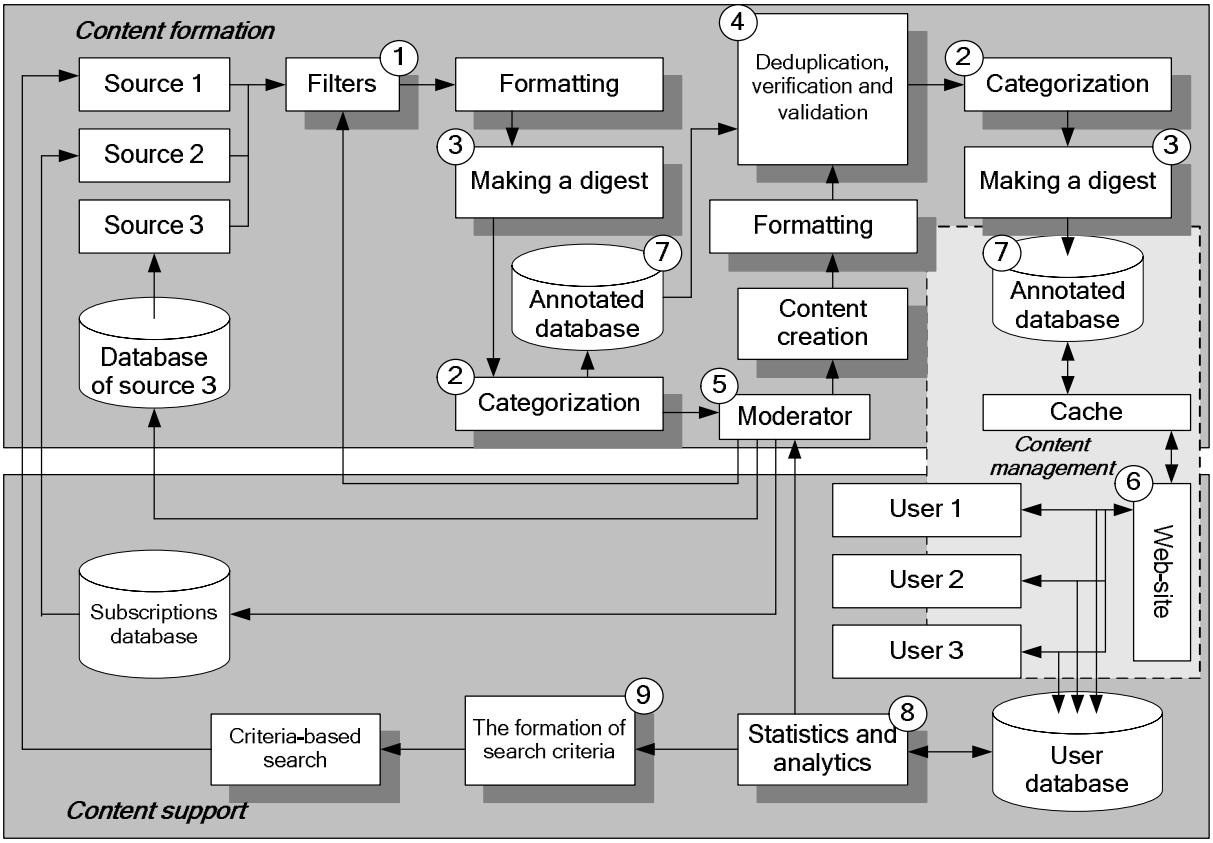


Fig. 7. The information resources processing methods

where: $X = \{x_1, x_2 \ldots, x_{n_X}\}$ is the input data $x_i \in X$ from various information resources or moderators under $i = \overline{1, n_X}$; α_1 is the operator that provides the content collecting from various resources; α_2 is the content reduplication detecting operator; α_3 is the content formatting operator; α_4 is the content's key words and concepts detecting operator; α_5 is the content automatic heading operator; α_6 is the content digest forming operator; α_7 is the selective content dissemination operator; $T = \{t_1, t_2 \ldots, t_{n_T}\}$ is the commercial content forming transaction's time $t_p \in T$ under $p = \overline{1, n_T}$; $C = \{c_1, c_2 \ldots, c_{n_C}\}$ is the commercial content set $c_r \in C$ under $r = \overline{1, n_C}$; $Verification(\langle X, U \rangle)$ is the content verification operator, $Qualification(\langle X, U \rangle)$ is the content qualification operator; $Conversion(\langle X, U \rangle)$ is the content conversion operator; $Downloading(\langle X, U \rangle)$ is the content downloading operator.

The process of commercial content formation for the information resource provides the link between the set of input data from various data sources and the formatted and saved commercial content set $S(x_i) \rightarrow x_i \rightarrow X \rightarrow \alpha(u_f, x_i, t_p) \rightarrow c_r \rightarrow C \rightarrow D(C)$, with $S(x_i)$ as the data resource, $S(x_i)$ as the commercial content database.

The content resources' types for the content formation subsystem are the following: the address list of information resources with confidential and other required

data; the address list of information resources with content subscription; the content set received from content moderators and authors; the request list with keywords for search systems. The content formation subsystem provides the gathering of information from various sources, its formatting, keyword detection, digest doubling and formation, heading and selective content dissemination. The commercial content formation subsystem is realized in the pattern of the content monitoring complexes which collect content from various data sources that provides the content database creation according to the customers' informational requests. In the result of the collecting process and pre-processing the content comes to the unique format, gets classified according to the fixed heading option, the descriptors with keywords becomes ascribed to the content. That makes the commercial content management process much simpler. The content managing system has the following tasks: the formation and rotation of the databases, providing access to them, the formation of the operative and retrospective databases, user work personalization, the retention of the personal users' requests and sources, functioning statistics conducting, the providing of the search within the databases, the output forms generation, the information interplay with other databases, the information resource formation. The commercial content managing subsystem is realized with the cashing usage (the presentation subsystem generated page only once, hereafter it loads several times faster from the cash which updates automatically after some period of time, when some parts of the informational resource was changed or manually by the administrator's request) or using the informational blocks (blocks are saved when the information resource is being edited; the page gets constructed of these blocks because of the user's request to open the corresponding page). The content maintenance subsystem provides the informational images formation; the content's thematic subject detection; the content interrelation table construction; the content ratings calculation; the detection of new events in the content streams, their monitoring and clustering.

CONCLUSIONS

The distribution is normally performed by moderators. The content distributional subsystem shortens the time and diminishes the resource usage for the further IRPIS functioning. The distributional process expects several stages to be processed: the distributional objects list formation (e.g. articles, software, books or digests); the estimation of the content distributional criterions / features from the received list (the content uniqueness percent, the amount of the content requests, the users' mark and the review time); the content authors ratings creation; the content's parameters evaluation for the purpose to use it within the distributional process. The listed criterions are not of the same importance and significance within their total analysis and the computing of the content authors' work quality composite mark. The content contains the thematics and the digest. The content distributional system selectively sends digests to authors according to their work quality ratings. The increase in the content volume causes the proper quality and productivity evaluation of the very content author. The increase in the evaluation criterions allows covering the broader aspect range of any author's / moderator's work.

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Analytical model of foil consumption for cylindrical bale wrapping

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Abstract. The work presents an algorithm for the calculation of the consumption of stretch foil used to wrap cylindrical bales of fodder in order to isolate the fodder from the air and other external factors. Mechanical properties of the foil, its arbitrary dimensions and any overlapping width of subsequent wrapped foil layers ware taken into account. A simulation program was written that allows to compute the number of foil layers in the bale lateral surface as a function of the width of the foil, the angle of the bale's rotation around its axis and the number of wrappings. The computer program contains graphical module which allows visualization of geometry of the distribution of subsequent foil strips and the arrangement of foil layer in a bale cross-section. The length and surface area of the foil taken from the roll are computed for different variants of the wrapping process. The computational example is presented for two geometrically different ways of wrapping and different initial widths of the foil. Conclusions and suggestions were formulated as a result of the simulation.

Key words: baled silage; stretch foil consumption; simulation model

INTRODUCTION

The quality of silage in the form of cylindrical and prismatic bales depends on the efficiency of its protection against the penetration of air and impact of other external factors. Anaerobic conditions facilitate the development of desired microbes that provide for the quality of the final product [5, 6, 17]. The conventional method of producing silage consisted in placing material in a specially prepared storage sites. The currently applied method of protecting silage involves mechanical wrapping of individual bales with a 25 μm thick tear-proof stretch foil. A comparative review of chemical, physical and biological processes occurring in the silage produced in storage sites and foil bales revealed that the conventional method was characterised by much lower losses and provided the silage of better quality [1].

The main reason behind the losses of silage when wrapped with foil is the lack of required leakproofness, which leads to fermentation, decay and development of fungi in the secured material [9, 18, 19]. Four layers of foil are usually sufficient to achieve oxygen-free conditions, but using 6 layers prevents the development of mould and reduces wilting to a higher extent, whilst the density of bales is of little significance [11, 14, 15]. Stretching the foil in 50% to 70% increases its adherence to the material being wrapped and to the previously applied layers. The degree of foil extension depends on the structure of the feeding unit, roller material, foil type and thickness as well as the temperature of air [12, 13] and has a significant influence on its consumption and leakproofness [9]. Excessive stretching of the foil might be the cause of micro-cracks or its visible damaging.

Financial expenditures on the purchase of stretch foil manufactured in the form of foil sleeves and tapes on rollers constitute a high percentage in the total costs of this technology of silage production [2, 16]. Foil consumption per unit of secured volume increases along with reducing the volume of the bale. More foil is consumed for wrapping single bales than in the case of collective wrapping of several bales [13]. Furthermore, the consumption is also determined by the method of applying the foil and its uniform distribution [6, 7].

In order to define the methods of reducing foil consumption while providing the required leakproofness, different authors analyse foil consumption by applying experimental methods for different extension degrees e.g. [4, 7, 8, 17] and various width of the mutual overlapping of adjacent strips [3, 6].

To conclude, the majority of studies on the subject focuses around experimental research following two separate directions – the study of the quality of secured silage in dependence on the physicochemical processes occurring in it, and the research of the dependence of the consumption of foil from the point of view of applied wrapping methods. However, there are almost no theoretical studies concerning the economical aspect aimed at reducing the costs of the applied technology. Only a few works provide mathematical expressions for the computation of foil consumption for wrapping individual bales e.g. [7, 10]. Different parameters describing the process are taken into account in these mathematical descriptions, and estimations performed with their use are, as authors claim, close to experimental results. In order to develop a mathematical description that improves the accurateness of the estimation of the measurement results, the mechanical properties of the foil and the geometry of the overlapping of subsequent layers must be taken into account.

The aim of this study consists in the development of mathematical model and writing computer software that

allows to compute the consumption of foil for wrapping separate cylindrical bales using the classic method illustrated in Fig. 1. The computations take into account the mechanical properties of the foil, which influence changes in its length and width after stretching and the width of the contact between adjacent foil strips, hereinafter referred to as overlap. The influence of the inclination angle of the foil strips relative to the cylinder height as well as the effect of the bale volume change and its deformations caused by the pressure of the foil were omitted in the study. Also, the geometry of the distribution of foil strips on the bales' top and bottom was not taken into account in the analysis.

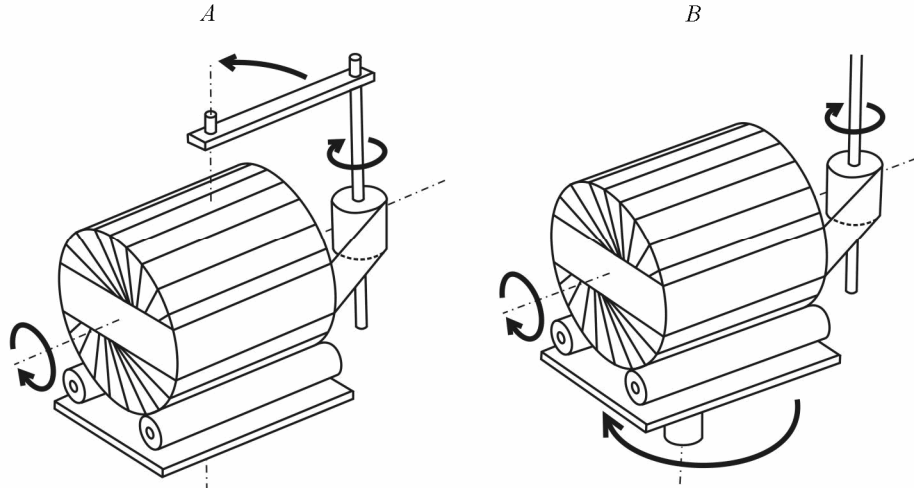

Fig. 1. Methods of individual round bales wrapping with the stretch film [2]: A – on the wrapper with a non-rotating table, B – on the wrapper with a rotating table

MATERIALS AND METHODS

Depending on the initial width of foil, its Poisson's ratio and unit deformation of the foil, the width of the foil after stretching was determined, and next the required number of wrappings was found. The distance between the edge, from which the wrapping begins, and the opposite edge of the final (applied for the final wrapping) foil strip was also determined. Then, the surface area of foil taken from the roll, used for wrapping the bale, was determined. A computing and graphic program was written to implement the derived mathematical expressions and facilitate the visualisation of the wrapping process. Exemplary computations were performed, in which foil consumption depending on its width and overlap was determined for two different values of overlap, which determine the different wrapping conditions.

FOIL CONSUMPTION

The following physical values were taken as input data for computations: D_b – bale diameter, H_b – bale height, b_f – width of unstretched foil, k_f – dimensionless relative ratio determining the width of the contact between adjacent foil strips, $0 < k_f < 1$, ν_f – Poisson's ratio of the foil, ε_{lf} – unit deformation of foil, n_b – assumed number of bale rotations around its axis.

Based on the definition of Poisson's ratio we obtain a formula, which allows to compute, for a given unit deformation ε_{lf}, its width after stretching b_{fr}:

$$b_{fr} = b_f\left(1-\nu_f\varepsilon_{lf}\right). \tag{1}$$

We assume that the geometry of movements determining the size of overlap are applied so that the subsequent strips of foil overlap one another creating the overlap $k_f b_{fr}$. We assume that the bale is wrapped correctly, when the last applied strip of foil overlaps the adjacent strips correctly, thus creating overlap $k_f b_{fr}$ on a preceding strip and overlap not smaller than $k_f b_{fr}$ on a foil strip applied in the previous layer. This means that the number of wrappings i_o for n_b rotations of the bale:

$$i_o = \frac{\pi D_b n_b}{b_{fr}\left(1-k_f\right)}. \tag{2}$$

Thus defined ratio i_o does not have to be (and usually is not) an integer. It provides the lower estimate of the total number of wrappings i_{oc}, hence, the number of wrappings i_{oc}:

$$i_{oc} = \lceil i_o \rceil \tag{3}$$

where $\lceil i_o \rceil$ is the smallest integer not lower than i_o (ceiling).

The ratio i_{oc} (3) not only makes it possible to determine the total number of wrappings that satisfy the assumed standard of bale wrapping, as characterised below, but is also significant for the design of algorithm for bale wrapping computations, as it allows to easily determine the "distance" z_o between the edge determining the beginning of wrapping and the opposite edge of the foil strip applied during the last wrapping. This "distance" for i_{oc} wrappings is equal to:

$$z_o = b_{fr}\left[1+\left(i_{oc}-1\right)\left(1-k_f\right)\right] - \pi D_b n_b. \tag{4}$$

The above expression, including the Eq. (2) can be rewritten in an equivalent form as:

$$z_o = b_{fr}\left[\left(i_{oc} - i_o - 1\right)\left(1 - k_f\right) + 1\right] . \quad (5)$$

On the basis z_o you can calculate the required angle of rotation of the beam α_b about the axis thereof:

$$\alpha_b = 2\left(\pi n_b + \frac{z_o - b_{fr}}{D_b}\right). \quad (6)$$

The length of stretched foil L_{fr} wrapped over the bale is given by the formula:

$$L_{fr} = 2i_{oc}\left(D_b + H_b\right). \quad (7)$$

The respective surface area of foil S_{fr} is equal to:

$$S_{fr} = L_{fr} b_{fr} , \quad (8)$$

whereas the length of wrapped foil L_f taken from the roll is equal to:

$$L_f = \frac{L_{fr}}{\varepsilon_{lf} + 1}. \quad (9)$$

The respective surface area of foil S_f is equal to:

$$S_f = L_f b_f . \quad (10)$$

GRAPHIC PROGRAM

The graphic program enables visualisation of the consecutive foil layers imposition in a bale's cross-section – see Fig. 2.

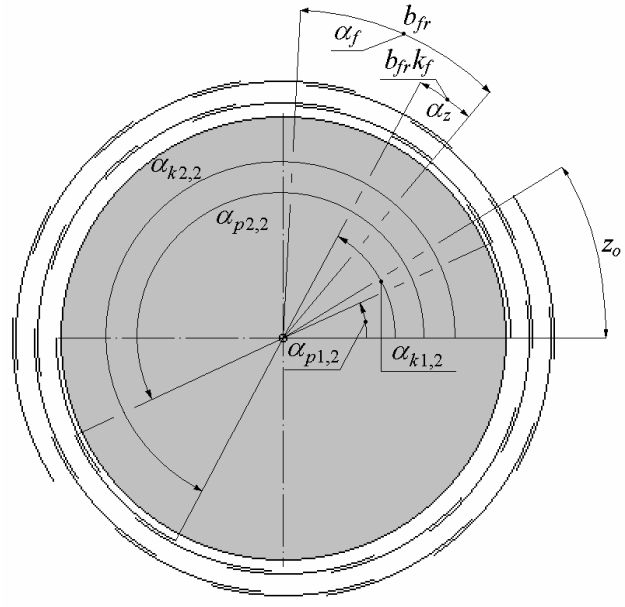

Fig. 2. The geometry of the foil layers distribution

For this purpose, the following values are computed:

- the radian measure of the central angle which subtends the arc of length equal to the width of stretched foil defined as the ratio of the length of the arc divided by the bale's radius:

$$\alpha_f = \frac{2b_{fr}}{D_b}, \quad (11)$$

- the radian measure of the central angle which subtends the arc of length equal to the width of overlap:

$$\alpha_z = \frac{2k_f b_{fr}}{D_b}, \quad (12)$$

- the radian measure of the angles of start and end of the i arc of length equal to the width of stretched foil:

$$\alpha_{p1,i} = (i-1)(\alpha_f - \alpha_z), \quad (13)$$

$$\alpha_{k1,i} = i(\alpha_f - \alpha_z) + \alpha_z , \quad (14)$$

- the respective radian measure of the angles of start and end of the arc of length equal to the width of stretched foil on the opposite (relative to the bale's axis) lateral surface:

$$\alpha_{p2,i} = (i-1)(\alpha_f - \alpha_z) + \pi , \quad (15)$$

$$\alpha_{k2,i} = i(\alpha_f - \alpha_z) + \alpha_z + \pi , \quad (16)$$

- radius of the arc:

$$R_f = \left(D_b + g_r i\right)p , \quad (17)$$

where: i is the number of the subsequent foil strip (subsequent wrapping) that changes from the value of 1 to the value of i_{oc}, p is the drawing scale, and g_r is the value by which the radius of the subsequent arc is increased in the graphic program. In Fig. 2 the starts and ends of arcs for the second wrapping are dimensioned.

Based on the computed values, the cross-section of the bale, with wrapped foil strips visualised as arcs, is drawn on the monitor screen. In order to make the drawing more legible, the next arc has bigger radius compared to the previous one, whilst retaining the same arc measure.

RESULTS

NUMERICAL EXAMPLE

The following fixed bale dimensions were adopted: diameter D_b = 1.2 m, height H_b = 1.2 m, and it was assumed that the bale is to be protected by at least four layers of foil. Computations were performed for two variants of wrapping, marked with letters *A* and *B*, in which the values of the ratio determining the width of the contact of adjacent foil strips and the assumed number of bale rotations around the bale's axis for successive variants were adopted as follows: *A*: k_f = 0.50, n_b = 1 rotation; *B*: k_f = 0.75, n_b = 0.5 rotation. The remaining numerical data used in the simulation were as follows: Poisson's ratio of foil ν_f = 0.34 and unit deformation of foil ε_{lf}= 0.7.

In order to study the influence of foil width on its consumption and wrapping geometry, the length and surface area of the consumed foil as the function of foil width were changed every 0.001 m within the range b_f = 0.25-0.75 m and presented in Fig. 3. The computations were performed for two examined variants.

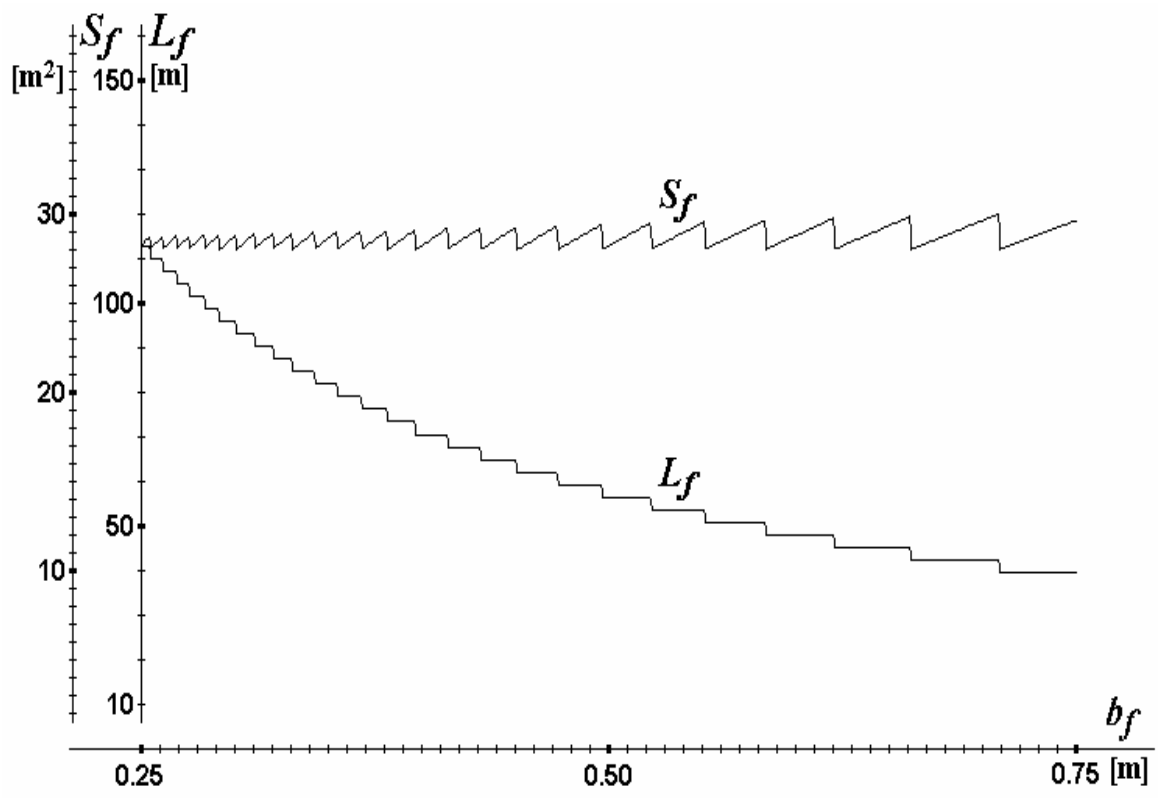

Fig. 3. The length and surface area of foil taken from the roll as the function of the foil width for variants *A* and *B*

The numerical values of computed factors and indices for three typical foil widths are presented in Table 1, whereas the cross-sections of the bales with indicated geometry of the distribution of foil strips are presented in Fig. 4.

Table 1. Numerical values of the computed factors and indices for three typical foil widths and two selected wrapping variants

Factor	**Unit**	**Numerical value**					
b_f/b_{fr}	**m**	**0.25/0.19**		**0.50/0.38**		**0.75/0.57**	
		A	***B***	***A***	***B***	***A***	***B***
$k_f b_{fr}$	**m**	9.50	14.25	19.00	28.50	28.50	42.75
i_o	**-**	39.68	39.68	19.84	19.84	13.23	13.23
i_{oc}	**-**	40	40	20	20	14	14
z_o	**$\times 10^{-2}$m**	12.53	15.77	22.03	30.02	50.53	53.77
L_f	**m**	112.94	112.94	56.47	56.47	39.53	39.53
L_{fr}	**m**	192.00	192.00	96.00	96.00	67.20	67.20
S_f	**m²**	28.24	28.24	28.24	28.24	29.65	29.65
S_{fr}	**m²**	36.48	36.48	36.48	36.48	38.31	38.31
α_b	**rad**	6.18	3.09	6.02	3.01	6.18	3.09

A: $k_f = 0.50$, $n_b = 1$ rotation; *B*: $k_f = 0.75$, $n_b = 0.5$ rotation

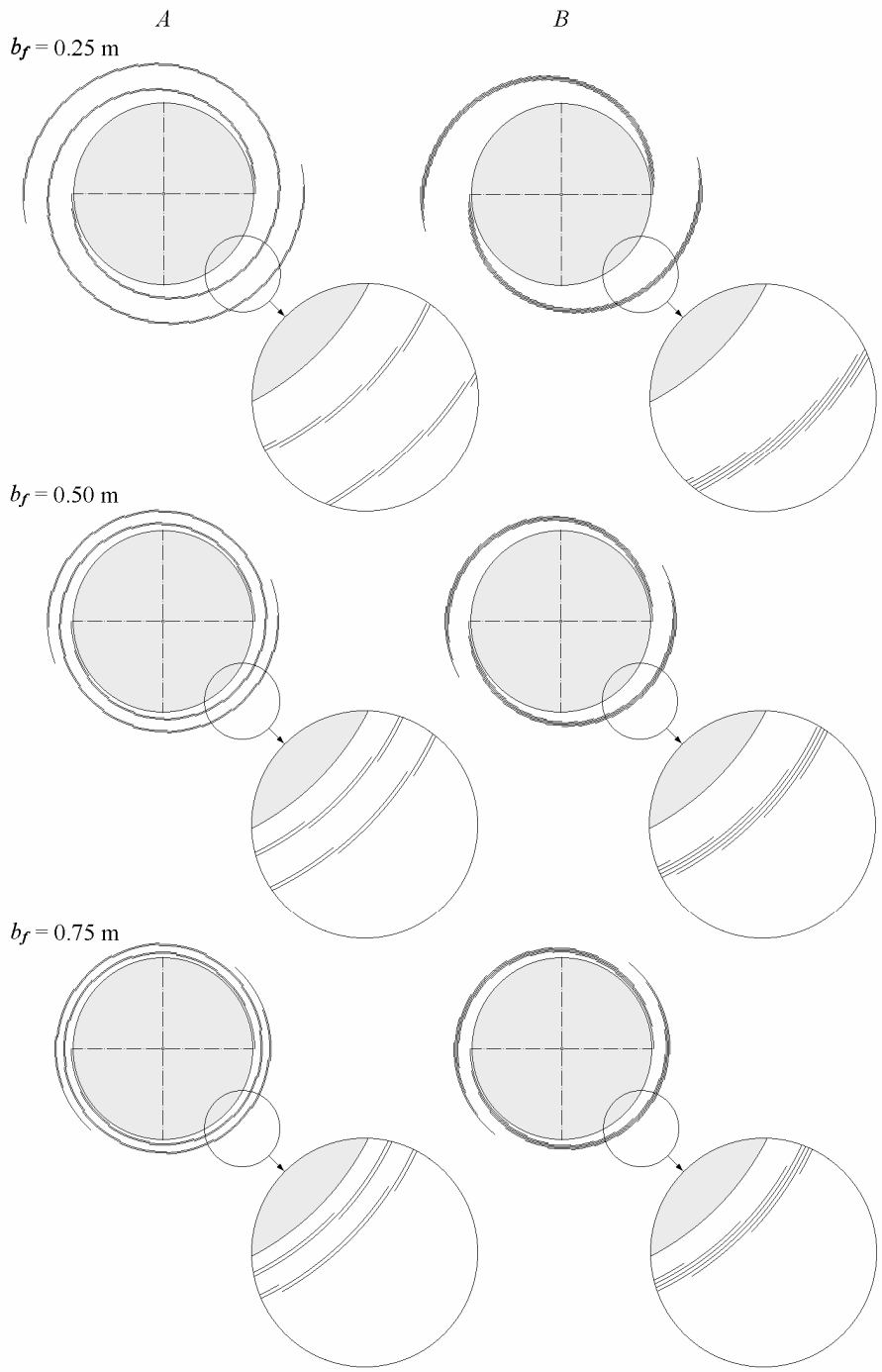

Fig. 4. The geometry of foil strips distribution in the bale's cross-section for the variants considered

DISCUSSION AND CONCLUSIONS

When using overlaps equal to 50% and 75% of the foil width (variants *A* and *B*), the required four layers are obtained and, as a result of applying the final foil strip, over 3% bale's covering of five foil layers is obtained. With the application of variant *A* one rotation about the bale axis is required, and with the application of variant *B* only half of such rotation guarantees the same number of wrappings. The courses of the length and surface area of foil taken from the roll are identical for both variants, which allows us to claim that the consumption of foil and the percentage shares of the numbers of layers are the same. Sawtooth waves of foil surface area as a function of foil width considered result from the variable and non integer value of the ratio of bale's perimeter to foil width, reduced by the value of overlap, which involves the necessity of applying the final supplementary wrapping. This also explains the increased consumption of foil in variant *B* for foil with the width of 0.75.

In general, foil width has no influence on its consumption. While foil width increases, the number of necessary wrappings decreases, and as a result the wrapping time decreases, too. The application of overlap of 75% of the foil width, half-rotation around the bale's axis and wider foil allows to obtain advantageous distribution of layers and much shorter wrapping duration time.

In the case of minimal reduction of foil width, e.g. as a result of applying higher stretching force or in the case of bale skidding during rotation, the number of layers may be lower than the computed according to the algorithm proposed. When using variant *A*, narrow "strips" are created on the bale's lateral surface, which are protected only by two layers, and when using variant *B* – by three layers. In view of the above, in order to obtain the assumed number of layers, overlaps larger than 50% and 75% for variants *A* and *B*, respectively, should be applied. It is recommended to distribute the resulting excess on all overlaps uniformly, which requires a respective program for the control of wrapper motors.

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Automation of determining the range of values for MEMS resistive parameters

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Abstract. This paper is devoted to the development of automating methods of the ranges determination process of the resistance values measurements for the investigated MEMS resistive parameters (strain gauges, piezoresistors, thermistors, magnetoresistors and photoresistors, etc.), electric resistance of which is changing during functioning of MEMS, in order to improve the accuracy of investigated resistive parameter value determining and optimization of the entire measuring process in general. The developed method for automation of values range determination of the MEMS resistive parameters measurand is based on the designed models and algorithm of automation for the process of an exemplary resistor value determination. A measurand of the investigated MEMS resistive parameter is located in a neighborhood of this exemplary resistor value. The abovementioned method is also based on the developed model and algorithm for automation of the values range determination of the MEMS resistive parameters measurand.

Key words: MEMS, resistor, range determination, automation.

INTRODUCTION

In recent years it becomes an increasingly distinct worldwide trend to actively implement the technologies of microelectromechanical systems (MEMS), components and devices [1-6] created by MEMS-technologies, into all areas of human activity. Such growth of popularity is caused, in particular, by a number of indisputable advantages, inherent to the devices, created by MEMS-technologies, unlike their macro analogues. Among those advantages are: micron size, low power consumption, high level of integration, functionality, reliability and others. However, the usage of MEMS leads to a number of problems, which are caused by peculiarities of these technologies. One of them is a problem of automation of the MEMS resistive parameters values determination, which involves the automation of electric resistance measurement process together with automation of a measured electric resistance value range determination process at a previous stage of working process in order to improve the accuracy of the measured value determination and optimization of the entire measuring process in general. Herewith an automation process of determination of the measurand value range of the investigated MEMS resistive parameter is preceded by automation of the process of determination of some exemplary resistor value, in neighborhood of which the measurand of the investigated MEMS resistive parameter is located.

PROBLEM OVERVIEW

There are many devices [7 - 15], which allows determining the measuring ranges of electric resistance automatically. By making the classification based on criteria of their applicability for solving the problem of automation for MEMS resistive parameters value ranges determination, the following basic types of deficiencies were identified:

- absence of narrow specialization and orientation of the devices in solving a wide class of problems (value ranges determination not only for resistive parameters, but also for inductive, capacitive ones, voltage, etc.),
- absence of narrow specialization of devices directly for the task of resistive parameters value ranges determination, and their orientation mainly on determination of the precise value of investiga-ted resistive parameter at one stage, that affects the accuracy of the measurand value, determined in such way,
- complexity (in some cases — impossibility) of realization (production) by MEMS technologies,
- complexity (impossibility) of extension the functionality,
- resistive parameters value ranges determination only in fixed value area, and complexity (in some cases — impossibility) of its extension.

Existence of at least one of the abovementioned deficiencies creates certain difficulties in using such approach for the given task accomplishment (and in some cases — makes their usage impossible).

Thus, there is a need for development of a new approach for automation of the investigated MEMS resistive parameters value ranges determination, which would maximally met all the criteria, the main of which are implementation simplicity and possibility of functionality expansion.

DEVELOPMENT OF THE ALGORITHM FOR AUTOMATION OF DETERMINATION OF AN EXEMPLARY RESISTOR VALUE, IN A NEIGHBORHOOD OF WHICH MEMS RESISTIVE PARAMETER MEASURAND IS LOCATED

Fig. 1 shows a flowchart of developed algorithm, which represents the process of determination of the exemplary resistor value, in a neighborhood of which MEMS resistive parameter measurand is located.

The developed algorithm works as follows. Index of electric resistance value range is established and it equals 1 (i:=1), thereafter the residual voltage ΔU of electric bridge imbalance is detected, its absolute value (ΔU:=|ΔU|) is calculated, which, in its turn, is stored into appropriate cell ΔUi. After that an increasing of electric resistance value range index (i:=i+1) occurs together with detection, processing and saving of the residual voltage of current electric resistance value range until all ranges (i>=n) will be analyzed. Next step of the algorithm is the process of distribution of residual voltages ΔU1–ΔUn by appropriate channels in order to determine minimal residual voltage ΔUj and the appropriate exemplary resistor Rj.

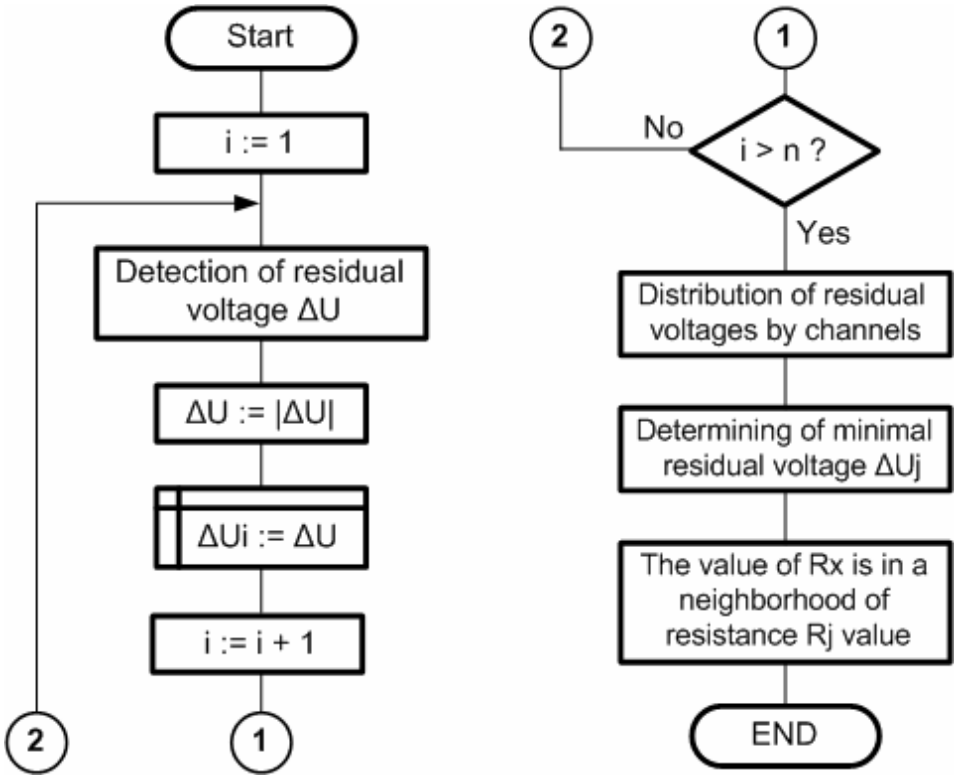

Fig. 1. Flowchart of the developed algorithm.

Thus, defining the minimal residual voltage ΔUj, which corresponds to some exemplary resistor Rj, we can say that the measurand of investigated MEMS resistive parameter is in the neighborhood of given exemplary resistor Rj value.

DEVELOPMENT OF A MODEL FOR ANALYSIS OF A DYNAMICS OF THE PROCESS OF DETERMINATION OF THE VALUE OF EXEMPLARY RESISTOR, IN A NEIGHBORHOOD OF WHICH MEMS RESISTIVE PARAMETER MEASURAND IS LOCATED

Fig. 2 shows the developed model, based on colored Petri nets [16 – 20], for analysis the dynamics of the process of determination of the exemplary resistor value, in a neighborhood of which MEMS resistive parameter measurand is located.

Developed model works as follows. Before an immediate start, the initial parameters are set, namely — a number of working ranges of electric resistance value in position p1 is assigned. If the number of ranges (n) is changed, the number of corresponding transitions of keys locking and individual positions of detected residual voltages has to be changed as well (see Fig. 2). After making all the necessary modifications in the developed model, a marker should be placed into work-starting position p2. In result of triggering of the transition t1, setting of the initial parameters of the model takes place, in particular the index of electric resistance value range is set to ‘one’ (i:=1), and marker moves to position p3.

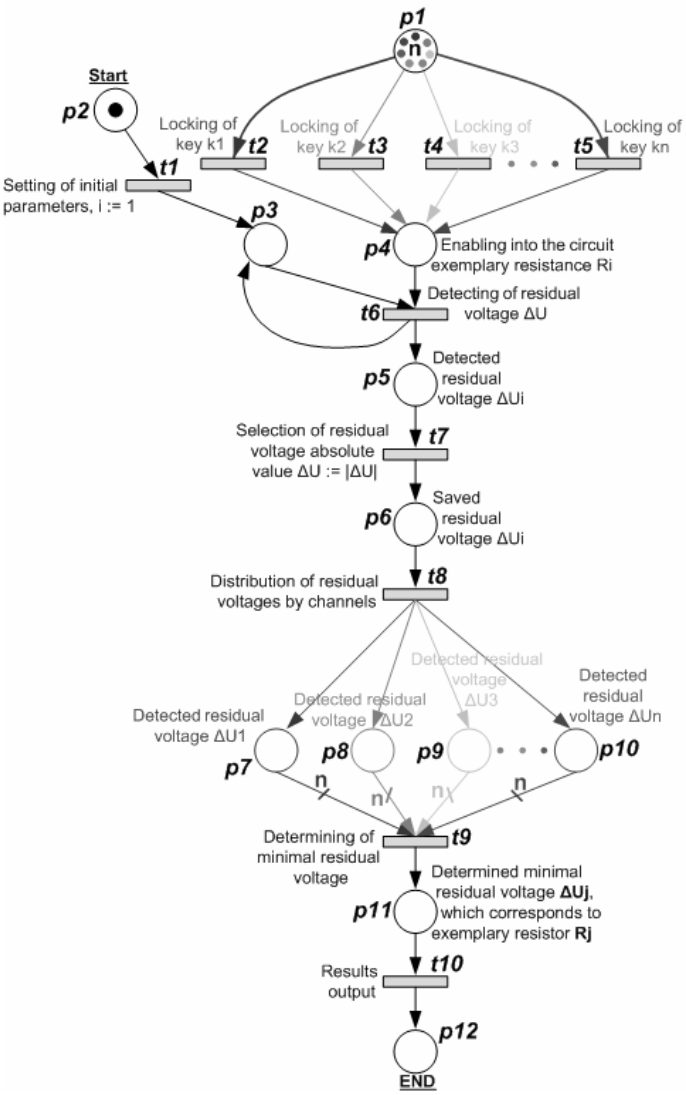

Fig. 2. Developed model, based on colored Petri nets, for the dynamics analysis.

After that the transition t2 is triggering, – the key k1 of the model is being locked, and the marker of first electric resistance value range moves from the position p1 into the position p4, which indicates the enabling into the model with exemplary resistance Ri an active electric resistance value range (in this case R1). Transition t6 is triggering and takes place the detection of residual voltage ΔU, which corresponds to the current exemplary resistor Ri, then marker moves into positions p3 and p5. Marker in position p5 activates the transition t7, which starts the process of evaluation of the residual voltage absolute value (ΔU=|ΔU|), and marker moves into position p6. By the marker from position p6 an activation of the transition t8 occurs and the mechanism of distribution throughout the channels of the residual voltages starts and also saving of current residual voltage ΔU in a corresponding cell ΔUi takes place as well. Marker moves into positions of detected residual voltages p7 – p10, increasing the number of markers in respective positions by 1 (the number of markers in these positions corresponds to the current range of electric resistance value), which indicates the completion of the analysis for the current working range of electric resistance value.

After that, analysis of the next electric resistance value working range occurs with activation of transition t3 by the second range marker of electric resistance value from position p1. Key k2 of the model is being locked, and enabling of the next exemplary resistor (in this case R2) into the model takes place, and analysis, processing and saving of the corresponding residual voltage ΔUi (in this case ΔU2), etc. occur until the last n-th working range of electric resistance value would be analyzed. In such case, positions p7 – p10 will be filled with n markers, so their number would be sufficient for triggering the transition t9, which launches the mechanism of determination of the minimal voltage. Marker moves into position p11, which indicates the determination of the value range of measured electric resistance. The transition t10 activates, and the output of model's working results is performed, and marker gets into the end position p12. The fig. 3 shows a state reachability graph of the above model, developed with colored Petri nets.

Constructed state reachability graph (see Fig. 3) shows sequential and parallel iterative working principle of the developed model, where markers of different types are processed by the same operations and only after all the markers will be processed, a transition to the final link of the tree would be carried out.

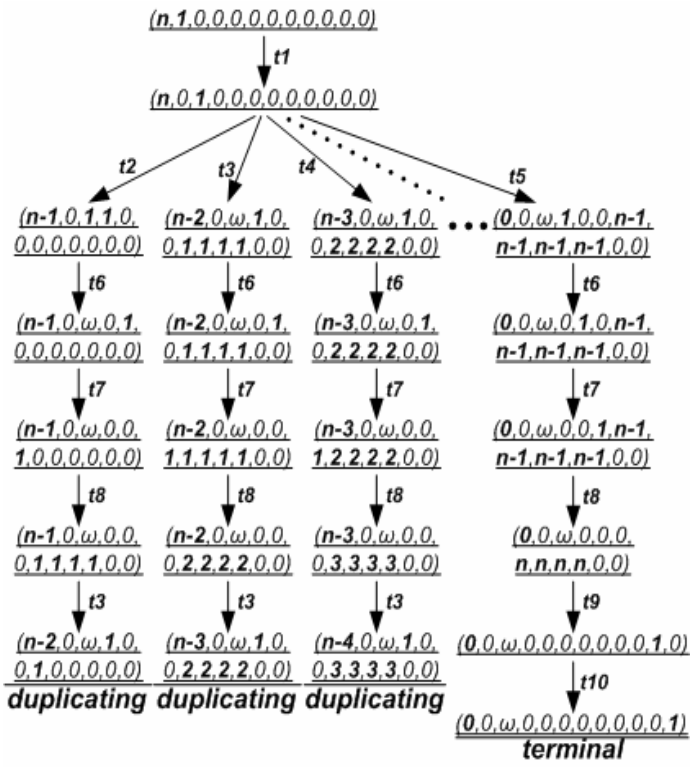

Fig. 3. The state reachability graph of the above model, developed with colored Petri nets.

Such structure of the graph is fully consistent with the developed model and method in general.

DEVELOPMENT OF A CIRCUIT MODEL FOR AUTOMATION OF DETERMINATION THE VALUE OF AN EXEMPLARY RESISTOR, IN A NEIGHBORHOOD OF WHICH THE INVESTIGATED MEMS RESISTIVE PARAMETER MEASURAND IS LOCATED

The fig. 4 below shows developed circuit model which realize the process of automation for determination the value of an exemplary resistor, in a neighborhood of which the investigated MEMS resistive parameter measurand is located.

Developed model contains the following main components (see Fig. 4): block of exemplary resistors R1–Rn, switching unit, based on keys k1–kn, measured electric resistance Rx (which represents investigated MEMS resistive parameter), two etalon electric resistances Rs1 and Rs2 (moreover, Rs1=Rs2), voltage absolute value selection unit, unit of distribution the residual voltages by channels, minimal voltage determining circuit and control unit.

In the results of sequential switching of keys k1-kn of the developed circuit model, some bridge circuit imbalance residual voltage ΔU appears in the neighborhood of equilibrium point of the electric bridge, formed by: 1) one of exemplary resistors Ri, 2) measured by electric resistance Rx (which represents investigated MEMS resistive parameter), 3) and sample resistors Rs1 and Rs2.

Thus, among all exemplary electric resistors R1–Rn the nearest (in magnitude) to measured value of investigated MEMS resistive parameter (represented by electric resistance Rx) will be that exemplary electric resistor Rj, during switching on of which into the bridge electric circuit of the model, the absolute value of residual voltage |ΔUj| of bridge circuit imbalance would be minimal. Thus, the measured value of investigated MEMS resistive parameter, represented by electric resistance Rx, is located in the neighborhood of the value of an exemplary electric resistor Rj.

DEVELOPMENT OF CIRCUIT MODEL AND ALGORITHM FOR AUTOMATION OF THE VALUE RANGE DETERMINATION OF THE INVESTIGATED MEMS RESISTIVE PARAMETERS MEASURAND

To establish ranges of measured electric resistance value, which is represented by the investigated MEMS resistive parameter, let us use the property of the residual voltage of electric bridge imbalance to change its sign to the opposite when passing through the equilibrium point. The fig. 5 below shows the corresponding graph of the change of residual voltage value in the neighborhood of the electric bridge equilibrium point (data were get from the results of modeling of the developed circuit model for automation of determination the value of an exemplary resistor, in a neighborhood of which the investigated MEMS resistive parameter measurand is located).

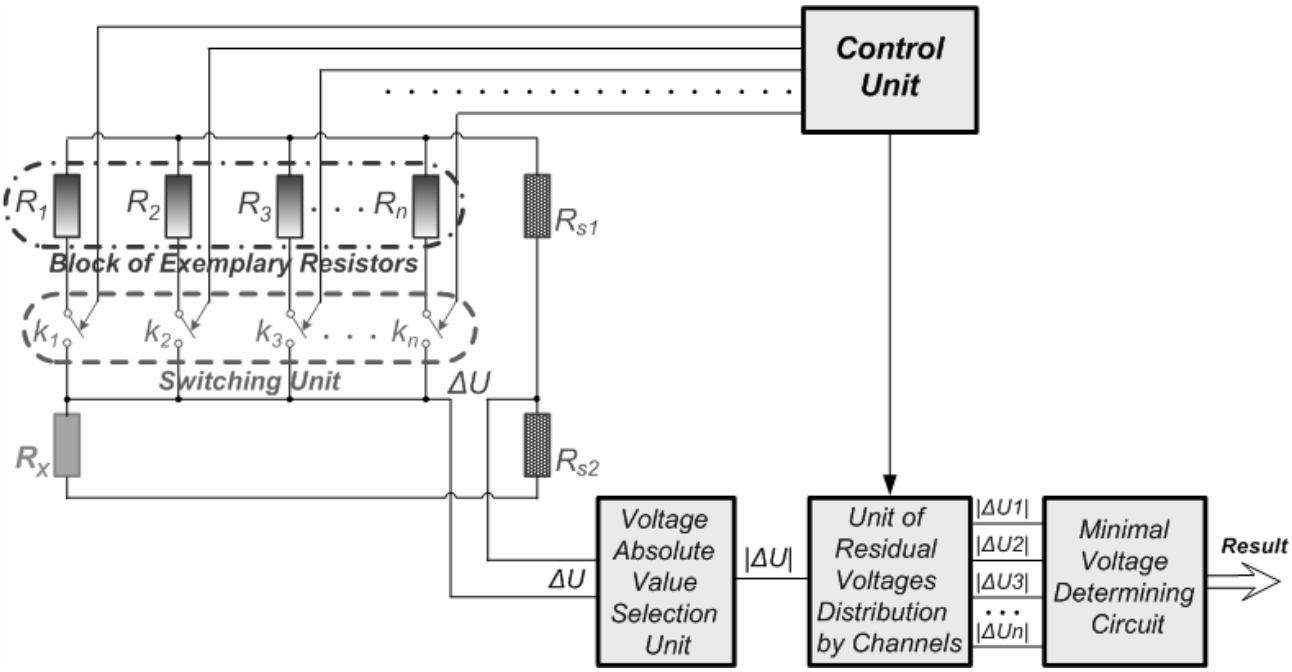

Fig. 4. Circuit model for automation of determination the value of an exemplary resistor, in a neighborhood of which the investigated MEMS resistive parameter measurand is located.

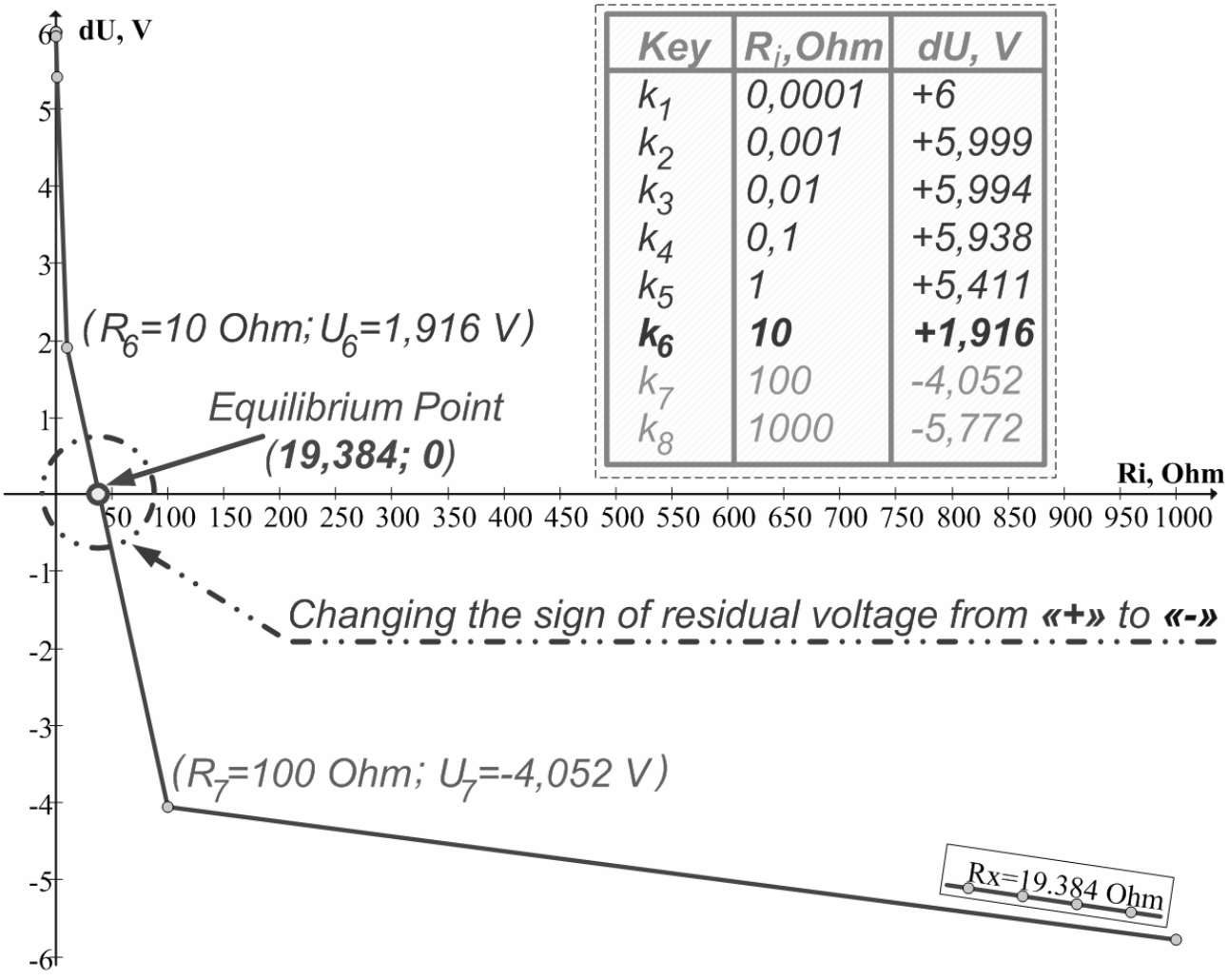

Fig. 5. Graph of the change of residual voltage value.

Thus, for determination of measuring ranges it is necessary to identify the moment when model is passing through the electric bridge equilibrium point, or moment of changing the sign of imbalance residual voltage, appeared in the neighborhood of electric bridge equilibrium point, to the opposite one. In this case, the last value of an exemplary electric resistance will be the lower measuring range (when the sign of residual voltage was still unchanged), and the upper measuring range will be the first value of an exemplary electric resistance, in case of which the sign of residual voltage has changed to the opposite. So, for the considered case of determination of the value range of measured electric resistance Rx=19,384Ohm (see Fig. 5), the lower measuring range will be 10 Ohm, and the upper one will be 100 Ohm.

The figures below shows the developed circuit model (see Fig. 6) and flowchart of the developed algorithm (see Fig. 7) for automation of determination of the values range of electric resistance for investigated MEMS resistive parameters measurand.

Developed model works as follows (see Fig. 6, Fig. 7). At the beginning the resetting of first (T_1-T_N) and second (T_{n+1}–T_{2*n}) rows of triggers occurs by using a high-level logical signal, which enters the corresponding inputs R ("Reset") of the triggers control unit, moreover the signal enters one of the inputs of logical "AND" schemes ($\&_1$–$\&_n$) from the outputs of the first-row triggers T_1–T_n. After that locking of the first key k_1 occurs,— and thus enabling of the exemplary resistance R_1 into the circuit takes place together with the switching of appropriate (in this case first one, in general – i-th one) first-row trigger by using a high-level logical signal, which enters it's input S ("Set"). The trigger switching, in its turn, activates the appropriate logical "AND" scheme ($\&_i$).

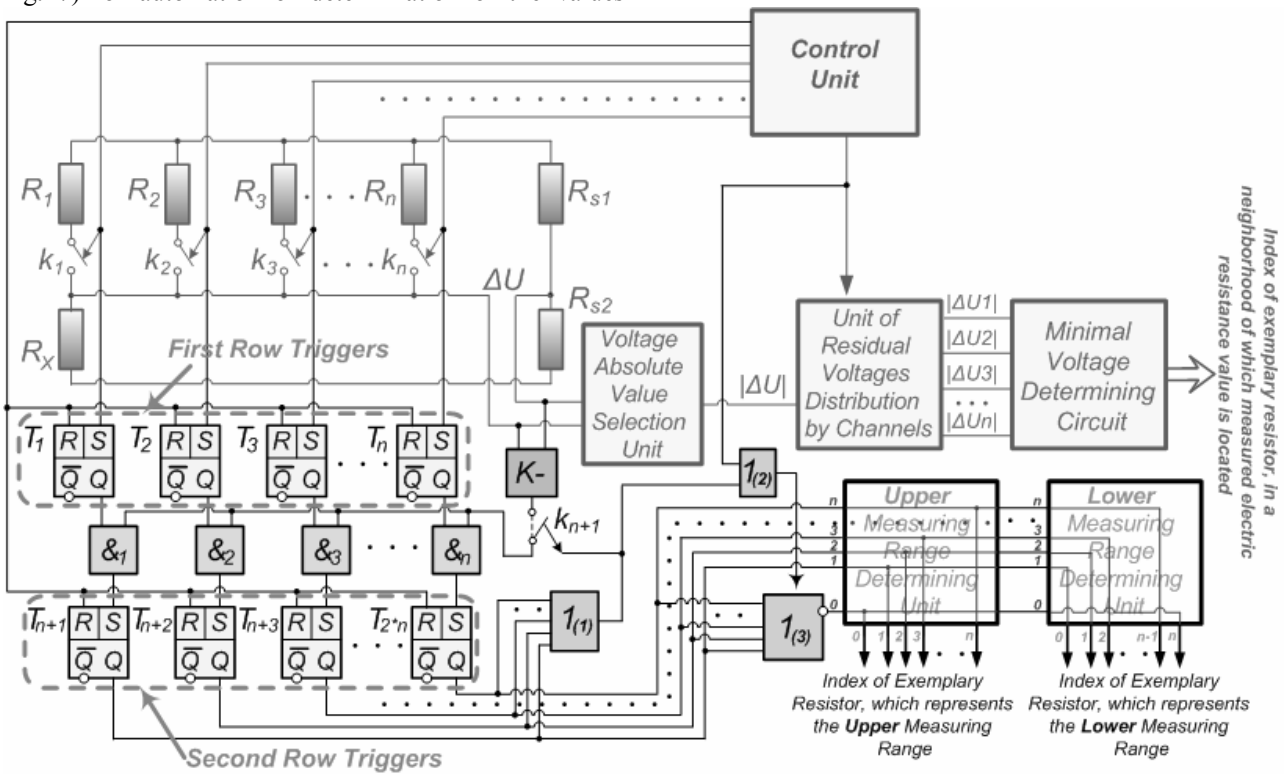

Fig. 6. Circuit model for automation of the values range determination of the investigated MEMS resistive parameters measurand.

A residual voltage ΔU appears in the neighborhood of equilibrium point of the formed electric bridge arises up because of locking of the electric circle. This residual voltage enters the input of negative-voltage comparator K–. Comparator works only when the residual voltage ΔU is negative at its entrance.

If the residual voltage ΔU is positive, then at the output of corresponding logical "AND" scheme ($\&_i$) we will have a low-level signal, or "logical zero", which enters the input of corresponding second-row trigger T_{n+i}. After that, the next working cycle takes place, which starts with enabling of the next exemplary resistor R_{i+1} into the circuit. If the residual voltage ΔU is negative, then a high-level logical signal from the output of negative-voltage comparator K– enters the second inputs of all logical "AND" schemes $\&_1$–$\&_n$.

In result of triggering of comparator K–a high-level logical signal enters also the second input of logical-"AND" active scheme $\&_i$, leading to appearance of a high-level signal on its output. This signal immediately switches a corresponding second row trigger T_{n+i}, a high-level signal ("logical one") appears on its output, and this signal, in its turn, enters the input of the first logical "OR" scheme.

A high-level signal appearance at one of the inputs of the first logical-"OR" scheme generates at its output the same high-level signal, which unlocks the key k_{n+1}. Unlocking of the key is done to avoid the repetition of appearance of a high-level signals on outputs of all other logical-"AND" schemes ($\&_{i+1}$, $\&_{i+2}$, …, $\&_n$), because we are interested only in the moment when electric bridge circuit passes over its equilibrium point, which is

evidenced by changing of the sign of residual voltage to the opposite (in particular, with increasing of the controlled resistance value — from "+" to "–").

A high-level signal from the output of the first logical-"OR" scheme also enters one of the inputs of the second logical-"OR" scheme, which leads to launching of the third logical-"OR" scheme (with inversion at its output). In result of the abovementioned triggering upper- and lower-range determining units are starting their operation, and output of results occurs. The same happens after locking of the last key k_n by activation of the third logical-"OR" scheme (with inversion at its output) by a control-signal from the control unit.If the detected residual voltage ΔU wasn't negative in any of cases after sequential locking of all n keys of the model (at the outputs of all logical-"AND" schemes (&1–&n), we will have low-level logical signals at the outputs of all second-row triggers T_{n+1}–T_{2*n}), which enter the inputs of the third logical-"OR" scheme (with inversion at its output).

Thus, at the output of the third logical-"OR" scheme we will have a high-level signal, which enters the zero-th input of the upper-range determining unit. As a result, at one of the outputs of the upper-range determining unit we will have a high-level signal ("logical one"). Moreover, presence of a high-level signal at 0-th output of the upper-range determining unit indicates the «open» (undetermined) upper limit, and a high-level signal at the i-th output of the unit (i [1,n]) indicates that the upper measuring range is the i-th exemplary resistor Ri of the model. The upper measuring range is «open» (undetermined) in case, when the value of measured electric resistance Rx, which represents the investigated MEMS resistive parameter, is higher, than value of the largest exemplary resistor (for the developed model it is resistor Rn, see Fig. 6).

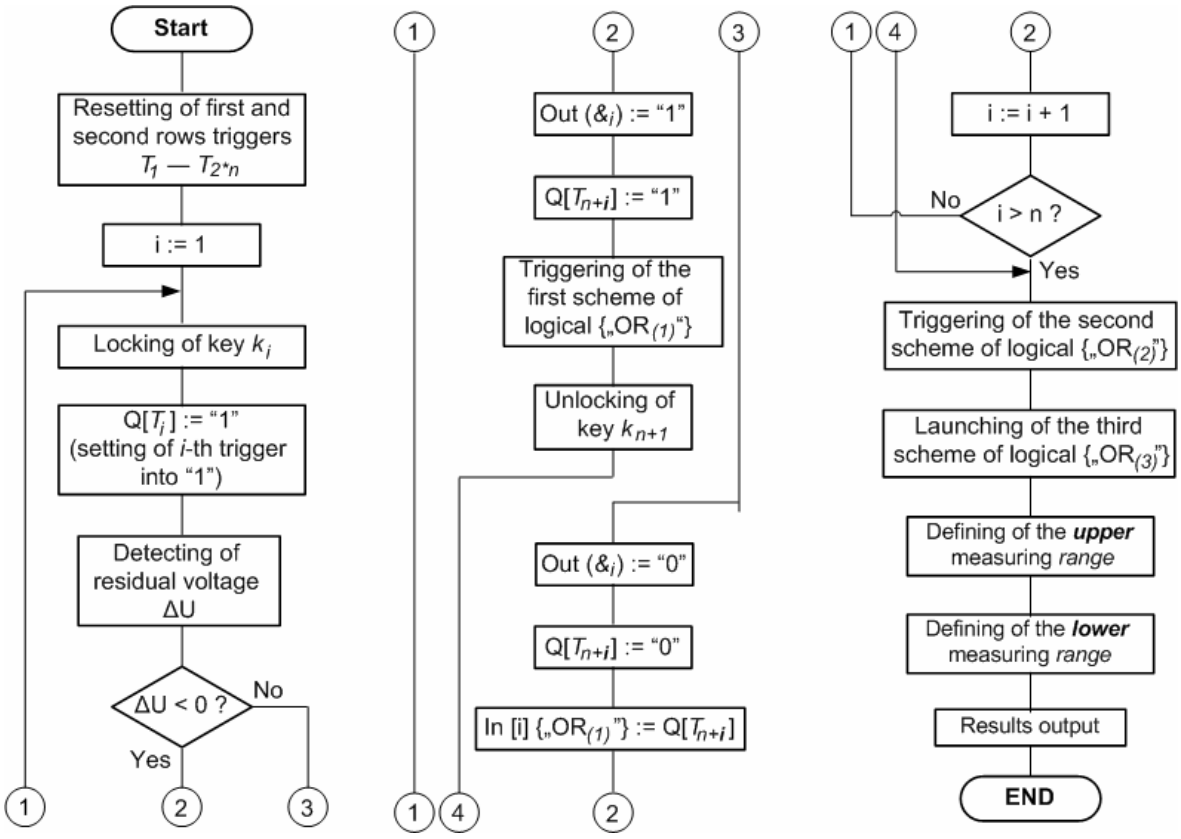

Fig. 7. Flowchart for the process of automation of determination the values range of the investigated MEMS resistive parameters measurand

At one of the outputs of the lower-range determining unit we will also have a high-level logical signal. Exactly the same like in the previous case, the "logical one" at i-th output of the lower-range determining unit (i [1,n]) indicates that the lower measuring range is the i-th exemplary resistor Ri of the model, and presence of a high-level signal at 0-th output of the lower-range determining unit indicates that lower limit is «open» (undetermined) — when the value of measured electric resistance Rx, which represents the investigated MEMS resistive parameter, is lower than value of the smallest exemplary resistor (for developed model it is resistor R1, see Fig. 6). Determination of measuring ranges also allows to choose the optimal step of change of the value of controlled electric resistance, in order to achieve the equilibrium state of electric bridge more quickly at the stage of precise determination of the value of some investigated MEMS resistive parameter, and the value of this optimal step equals the value of determined lower measuring range.

So, for the considered case of determination the precise value of investigated resistive parameter with the value of electric resistance Rx=19,384 Ohm it has been found that its value is in the ranges from R6=10 Ohm

(lower measuring range) to R7=100 Ohm (upper measuring range) in the neighborhood of the value of exemplary resistor R6=10 Ohm. A further direction (in our case it's increasing) of change of the controlled electric resistance (which would be use later, on the stage of precise determination, to achieve the equilibrium state of the electric bridge), as well as the optimal step of change of the value of controlled electric resistance (which equals the determined lower measuring range R6=10 Ohm), were determined.

Thus, obtained results serve like an effective mechanism for increasing the speed of determining the precise value of investigated MEMS resistive parameter, since they remove the necessity of additional analysis of investigated object (MEMS resistive parameter, represented by measured electric resistance) on the stage of determination of its precise value.

CONCLUSIONS

The developed method for automation of determination the value range of investigated MEMS resistive parameters measurand is presented in this paper. This method is based on the developed models and algorithm for automation the process of determination of an exemplary resistor value, in a neighborhood of which MEMS resistive parameter measurand is located, as well as on the developed model and algorithm for automation of the value range determination.

Developed model, based on colored Petri nets, for analysis of a dynamics of the process of determination of the value of exemplary resistor, in a neighborhood of which MEMS resistive parameter measurand is located, was also presented in this article.

Developed circuit models (circuit model for automation of determination the value of an exemplary resistor, in a neighborhood of which the investigated MEMS resistive parameter measurand is located AND Circuit model for automation of the values range determination of the investigated MEMS resistive parameters measurand) give an opportunity to take into account the features and specifics of MEMS–technologies. Developed algorithms (the algorithm for automation of determination of an exemplary resistor value, in a neighborhood of which MEMS resistive parameter measurand is located AND the algorithm for automation of the value range determination of the investigated MEMS resistive parameters measurand) provide an opportunity to fully automate the process of determining and controlling of the values of investigated MEMS resistive parameters.

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Specifics personalized approach in the analysis of medical information

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Abstract. In this article suggest some new approaches to solving the problems of medical data analysis and their personalization. To accomplish this was proposed to create a decision support system to the execution of sequence stages of analysis of patient's data.

The main stages of development and design of decision support systems that enable to make decomposition of control process and describe the relationship between input and output control flows. Applying the theory of decision trees during construction of decision trees of decision support system is due to the formation of a sequence of questions asked by the doctor when searching an individual approach when choosing a treatment.

Decision tree creates a hierarchical structure of rules. This approach allows you to present the logic of sequence issues by doctor in solving the medical problem history and it makes possible to simulate decision making process by physician when selecting treatment scheme.

Search the target value of output of decision medical support system makes it possible to select top of graph system that is located with more probability on the best way to the target. Important step in addressing the process of personalizing treatment schemes is estimated function that is based on Bayes theorem. Weight of occurrence next event corresponds to the highest value of the posterior probability of occurrence of the next state, given the time-dependent input parameters.

Proposed improved method of decision-making for personalization standard schemes by modifying the method of decision-making based on decision trees considering relationship between the input parameters and evaluation function and result of its works is a personalized therapeutic scheme of treatment.

It analyzed the quantitative results of applying the proposed method and existing for determining personalized schemes.

Key words: decision support system, data formalization, therapeutic treatment schemes, personalized of data.

INTRODUCTION

The problem of personalizing data is one of the important problems that arise in the development, design and improvement of information systems in all fields of human activity. Personalizing makes it possible to use standardized methods of processing information of particular objects to their individual characteristics. Medicine is a branch of human activity where personalizing plays an important role in providing valid medical care to patients with any disease. Consequently, personalized medicine a certain model of health care for people based on the selection of diagnostic, therapeutic or preventive measures that would be optimal for the chosen people because of its genetic, physiologic, biochemical or other features. The main goal of personalized medicine is optimization and personalization of the prevention and treatment to avoid undesirable side effects by identifying the individual characteristics of the human body.

The development of personalized medicine is increasingly affecting the direction of the development of medicines. This is why pharmaceutical companies to change their paradigm of research and development, in addition to changing the process of deciding on whether to use a drug for the treatment of a particular patient. Although the development of personalized medicine requires more resources and more organizational changes, in addition, most of these changes should be carried out outside the pharmaceutical industry. It promotes the study of personalized medicine approaches in the analysis of individual patient data, development of methods of treatment assignment and personal disease risk assessment, taking into account the quality of life, and forming recommendations for pharmaceutical production allowing for the patient. For realization this approach need the creation and implementation of new technologies of personalized medicine.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

By using current mathematical techniques such as Bayesian approach, the method of cluster analysis, method of reverse output developed expert systems like Hastrohraf, Whonet, Casnet et al., which are aimed at processing the received medical data presented in the form of spectral characteristics results maintaining a database of patients. Some large medical centers are trying to develop "intelligent" programs that allow diagnosis or narrow range of diseases in the differential diagnosis or to determine the minimum set of diagnostic tests such as expert system installation diagnoses Internist, BPLab, SpeseLabs Medical, Meditech, A & D, Omron, CardioVita [1,13,18].

Application of semantic networks in decision making implemented through relationships between objects, may make it possible appearance of conflict between elements of classes of pharmaceuticals and diagnosis [8,14,15].

OBJECTIVES

The main objective is to develop new approaches concerning personalizing of medical information in the process of support medical decision for determine the stages of treatment, in the decision making process for formation of recommendations of therapeutic schemes for specific patients with different pathologies and other diseases.

THE MAIN RESULTS OF THE RESEARCH

The process of decision making support can ensure that the priority requirements for data management that determine its practical expediency and effectiveness.

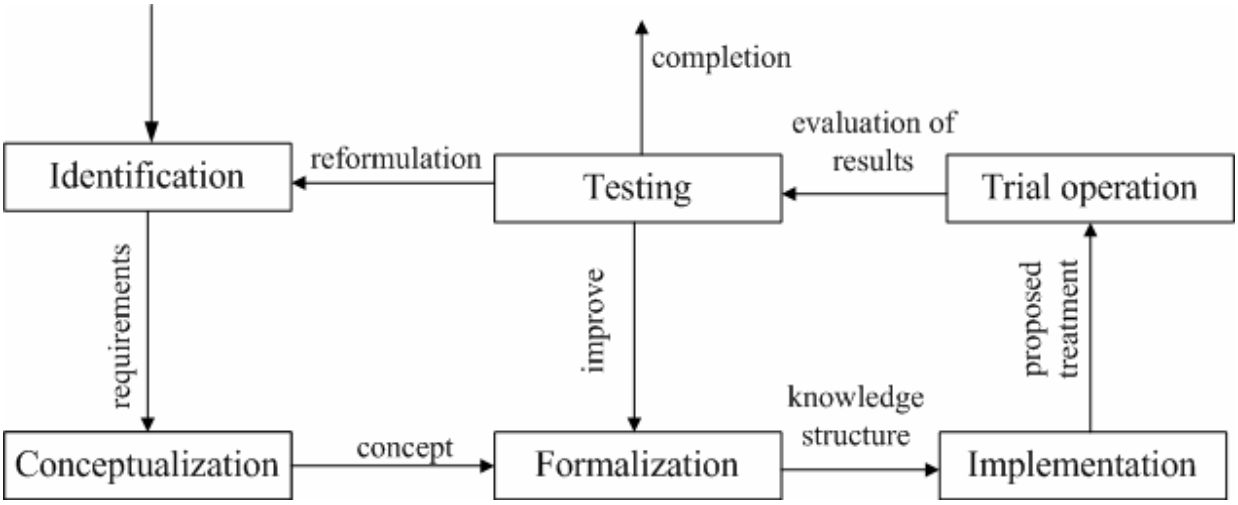

Fig. 1. Stages of development and design DMSS

Data integrity is achieved by preserving the correctness and accuracy of the knowledge base. To balance the conflicting demands knowing the general requirements of all facilities required to structure the knowledge base so that the service was generally better. To this purpose apply public medical ontology (Galen to determine the clinical condition, UMLS for the National Library of Medicine USA, ON9 for certification of health of the general parameters as well as engineering, chemical ontology, Suggested Ontology for Pharmacogenomics, Symptom Ontology, NCI Thesaurus, Ontology of Medically Related Social Entities, Ontology for General Medical Science, etc.) containing information about the hierarchical diagnosis and treatment of diseases, represent an area of knowledge in health care, pharmaceutical industry, etc. [2,9,10,12]

Providing universal access to data makes it possible to access to existing applications and databases to develop new applications to work with these same data. That is, new applications can access to most of these data, and there is no need to create new data [7].

The decision medical support system (DMSS). One approach solving the problem of personalization is to create DMSS that comes down to the execution sequence of stages analysis of patient's data:

– Identification of the patient as an object system,
– Conceptualization of data that determine the time-dependent and time-independent object parameters,
– Data formalization, converting data into quantitative indicators,
– Implementation process of processing the entire data set.

The main stages of development and design of decision support systems are presented in the form of transitions state diagram that enable to make decomposition of control process and describe the relationship between input and output control flows.

When developing DMSS often need to reconcile the results from previous phases and evaluate decisions taken there. The result of the development stages DMSS is the answer to the question what should be done and what resources are necessary involve, namely [3,11,15]:

– Identification tasks,
– Determine the participants of the design process and their role,
– Identify resources and target,
– Definition ways of presenting of all knowledge types,
– Formalization of basic concepts,
– Definition of search strategy decision,
– Modeling of the system work,
– Evaluating the adequacy of the system of targets selected methods, concepts and tools,
– Filling the knowledge base by expert,
– Verification the validity and competence DMSS,
– Formulation of requirements to DMSS.

The scheme of processing the input patient's data characterize by main stages providing the following steps in the DMSS (Figure 2).

It is known that the main source of knowledge for DMSS is an expert. Therefore, to create the medical DSS great importance is the modeling logical doctor reasoning. As a first approximation, logical doctor reasoning can be considered as process of operating with "medical

memory" input information for which is the patient's characteristics. This approach "medical Memory" is the primary and logical reasoning - secondary. However, the considerations can have a significant impact on the structure and nature of "memory care."

Due to the lack single algorithm description of the patient's state, diagnostic and therapeutic processes should consider traditional methods of information processing and decision making. It should be noted that until last time most widely used so-called tabulated algorithms, based on calculations using relationship.

Decision tree is one of the most popular approaches to solving problems of Data Mining. Objectives arising from the objective needs have hierarchic character [6,16]. Top-level objectives cannot be achieved until the goal of next lower level will be solved. The objectives are specified in the move down the hierarchy of levels. In the process of building an expert system by means of decision trees should seek clear and specific formulation of objectives, provide for a quantitative or ordinal assessment of the degree of their achievement.

Construction of DMSS decision trees when using this approach is caused by the formation of a sequence of questions being asked the doctor when seeking an individual approach when choosing a treatment.

Decision tree creates a hierarchical structure of rules, classified on a "if - then" that looks like a tree [4,17,20]. Each vertex of this tree is a specific question that to put to a patient and a branch of tree that comes from the top responsible on the alternative answers and lead in its turn to new issues.

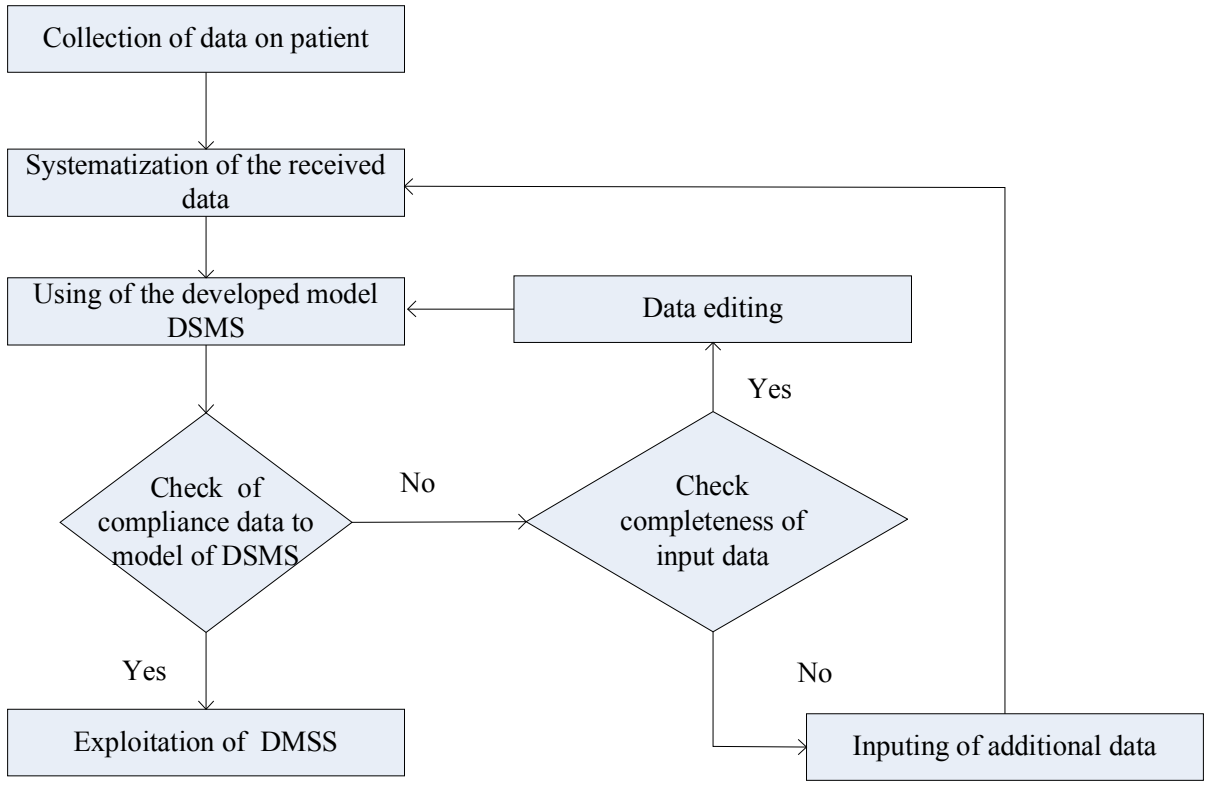

Fig. 2. Scheme of processing the input data of patient

The question may be, for example, the following: "Is applied prior antibiotic therapy?" If answer is yes, there is a shift to the right node of the next level, if it is negative - to the left node. Then again put a question related to the corresponding node. The program moves from question to question as long as no solution is found or been exhausted possible transitions.

Main stages of medical decision making shown at the transition of states diagram of decision medical support system (Figure 3).

The disadvantage of this approach is as follows:

– when trying to build a similar tree to solve complex the medical problems the number of vertices of branching becomes so great that the analysis of the logical tree detected extremely difficult,

– slightest changes made to the application logic, leading to the need to re-build tree and reprogram the entire task.

At the same time, this approach is very convenient because it allows you to present the program logic assembly sequence issues by doctor in solving the medical problem history taking in clinical conditions. This approach makes it possible to simulate decision making process by physician when selecting treatment regimens.

Medical decision-making by using of statistical data processing is the employ methods of mathematical

statistics. It is based on processing large volumes of information collected on diseases that are subject to machine diagnostics.

Processed information can be used in different ways. Some the medical expert systems based on the use of pattern recognition theory. It is necessary to have specific case histories with known diagnoses.

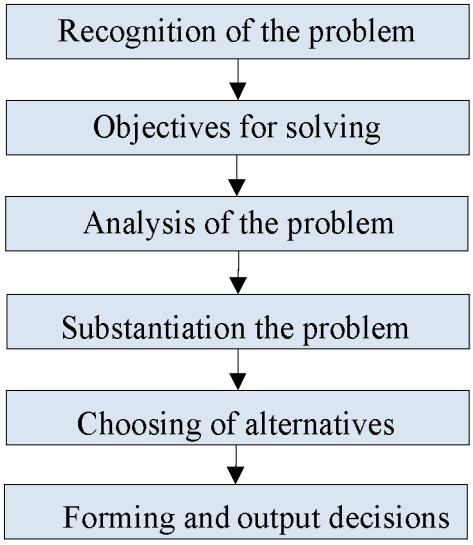

Fig. 3. Main stages of the decision-making medicines

The data are analyzed to determine the statistically "typical" treatment schemes for each disease. Appointed drugs that are more characteristic of him, based on the information collected, processed by statistically. Case of diseases used in the analysis of the history of each patient to determine how "similar" case considered the "typical". In assessing the difference between comparable cases, the program generates a decision about treatment.

$$A \subseteq B \Rightarrow Z, \quad (1)$$

where: A - set of time-dependent data of the patient's state, B - set of characteristics of the drug research, Z - set of source data that is relevant scheme of treatment.

We propose visualization of decision-making process when selecting patient treatment schemes where set productions and output data are organized in some system of conservative treatment presented as a decision tree. A fragment of the tree selection schemes from the tops - drugs $z_1, z_2, ..., z_{12}$ and ribs - the rules of $p_{12}, p_{13}, ..., p_{8,15}$, which performed the selection, shown in Figure 5.

Definition of conservative treatment schemes in the analysis set time-dependent and time-independent parameters $\Psi = \{S, A\}$, where $A = \{a1, a2, a3\}$, $S = \{s1, s2, s3\}$ and related productions.

In applying this approach for processing large arrays of information does not result in a balanced decision tree that is height is obtained very different, it slows down the process of obtaining valid information about the treatment.

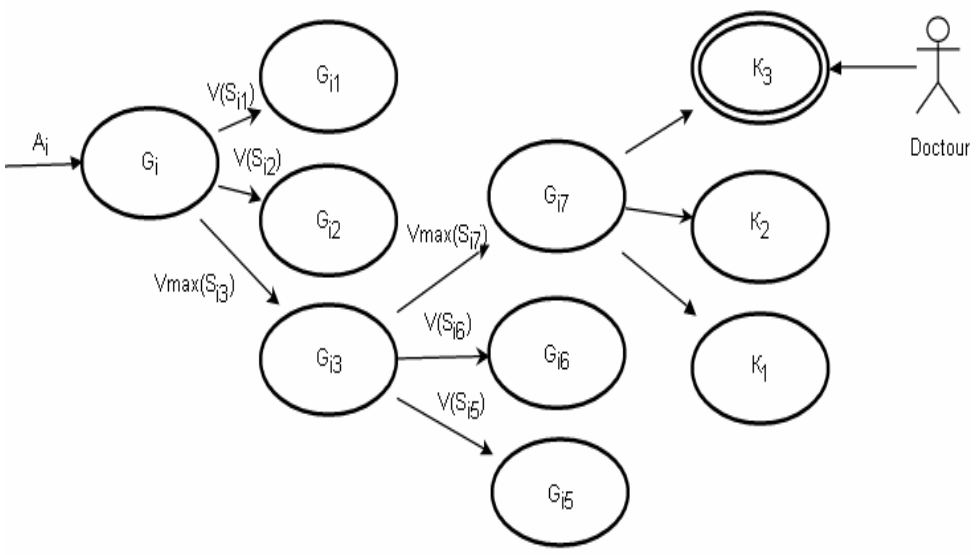

Fig. 4. Search target value of outputs system of decisions medical support.

However, the decision tree (tree classification) cannot be used when the classification parameters are dependent. When analyzing the patient's state cannot be said about the independence of the patient's parameters, even if there are no obvious signs of this.

So for selection of personalized treatment schemes should be modified algorithm for constructing decision tree and its properties.

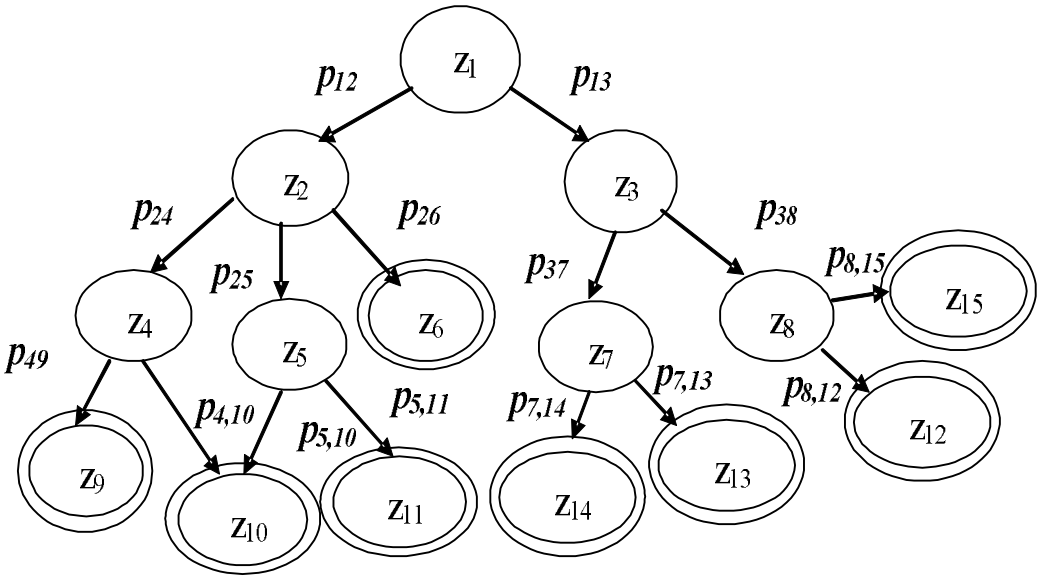

Fig. 5. The decision tree in finding therapeutic treatment schemes

Search the target value of output of decision medical support system. To assess the occurrence of the next event in the DMSS we suggest a proprietary method that will provide orientation when choosing target schemes of treatment.

This makes it possible to select top of graph system that is located more likely on the best way to the target. So placing the vertices should be in order of increasing values of *V (Ψ)*.

Another important step in addressing the process of personalizing treatment schemes is estimated function *V(Ψ)*, which is based on Bayes theorem. Weight of occurrence next event corresponds to the highest value of the a posterior probability of occurrence of the next state, given the time-dependent input parameters (*S*), ie,

$$V(S) = max\left(p\left(G \mid S\right)\right) \qquad (2)$$

In determining the outputs function taken into account the probability of all states according to the input parameters, it gives the doctor-expert whole range of possible therapeutic schemes on which it makes the conclusion of an optimal treatment scheme of the patient, taking into account his personal data.

As a result of applying the theory ordered search algorithm and evaluation function definition, characterized by probability of occurrence next state in the presence of specific system parameters, gives orientation in choosing the appropriate targeted treatment schemes.

In Figure 4 shows a piece of finding tree of targeted solutions by using evaluation function.

So, using the Bayes formula, we obtain the posterior probability of an event *G* of an event at *S*:

$$P(G \mid S) = \frac{P(S \mid G)P(G)}{P(S)} = \frac{P(S \mid G)P(G)}{P(S \mid G)P(G) + P\left(S \mid \overline{G}\right)P(\overline{G})} \quad (3)$$

where: all values are known.

So, we have a priori the probability *P (Z)*, contained in the knowledge base. But getting input parameter S and the probability listing on Bayes formula, we can write it in place of *P (G)*. When there is a new incoming parameter this leads to a new update (increase or decrease) of this probability. Each time the current value of the probability will be considered as a priori when applying Bayes formula.

Arises the problem of management logical conclusion, namely in the Knowledge Base has a set of hypotheses that system states

$$Z_1, Z_2, \ldots, Z_n,$$

and the final set of indicators (input time-dependent parameters):

$$S_1, S_2, \ldots, S_m.$$

Each hypothesis *Z*, has a corresponding subset associated with its parameters (input parameters). According to the strategy ordered search algorithms in the space of states system of medical decision-making can consistently processing the full list of possible parameters. In the end, counting all the hypotheses that take into account the emergence of all possible input parameters, the system comes to the end result, but it is more probability to assigned to the value of evaluation function *V (S)*, which is a defining for determining the next state of the system.

According to this we offer a practical example of finding the next state of the system.

Example: Suppose there is some state G and the patient has a diagnosis of furunculosis. It is believed that in accordance with the statistical data is known a priori probability *P(G)* that the patient has a diagnosis furunculosis. Let S means that the patient who has a defined diagnosis furunculosis, has renal failure.

So evaluation function *V(S)*, defined using the Bayes formula, enables to get the probability that when diagnosis furunculosis the patient has renal failure of specified input parameters. In order to use the Bayes formula, you need to know probabilities:

$P(S \mid G)$ - probability that the a patient has renal failure at diagnosis furunculosis specified input parameters,

$P(S \mid \overline{G})$ - probability that a patient hasn't renal

failure at diagnosis furunculosis specified by input parameters.

So all three numbers $P(G), P(S|G), P(S|\overline{G})$ - received in advance based on previous statistical research and have a universal character. So $P(\overline{G}) = 1 - P(G)$.

Can use Bayes formula for determining *V(Ψ),* for which all parameters are known.

Suppose

$$P(G) = 0,001,\ P(\overline{G}) = 1 - P(G) = 0,999;$$

$$P(S|G) = 0,9;\ P(S|\overline{G}) = 0,01.$$

Then using the formula, we get:

$$P(G|S) \cong 0,083.$$

So $P(G|S)$ - the probability that when patient has a diagnosis furunculosis at renal failure, increased relative to initial priori probability *P(G).*

The method of decision-making for finding personalized the standard scheme. In recent years actively using ID3 algorithm and its modifications C4.5, See5 for construct decision trees [5,19,20]. These algorithms build a tree and generate rules based on examples.

ID3 algorithm builds a decision tree from the root. The roots of the tree and each of its domestic top will be treated in accordance with certain test set checks. For building inspections will use the fact that the value of each conditional attribute allows you to split the set into subsets of examples in which all examples have the same value for this attribute. If recursively apply this fact,

putting in line the inside top of each tree that build a received as a result of breaking the set, for each of the subsets obtained will build a new subtree. The process building of subtrees will continue until the division will not go subset of elements of the same class with the same values attribute decision making. Each class meets decision tree leaf. Since the order in which the tops of trees ascribe attributes to test, is important for building a decision tree, the result will depend on the classification of attributes assigned to root and to inside the tree tops.

ID3 algorithm is using growth criterion information (information gain), or a decrease in entropy (entropy reduction) to select attribute. The degree of increase information calculated as

$$Gain(S) = Info(T) - InfoS(T), \qquad (4)$$

where: *Info (T)* - entropy of set T to breaking, *InfoS (T)* - entropy of after breaking *S.*

Increase of information quantity obtained by dividing set into subsets *T* T_1, T_2,..., T_k by means of to splitting *S.* As best attributes for use in a partition of set *(S)* selected the one attribute that provides greater gain information *(Gain (S)).*

Criterion Gain is calculated for all the independent variables, and then selects the variable with a maximum value of Gain. Selects the variable to partition on it at one of the classes had a greater probability of occurrence. This is possible when the entropy of *InfoS* a minimum value and therefore the criterion Gain (S) reaches its maximum.

Practical application of classical ID3 algorithm associated with a number of problems specific to models based on learning and decision trees in particular. One disadvantage of ID3 algorithm is that it is incorrect attributes with unique values for all objects of the training set. For objects such information entropy is zero and haven't new data from the built tree with this dependent variable will not be able to receive as obtained after splitting subset will contain one object. To effectively overcome the shortcomings of ID3 finalized, resulting in its expansion was named C4.5.

C4.5 algorithm solves this problem by introducing normalization. Evaluated number of objects is not one or another class after splitting, and the number of subsets and their power (number of items). However, the problem of processing also entirely independent parameters remains [4,14].

We propose improved method of decision-making for personalization standard schemes by modifying the method of decision-making based on decision trees considering relationship between the input parameters and evaluation function. The result of the method works is a personalized scheme.

At first formed a set of pre-drug therapy Z_{prev} on the basis of pre-processed items set of output signals *Z* mealy machine, that characterize standard schemes of treatment, where g_0 - initial state:

$$Z_{prev} = \beta(g_0) \qquad (5)$$

I. If the top of making medical decisions tree delivered in line with the set drugs *Z* and each determines $a \in A$ and $s \in S$ then this top is a piece of tree. At the end the function definition f selects personalized drug scheme with set *Z* of time-independent a_i and time-dependent s_j parameters of the patient's state.

II. If the top stage I is not satisfied, it is considered a set of stated time-dependent parameters S_1. The current top - G_i. If the pre-set drug therapy $Z_{prev} \neq \varnothing$, where Z_{cur} - the current set of drugs is defined as the difference between the sets Z and Z_{prev}.

III. If Z_{prev} = Ø to step II, then to the top, which should be a leaf applied P production rules which takes into account the elements of *Z* drugs set, a subset of time-independent and time-dependent patient's parameters and identifies the personalized treatment scheme *K.*

$$P = \left\langle Z_{prev}, a_{\psi}, Z_{cur} \to K, K \right\rangle, \qquad (6)$$

$$Z_{prev} = Z_{prev} \cup K. \qquad (7)$$

where: a_{ψ} - real time-independent parameters of the patient considering its time-dependent parameter *s*, which is a condition for revitalization of production, *Z* - set of drugs that describes a class situation, $Z_{cur} \to K$ - core products, *K* - personalized scheme of treatment, which is the result of the production rules.

So, the each internal top is the root of subtree, the examples of the same value of one of the attributes and the attribute various values of decision-making to him correspond. The examples that have the same value of one of the attributes of decision-making correspond to the each sheet of the tree.

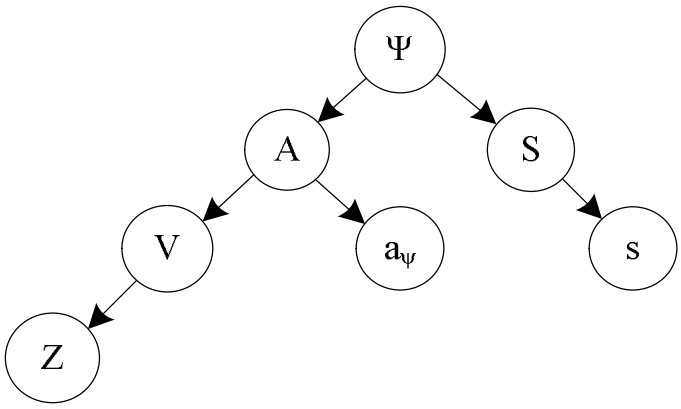

Fig. 6. The tree of output personalized treatment schemes

One question that arises in the decision tree algorithm - is the optimal size of the final tree. So, a small tree cannot cover this or that important information about the selective space. However, it is difficult to say when the algorithm has to stop, because it is impossible to predict whether the addition of a node will reduce the error. This problem is known as the "horizon effect". However, the general strategy of limiting tree remains, ie removal of nodes implemented in case they do not give more information.

It should be noted that the adjusting the depth of tree has to reduce the size of the training models of tree without reducing the accuracy of prediction or through the cross-checking.

Reducing of tree can be top-down and bottom-up. When using a top-down approach - trimming starts from the root, from the bottom-up - reducing the sheets number of tree. One of the simplest methods of management - reducing the error of tree limits. Starting from leaves, each node is replaced by the popular class and if the accuracy of the prediction don't affect then the change is stored.

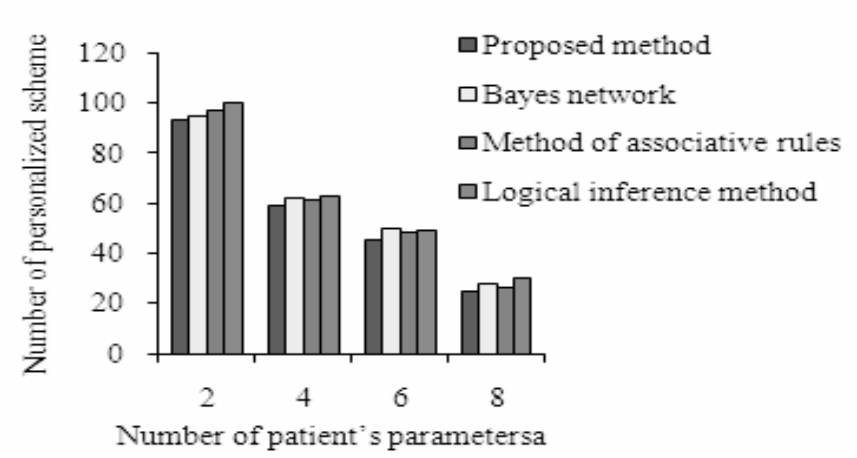

Fig. 7. The comparative diagram of the number results.

To compare the efficacy of the proposed method of data analysis was chosen three methods are similar in purpose: Bayes network, the method of associative rules and logical inference method.

High-performance unified selection method because the method by balancing search of tree treatment schemes processes only the personalized data specified in the input data set. As a result, increase in the selection criteria (the patient's parameters) inverse proportion to affect the list of proposed therapeutic schemes.

According to the analysis derived therapeutic schemes by using the submitted methods occurs the proportional reducing of the results number obtained by increasing the input patient's parameters. A result of analysis a unified selection method gives the most personalized list of therapeutic schemes.

CONCLUSIONS

The main approaches to personalized medical data envisage:

1. Design and development of decision medical support system;
2. Application of the theory of decision-making tree;
3. Developing a finding method of target value to exit decision medical support system;
4. Developing a method for decisions-making about personalization standard therapeutic schemes.

To resolve these tasks offered:

– main stages of development and design of a decision support system that enable the decomposition control process and describe the relationship between input and output control flows,

– the development DMSS need to reconcile the results from previous states and evaluate decisions making there,

– outlined the main stages of the process of making medical decisions,

– improved the method of decision-making for personalized standard schemes by introducing evaluation function the emergence of the next state in the presence time-dependent and dependent between them data a system that unlike the ordered search algorithm provides orientation when making decisions on the choice of targeted treatment regimens.

According to the results analyzed the quantitative results of applying the proposed method and existing for determining personalized schemes. It is established that the amount of received personalized schemes by increasing the input patient's parameters decreased by 7% compared to other methods.

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Research of influence of calculation precision on the effectiveness of stochastic optimization methods

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Abstact. This paper describes the influence of the varying computation precision when performing calculations using the optimizing algorithms. A comparative analysis of the computation speed and obtained result accuracy of the Rastrigin's direct cone method with adapting of the step length and the angle of the cone's disclosure for varying precision was performed. It is shown that the speed of the optimization algorithm practically does not depend on used computation precision. The difference is observed only in accuracy of the obtained results.

The investigation of optimizing algorithms behavior under the presence of noise, in particular due to rounding errors was conducted. It is shown that the optimizing algorithm under research becomes unsuitable after some noise level. Characteristics of the optimization algorithm during calculations with a single precision proved to be better then the characteristics of the algorithm when performing calculations with double precision.

The analysis of possibilities of the effective graphics processors (GPU) application in order to conduct optimization was carried out. In particular, the difference in the speed of the GPU when performing calculations with a single and double precision was considered.

To ensure the efficiency of calculations based on optimization algorithms, it is recommended to carry out calculations with the use of single precision, and increase the calculation precision in case of impossibility to achieve the desired accuracy of the result.

There is considering the significantly higher performance of graphics processors when doing calculations with a single precision in comparison with calculations with double precision it is expedient to use a single calculation precision when graphic processors are used to solve considered problem. Double precision can be used if it is difficult to get sufficiently correct solution by single precision calculations.

The results of numerical experiments confirm that the use of lower precision to perform optimization for macromodels creation has a slight influence on the speed of achieving of predetermined optimization accuracy.

*Key words:*stochastic optimization methods, graphics processors, optimization speed.

INTRODUCTION

Optimization algorithms are now widely used to solve mathematical problems of different range. One of the common problems users have to deal with when using computer calculations based on optimization algorithms are local minima that appear as a result of rounding errors, especially if goal function is not described analytically.

From the other side, optimization algorithms generally require significant amount of computations to be performed. Thus different techniques to perform calculations faster are used, in particular by utilizing high computational power of GPU cards.

In order to make optimization algorithm efficient it would be good to perform the calculations using single precision values, because such calculations are executed much faster than when using double precision values.

A comparative analysis of the optimization algorithms characteristics using different precision of calculations is presented in this article.

The analysis shows that the speed of the optimization process in terms of required algorithm iterations does not noticeably depend on the used precision of calculations. Different precision of calculations affects only the achievable precision of the result. Thus in order to make optimization algorithms work faster it is recommended to start calculations using single precision values and switch to double precision only when sufficient precision of the result is not obtained.

THE ANALYSIS OF RECENT RESULTS AND PUBLICATIONS

Currently the optimization approaches are used more and more widely to solve mathematical problems of

different range, in particular for analyzing of large systems of algebraic equations, numerical integration and macromodeling [3]. When above-mentioned approach are implemented using computer technique users have to deal with local minima that appear as a result of rounding errors, as well as in cases when the goal function is not described analytically, that leads to a growth of computational complexity of the tasks mentioned above.

Optimization algorithms generally require significant amount of calculations, especially when the goal function is a multi-dimensional function with long and narrow flat valleys, which is common for many areas, in particular for macromodel construction [1, 7].

Not so many optimization algorithms can be effective in such conditions [14, 15]. The Rastrigìn's direct cone optimization method with special procedures for automatic adaptation of the length of optimization step and the angle of the cone's disclosure [2] was used in this research. As to our mind it is the most effective method for practical implementation to solve the problems appearing during macromodelling of dynamic systems. It was used by authors to create macromodels of objects of different types [1].

The essence of the researched direct cone method is as follows:

1. Orientation at the starting point. The hyper sphere with the center at the point $\vec{x}_0$ and radius h should be constructed. On the surface of the hyper sphere m random points of uniform law of distribution should be selected. Among them the point where the value of the goal function is lowest should be found out. This point is designated as $\vec{x}_1$, and is used to determine the initial memory vector:

$$\vec{W} = \frac{\vec{x}_1 - \vec{x}_0}{h}; \qquad (1)$$

2. At each step the hyper cone is built. It has the apex at the point $\vec{x}_i$, the angle of the disclosure ψ and axis $\vec{W}$. This hyper cone will trunk some surface from the hyper sphere with center at the point $\vec{x}_i$ and radius h. On this surface m random and uniformly distributed point are selected. Among them the point $\vec{x}_{i+1}$, in which the value of the goal function is the lowest is selected. The memory vector should be recalculated using the following law:

$$\vec{W}_{i+1} = \alpha \cdot \vec{W}_i + \beta \cdot \frac{\vec{x}_{i+1} - \vec{x}_i}{h} \qquad (1),$$

where: $0 \le \alpha < 1$, $0 < \beta \le 1$.

The searching process continues until the value of the goal function goes down. In order to improve features of the Rastrigin's direct cone method several additional procedures were developed. The most important and frequently used improvements are adaptation of the length of the search step h and the angle of the cone disclosure ψ [2].

OBJECTIVES

Our task is to research the efficiency of optimization process with different precision of calculation.

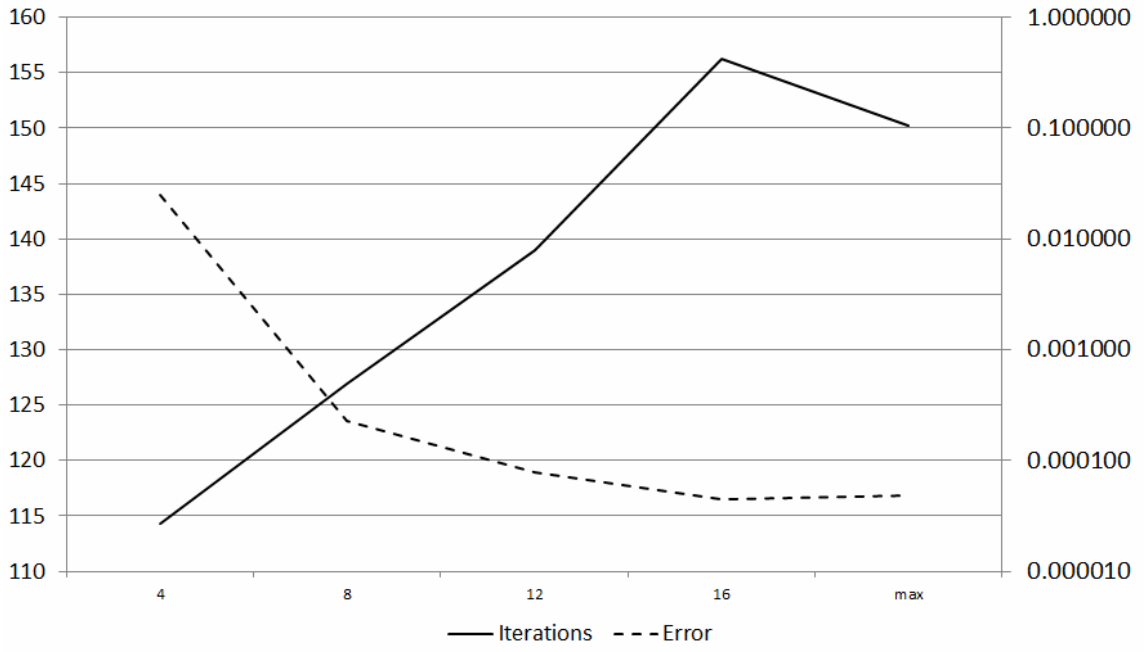

Fig. 1. Number of iterations carried out by the algorithm and resulting deviation of the searched point as a function of calculation precision. The number of decimal places that are taken into account in the calculations are depicted along the horizontal axis. The left vertical axis displays the number of iterations, the right vertical axis – the deviation of the obtained position of the minimum point from the optimal solution.

The research uses a variant of the Rosenbrock's function of the following form [5]:

$$f(\vec{x}) = (1-x_1)^2 + 100\left(x_2 - x_1^{\,2}\right)^2 + 100\left(x_3 - x_2^{\,2}\right)^2 + \\ + 100\left(x_4 - x_3^{\,2}\right)^2 + (1-x_5)^2 + 100\left(x_6 - x_5^{\,2}\right)^2 + \\ + 100\left(x_7 - x_6^{\,2}\right)^2 + 100\left(x_8 - x_7^{\,2}\right)^2 + \\ + (1-x_9)^2 + 100\left(x_{10} - x_9^{\,2}\right)^2 \quad (2)$$

The specified goal function has a long and narrow flat valley that is typical for optimization problems.

To assess the effectiveness of the proposed optimìzation method it is expedient to use the following three dependencies:

1. The dependence of the number of iterations and obtained accuracy of results on the precision of calculations. In this case optimization algorithm will be allowed to stop according to standard criteria. In our case, the following criterion has been used: a failure to improve the value of the goal function within 30 iterations of the algorithm;
2. The dependence of the optimization speed on the precision of calculations;
3. The dependence of the optimization speed of calculations on the precision under presence of random noise imitating the rounding errors.

MAIN RESULTS OF THE RESEARCH

To study the dependence of the number of iterations and reached accuracy of the results on selected calculation precision a search of the global minimum of the function (3) in 2d-space was carried out. For a specified precision of calculations 10 experiments were conducted and data averaging was used.

Obtained dependencies of number of iterations carried out by the algorithm and resulting deviation of the searched point from the optimal solution on calculation precision are depicted in the Fig. 1. According to the chart (Fig. 1), under higher calculation precision the deviation of position from the exact solution is smaller. However, in such a case number of iterations of the algorithm is greater. This result is fully consistent with expectations.

To compare the optimization speed when calculations with different precision are used let us carry out three series of experiments: for double precision (~ 16 significant digits), single precision (~ 8 significant digits), and for 4 significant digits.

In each experiment type five attempts of the optimization procedure of the goal function was carried out and the average value for the specified number of iterations of optimization algorithm was done.

In Fig. 2. the dependence of the goal function values on the number of executed iterations of optimization algorithm for varying precision is presented.

According to presented dependencies (Fig. 2), the nature of optimization process does not depend practically on settled calculation precision. In all cases the value of the goal function decreases gradually, while the

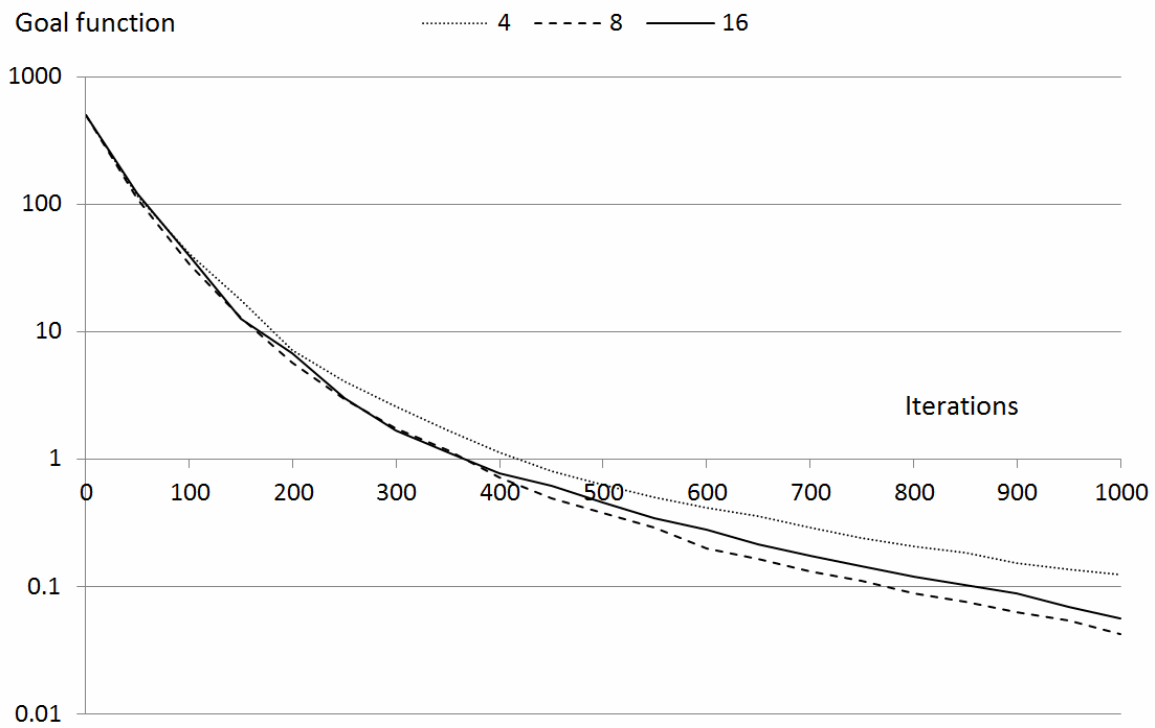

Fig. 2. The dependence of the goal function on the number of conducted iterations of optimization algorithm under different precision of calculations

computation speed becomes slower in the process of the minimum approaching.

In order to research a dependence of optimization speed on selected precision of calculation under presence of random noise the function (1) should be modified in the following form:

$$\tilde{f}(\vec{x}) = f(\vec{x})(1 + k\xi) \qquad (4)$$

where: ξ a random value uniformly distributed along with the interval [-1, 1], k is a weighting coefficient.

Six series of experiments were carried out: two experiments in the absence of noise ($k = 0$), as well as for the following values of the noise intensity: 0.1% ($k = 0.001$) and 0.2% ($k = 0.002$). In each pair 10 repeating were performed of the function (4) optimization for double precision (~ 16 significant digits) and for single precision (~ 8 significant digits). The experimental results were averaged for each series.

The results of the experiments are in the Fig. 3.

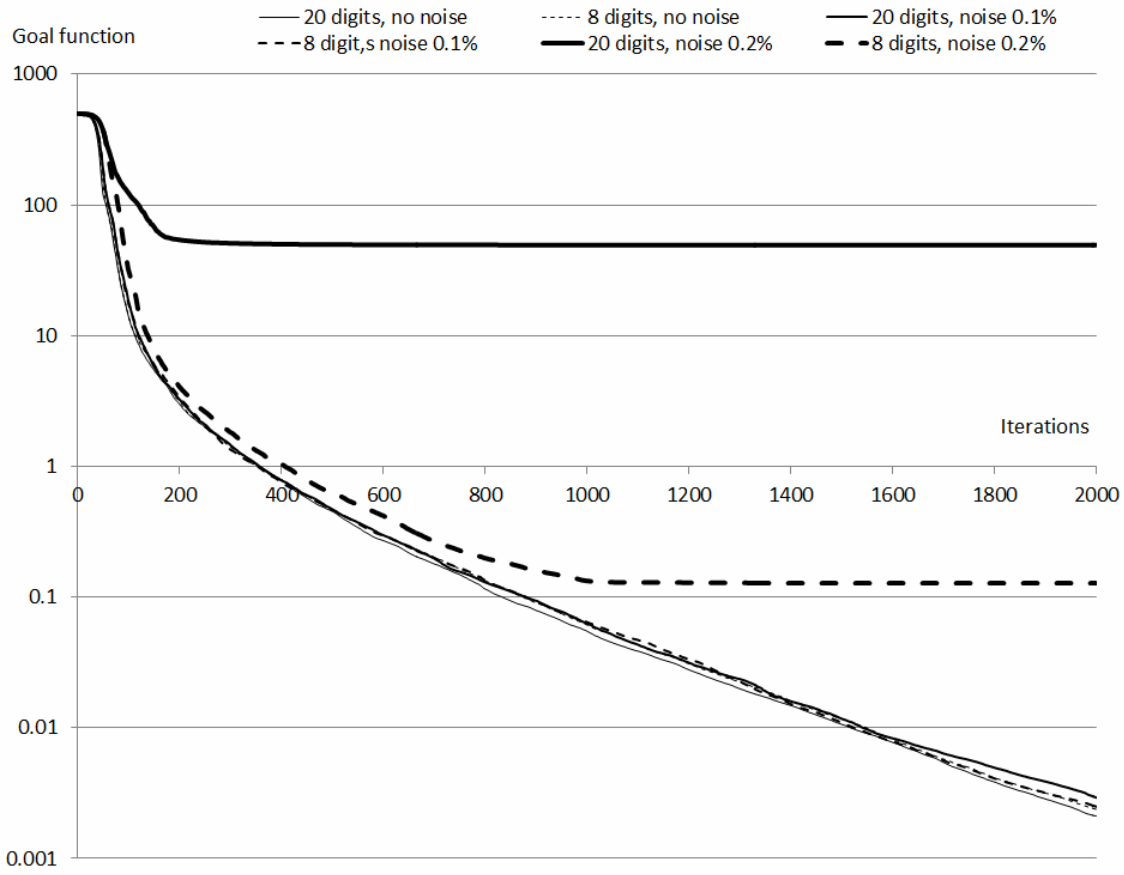

Fig. 3. The dependence of the goal function on number of executed iterations of optimization algorithm for varying precision of calculations and the level of noise.

We should note that the third presented research has an interesting results. As it can be seen from the figures a nature of the optimization process does not depend on the used precision of calculations (double or single). Also the optimization speed does not change under the noise level of 0.1%. It indicates that the selected algorithm of optimization is not sensitive to small noises. But when the noise level is increased up to 0.2% the nature of optimization process changes dramatically. Actually the algorithm is not able to solve this optimization problem both when double-precision and single precision calculations are used. Moreover, if you use a better precision of calculations the optimization algorithm showes worse results.

Additional studies have shown that limits of the noise level at which this change can occur depends on the minimum allowed length of the searching step, which is appointed for the algorithm. In particular, under increasing of the length of searching step the permissible noise level increases too.

As to our mind the following explanation of the optimization algorithm approach is possible: if the noise level is essential the calculation of the goal function at some iteration can give us a randomly lowered value (due to the presence of noise). This lowered value is selected

as a further initial assumption because it is better than other known values. However, the further calculations of the goal function give only worse results, and the algorithm stops.

We should underline that if the rounding error is considered to be the reason of the noise appearing then usage of higher calculation precision will lead to the lower noise amplitude and it will reduce the risk of preterm stop of the optimization algorithm. It is the opinion of the authors, and it is the reason of the relationship between precision and reached accuracy of the solution presented in the Fig. 1.

CONCLUSIONS

The results of numerical experiments confirm that the use of lower precision to perform optimization for macromodels creation has a slight influence on the speed of achieving of predetermined optimization accuracy (if the algorithm is able to achieve it).

Obviously, if the lower calculation precision is used a preterm stop of optimization algorithm can happen. It will lead to impossibility to obtain a desired level of the result. In this case one should continue the optimization using double-precision calculations, taking the result obtained from single-precision calculations as an initial approximation.

Based on presented facts, it can be recommended to pay attention to the possibility of usage of graphic processors for solving tasks discussed in this paper. For these calculation means a speed of calculations essentially depends on the precision of the calculation.

For example, on architecture "Maxwell" of NVIDIA Corporation the speed of calculations with double precision was equal to 1/32 of the speed of calculations with single precision. For the next generation of the graphic processors with "Kepler" architecture this factor was improved essentially and it was equal to 1/3 [6]. As it can be seen, in spite of all efforts of graphic processor producers to improve characteristics of their devices and to ensure high speed, if calculations with double precision should be carried out, conduction of operations with single precision is still essentially faster. This situation is caused by the significant difference in the complexity of the respective computer modules, and therefore it is expected that the difference in performance for single and double precision will be preserved.

Therefore, considering the significantly higher performance of graphics processors when doing calculations with a single precision in comparison with calculations with double precision it is expedient to use a single calculation precision when graphic processors are used to solve considered problem. Double precision can be used if it is difficult to get sufficiently correct solution by single precision calculations.

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Mineral components analysis of selected dried herbs

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Abstract. This study includes the content of water, ash and volatiles in dried herbs like Oregano, Basil and de Provance. Moreover, amounts of H, N and C, and their calorific value were measured. The content of the following elements (Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, S, Sr, Zn) in the tested herbs were established using the ICP-OES method. Basil leaves had the highest nitrogen and ash content at the level 4.5% and 15,9%. These herbs were characterized by a darker color as compared to oregano. Basil contained the richest source of Ca, K, Mg and P, while the lowest was found in herbs de Provence. The best source of Ca, K, Mg and P was basil, while their lowest amount was found in herbs de Provence (containing a mixture of different herbs), which mostly likely was the reason for the low amount of macro- and micro-components.

Key words: physical parameters, de Provence, Basil and Oregano herbs, caloric value, color, minerals, ICP-OES.

INTRODUCTION

From the earliest times medicinal plants were the primary source of drugs, and the knowledge of their operation and application has been passed on to future generations [14]. In Western Europe, the art of plant treatment originated from medieval herbalism. Herbs first gave proper taste and aroma to dishes and an additional function was also the preservation of food. They have also been used as drugs for a number of medical conditions. Many species of herbal plants have medicinal properties that beneficially impact the process of digestion and assimilation of nutrients. They became less significant as drugs when their place was taken by chemistry, in particular antibiotics.

According to Kaiser et al. [2] marjoram extract contains 78% polyphenols. Most rosemary acid is contained by thyme and rosemary herbs, respectively 157 mg/g d.w. and 84 mg / g d.w., while oregano is rich in caffeic acid- 12.6 mg/g d.w. [18].

The primary source of minerals for humans is food, and pharmaceutical preparations should complement the deficiency of certain elements [11]. Plant materials can be a valuable source of many micronutrients present in herbs. An additional asset for herbs is their bioavailability [18]. Heavy metals are a threat that affect processed and unprocessed food. According to the RASFF - Rapid Alert System for Food and Feed [12] they concern mainly lead, cadmium and mercury (more than 50% of reported alerts). The high-concentration of heavy metals in plants is a well-known problem.

According to studies, it is difficult to clearly determine the primary source of pollution, in particular since (in the case of herbs) heavy metals accumulate both in leaves and roots. The influence of heavy metals and other elements should be controlled so as not to exceed the recommended values given by WHO [19]. This is of particular importance not only in the case of herbs used in medicine, where the concentration of heavy metals is a major criterion in the production of the drug, but also in foods which partly consist of herbs. In the case of food, the acceptable level of micronutrients does not harm health.

According to Łozak et al. [5] a good source of iron can be found in infusions of mint and nettle (227 and 107 mg/kg). In contrast, fennel leaves are rich in compounds of potassium (29%) [16]. Rosemary herbs contain a significant amount of calcium, iron and potassium [8].Basil is one of the most valued and most used spices and the aromatic fresh or dried herb is used as an additive to many dishes. In the *Ocimum basilicum* L. type, large variations can be observed not only in the content and composition of essential oil [6, 10]. Basil herb contains 0.5-2.5% essential oil with a variable chemical composition [1]. Apart from the above, Basil contains 16% protein, 4.7% fat, 12% fiber, 5% of tannins, vitamin C and E and carotenoids and chlorophyll pigments and minerals. Oregano, aromatic and rich in taste *(Organum vulgare)* contains antioxidants (8%) and tannins (2%). This herb also contains vitamins C, A, beta-carotene and minerals. Many authors have reported that oregano is not harmful to health. One of the most popular spice mixtures are Herbes de Provence. The blend includes herbs such as basil, thyme, sage, peppermint, summer savory, marjoram and basil. The richness of the mixture sees it used in salt-free diet. An objective of this paper was to

define the active ingredients and the assessment of cumulative elements in popular herbs.

Methods

The materials consisted of herbs of basil, oregano and de Provence herbs purchased at the market. Each time 3 samples were taken to measure average values with standard deviation. In the study, the content of ash, moisture and volatile substances in the herbs was determined by the LECO TGA 701 camera. The moisture content was performed at 105°C, and the ash at 600°C under nitrogen 0.01% comparator. The herbs' calorific value was determined using an AC 500 camera.

For this purpose, the homogenized material was dried in the oven at 105°C and then small tablets were made using the Lormann press.

The calorific value was determined by the sample's combustion in the oxygen atmosphere in a bomb calorimeter placed in water. The content of sulfur, carbon, hydrogen and nitrogen were determined using an S module and CHN TrueSpecTM camera. The measurements of Carbon, Hydrogen and Nitrogen were carried out in an oven at 950°C and Sulphur at 1350°C.

The color of the samples was measured using the UltraScan VIS spectrophotometer Hunter Lab. The white plate standard was taken to establish the optical white parametres values of L*=100.000, a*= 0.005, b*= -0.010. The differences in energetics distance (between standard and each herb sample) measured in the Lab color scale were expressed as:

$$\Delta E = \sqrt{\left(\Delta L^2\right)+\left(\Delta a^2\right)+\left(\Delta b^2\right)}, \quad (1)$$

where: ΔE is the difference in energetic distance,
Δ L, Δ a, Δ b - the difference in energetic distance in the space for the parametres, respectively, L, a, b between the optical plate parameter and sample.

The content of elements in the tested herbs was determined by the ICP-OES method. The samples of the studied herbs were mineralized in nitric acid 65% HNO_3 (V) using the Milestone Spectro-Lab.

Standard solutions were prepared by diluting polycyclic (Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, S, Sr, S, Zn) (Merck Millipore) standard solutions at the concentrations of 1000ppm (mg/l). For the preparation of standard solutions deionized water was used. In order to determine the calibration curve, standard solutions at the range of concentrations from (0.001-1 ppm) were used. The study used the analytical lines of highest intensity.

Samples of the test material (5 g) containing 8 ml of HNO_3 were mineralized in accordance with the following program: 5 minutes in temperature 150°C; 10 minutes in temperature 150°C; 20 minutes in temperature 200°C; 30 minutes in temperature 50°C. An analysis of samples for the presence of elements was carried out using an optical emission spectrometer with the inductively coupled plasma (ICP-OES). The operating conditions for ICP-OES are shown in Table 1.

Table 1. ICP-OES operating conditions for the determination of some elements in the herbs

Rf powers (W)	1150
Gas flow rate (ml/min)	5
Coolant gas	12
Auxiliary gas	0,7
Nebuliser gas	0,4
Sample uptake rate (ml/min)	1
Pump rate (rpn)	70
Read time (s)	5

One-way analysis of variance (ANOVA) was performed at the significance level of p = 0.05, n = 3 in the test herbs for the mean values of water content, ash content, volatile components, caloric value, C, H, N, and measurement of color. The results were subjected to statistical analysis in the Statgraphics Plus 4.1. program, using the Student's t-test and Duncan's test at p = 0.05, n = 3. The principal component analysis of minerals and the correlation matrix of macro-and microelements were determined using the Statistica software package (Statistica 6.0).

RESULTS AND DISCUSSION

Biologically active ingredients present in herbs are important for the quality of herbal raw materials and products, which are an additional component of the herbs [15, 20].

Physicochemical parameters of the tested herbs

Table 2 shows the water, volatility, and ash content in the tested herbs. The water content changed from 7,80 to 9,59% depending on the type of herbs.

Table 2. Identified parameters for herbs

Identified parameters for herbs	Type herbs		
	De Provence	Basil	Oregano
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
Humidity (%)	8,72 ± 0,7^{b}	9,59 ± 3,5^{c}	7,80 ± 4,9^{a}
Ash (%)	9,83 ± 0,7^{e}	15,9 ± 0,8^{f}	7,81 ± 3,0^{d}
Volatiles (%)	22,2 ± 0,9^{g}	22,6 ± 0,8^{g}	22,4 ± 1,5^{g}
Nitrogen, N (%)	2,8 ± 0,7^{B}	4,5 ± 3,1^{C}	1,5 ± 0,6^{A}
Carbon, C (%)	48,6 ± 1,7^{F}	43,4 ± 0,7^{D}	47,3 ± 1,1^{E}
Hydrogen, H (%)	5,8 ± 0,4^{G}	5,3 ± 0,6^{G}	5,4 ± 0,5^{G}
Calorics (MJ/kg dry weight)	21382 ± 105^{b}	17846 ± 150^{a}	24015 ± 104^{c}

Explanatory notes:

Values are means with standard deviation.

a-g; A-I; a-c- (the same letters denote no statistically significant differences at p = 0.05)

Dried herbs of different species did not significantly influence the amount of volatile compounds. On the other hand, the difference in ash content was significant. The amount of ash in basil was 2 times higher than in oregano. According to Kaloustian et al. [3], the value of ash is closely related to the species of dried herbs. The ash content of the tested herbs ranged from 7.8-15.9%. Similar results were obtained by Santos et al. [13].

The results of the analysis of nitrogen, carbon and hydrogen were different (Table 3). The highest content of nitrogen at the level of 4.5% was reported in basil herbs, while oregano contained only 1.5% of this element. The contents of carbon and hydrogen, according to the tested herbs, ranged respectively from 43.4-48.6% and 5.3-5.8%.

The highest energy content with value of 24015 MJ/kg d.w. was found in oregano, while the lowest one was obtained for basil, in which it amounted to 17 846 MJ/kg d.w.

The parametres of the dried herbs colors are shown in Table 3. Type of herb significantly affected the L* parameter. Colors of the tested herbs were characterized by lightness with ΔL value in the average of 50 (mid gray), greenness with negative Δa from -2.55 to -1.76 and yellowness refereed by positive Δb value from 10.9 to 14.1.

Table 3. Color assessment of herbs de Provence, basil and oregano

Identified color parameters	Type of herbs		
	Herbs de Provence	Basil	Oregano
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
ΔL	46,9 ± 0,01^{a}	50,3 ± 0,04^{b}	52,3 ± 0,02^{c}
Δa	-2,55 ± 0,02^{d}	-2,52 ± 0,01^{d}	-1,76 ± 0,01^{e}
Δb	10,9 ± 0,32^{f}	12,8 ± 0,35^{g}	14,1 ± 0,13^{h}
Δ E	6,56 ± 0,09^{B}	3,88 ± 0,03^{A}	3,75 ± 0,07^{A}

Explanatory notes:

Values are means with standard deviation.

a-h; A-I (the same letters denote no statistically significant differences at p = 0.05)

In his studies Alibas [1] proved that the loss of color (L*, a*, b*) nettles was the result, among others, of thermal degradation. Changes in the content of parameters a* and b* influenced the saturation of color in the tested herbs. The total color difference (ΔE) between the standard and sample was 3.75 for oregano, similar for basil (3.88) and amounted to 6.56 for de Provence herbs.

Mineral components

Content of mineral significantly depends on macro- and microelements. The threshold of measurement for ICP-OES methods was above 0.001mg/g. Table 4 shows the mineral content of basil, de Provence and oregano herbs. The content of macro-and microelements was significantly different in the tested herbs, with the exception of copper for all herbs and chromium for basil and oregano. Herbs de Provence constitute a mixture of herbs with a similar amount of mineral components compared to oregano (Table 4). In the case of basil the content of elements was two times higher. Basil herbs contain 25.1 mg/g Ca, 33.2 K, 9.59 mg/g Mg and 4.38 mg/g P. Similar results were obtained by Pachkore and Markandeya [9], with reference to potassium. In the study conducted by Özcan et al. [7, 8] chromium and manganese, for the same varieties of basil, amounted to 0.068 mg/g and 0.17 mg/g.

In the studied spices, there was a high content of Mg (2.92-9.59 mg/g), for which the range was similar to herbal medicinal products tested by Ulewicz-Magulską and Wesolowski [17].

In the case of herbs, the degree of accumulation of minerals in leaves which are eaten directly or subjected to drying methods, is of significant meaning. The analyzed herbal plants differ in macronutrient content due to differences in species.

Table 4. Concentrations of elements in tested herbs

Minerals [mg/g]	Type of herbs		
	Herbs de Provence	Basil	Oregano
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
Al	0,32 ± 0,27^{a}	0,44 ± 0,06^{c}	0,35 ± 0,17^{b}
Ba	0,019 ± 0,05^{d}	0,023 ± 0,04^{e}	0,026 ± 0,03^{f}
Ca	15,3 ± 0,31^{g}	25,1 ± 0,42^{i}	16,3 ± 0,47^{h}
Cr	b.t.m.	b.t.m.	b.t.m.
Cu	b.t.m.	b.t.m.	b.t.m.
Fe	0,43 ± 0,10 ^{B}	0,74 ± 0,18^{C}	0,41 ± 0,70^{A}
K	18,1 ± 0,07^{E}	33,2 ± 0,12^{F}	13,4 ± 0,39^{D}
Mg	5,07 ± 0,02^{H}	9,59 ± 1,39^{I}	2,92 ± 0,02^{G}
Mn	0,08 ± 0,08^{a}	0,07 ± 0,02^{a}	0,05 ± 0,03^{a}
Na	0,21 ± 0,09^{c}	0,66 ± 0,03^{d}	0,07 ± 0,02^{b}
Ni	b.t.m.	b.t.m.	b.t.m.
P	2,94 ± 0,12^{B}	4,38 ± 1,21^{C}	2,07 ± 0,01^{A}
Pb	b.t.m.	b.t.m.	b.t.m.
S	3,32 ± 0,31^{E}	4,19 ± 1,03^{F}	2,22 ± 0,05^{D}
Sr	0,080 ± 0,003^{H}	0,180 ± 0,007^{I}	0,020 ± 0,002^{G}
Zn	0,026 ± 0,005^{K}	0,033 ± 0,001^{L}	0,017 ± 0,003^{J}

Explanatory notes:

Values are means with standard deviation.

a-k; A-J; a-I; A-J; *A-F* (the same letters denote no statistically significant differences at p = 0.05)

b.t.m. - below the threshold of measurability

An analysis of the major components (Ca, Mg, K, P) of the tested herbs showed the formation of two groups. The dendrogram in Figure 2 shows the first focus, which includes herbs de Provence and oregano, and the second bond (basil, herbs de Provence, and oregano). The distances of the first and second bond were 5.3 and 22.2, respectively.

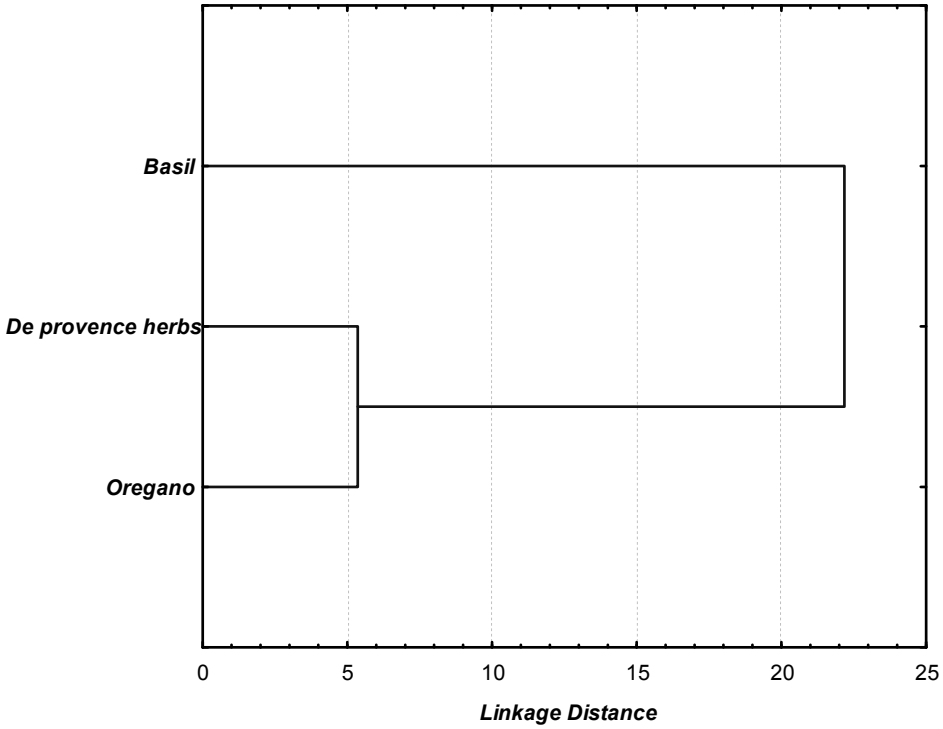

Fig. 1. Dendrogram of cluster analysis

A correlation analysis is shown in Table 5. The correlation coefficient, which is a measure of linear dependence, can range from -1 to +1. The correlation coefficients shown in Table 5 indicate a powerful relationship between the elements in the tested herbs. This may attest to the fact that to a large extent, the correlation coefficient between the elements is higher than 0.5. Similarly, high correlation coefficient elements were obtained in the research of Karadaş i Kara [4] analyzing selected herbs and spices.

This study showed significant correlations between Ca, K, Mg, P. The elements which most often performed in the correlation to other components were aluminum and calcium. Generally herbs matrix was characterized by a high propensity to the prevalence of high positive correlation.

Table 5. Correlation matrix for the elements in dried herbs

	Al	Ba	Ca	Fe	K	Mg	Mn	Na	P	S	Sr	Zn
Al	1,00											
Ba	-0,18	1,00										
Ca	0,98	0,02	1,00									
Fe	0,94	0,16	0,99	1,00								
K	0,87	0,33	0,95	0,98	1,00							
Mg	0,82	0,42	0,92	0,96	1,00	1,00						
Mn	-0,08	0,99	0,13	0,27	0,43	0,51	1,00					
Na	0,87	0,34	0,95	0,98	1,00	1,00	0,43	1,00				
P	0,78	0,47	0,89	0,95	0,99	1,00	0,56	0,99	1,00			
S	0,64	0,64	0,78	0,86	0,94	0,96	0,72	0,94	0,98	1,00		
Sr	0,79	0,45	0,90	0,95	0,99	1,00	0,55	0,99	1,00	0,97	1,00	
Zn	0,65	0,63	0,79	0,87	0,94	0,97	0,71	0,94	0,98	1,00	0,98	1,00

CONCLUSIONS

Dried herbs are still high in biologically active compounds. The highest value of total color difference (ΔE) between the sample and standard was found for herbs de Provence. Physicochemical properties of herbs depended on the type of the herb. Generally, high contents of nitrogen and ash were found in dried leaves of basil. Oregano herbs had the higher caloric value up to 35% compared to basil.

Mineral content varied and was strictly correlated with the grade of herbs. The best source of Ca, K, Mg and P was basil, while their lowest amount was found in herbs de Provence (containing a mixture of different herbs), which mostly likely was the reason for the low amount of macro- and micro-components.

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The problem of covering the fields by the circles in the task of optimization of observation points for ground video monitoring systems of forest fires

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Abstract. The problem of covering the area by circles, mathematical model of the coating offers a new coverage criteria based on which analytically describes the range of permissible solutions of the problem. Based on the analysis of the properties of the model, it is shown that the solution of the problem can be reduced to the solution of problems of nonlinear programming sequence.

At the moment, there are systems of video monitoring forest land. An important class of geometric design problems is problems of irregular covering the field by geometric objects, as well as regular. In the problems of covering it is set up a claim that all points of the field were covered by geometric objects, while the conditions of non-intersection of objects between themselves and their placement in the field may be violated. One problem with the design of terrestrial video monitoring systems is to optimize the placement of observation points. optimal placement of towers problem can be formulated as a coating task.

An approach to the placement of towers terrestrial video monitoring of forest fires, the main stage of which is set forth search method local extremum in the problem coverage area circles of varying radius.

There is build a mathematical model to optimize the placement of variable radius circle and on its basis – the development of methods of solution and proposed an approach to obtaining a local extremum of covering problem.

Key words: circle, coverage criteria, optimization, nonlinear programming.

INTRODUCTION

One of the approaches to the early detection of forest fires is a monitored [1], as space [2], and ground [3, 4]. Satellite monitoring allows you to quickly identify pockets of fires on forest area of more than (6 - 8) hectares in remote areas with a high update rate and wide coverage area of observation. In this case information obtained remotely, allows not only to analyze the current situation with forest fires, but also to further analyze the dynamics of fire [5–7]. For the detection of fire outbreaks, forest areas are smaller local terrestrial methods using watchtowers and match different designs, industrial video systems. The monitoring data of different levels (ground and space) constitute a single architecture information layers of geographic information systems for monitoring forest fire.

At the moment, there are systems of video monitoring forest land [8–12]. The simplest system [8] allows on the basis of the color image to increase the efficiency, quality and identification of fires in the forests. The monitoring system [9] based on network principle. Video cameras transmit information by radio to a single control point. In the Pskov region tested the system [10], based on forest monitoring with the help of video equipment. The German company offers their Fire Watch developed a system using equipment company IQ wireless [11].

In 2008, the Nizhny Novgorod company "Remote control system" developed an innovative "Forest Watch" forest monitoring system for the early detection of forest fires and determine their origin. [12] "Forest Watch" operates on the basis of modern technologies: IP-CCTV, mobile applications, geographic information systems (GIS), Internet applications and "computer vision".

One problem with the design of terrestrial video monitoring systems is to optimize the placement of observation points. optimal placement of towers problem can be formulated as a coating task. These problems are referred to a class of optimization geometric design problems [13], which solution as well as the development of their methods is important. This class of problems include the problem of optimal material cutting (both regular and irregular), the problems of building the optimal ways and linking networks, coverage, partition, some scheduling problems, and others [13–19].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIOS

An important class of geometric design problems are problems of irregular covering the field by geometric objects [20], as well as regular [20–24]. In the problems of covering it is set up a claim that all points of the field

were covered by geometric objects, while the conditions of non-intersection of objects between themselves and their placement in the field may be violated. Results and detailed reviews on given researches are in [25–27]. The problems of single covering a limited area by N-circles (such as in a Euclidean metric, and in some other metrics) is also known as the problem of N-centers. For the problem of N-centers in different metrics it is offered a variety of heuristics and algorithms using Voronoy's regions [28].

Problems of coverage are models of many practical problems. In [29] it is set and solved the problem of interaction between militarized security subdivisions of the railroad and fire-rescue units, which is reduced to covering the area by the circles of different radii. In [30-32] it is set the problem of the placement optimization for observation points, which arises when designing ground video monitoring systems. The problem is reduced to the problem of covering the area by the circles of variable radii, the value of which depends on the class of fire danger of covered area and its relief. Thus, the important practical problems require to develop the methods of covering the fields by circles of variable radius.

OBJECTIVES

The purpose the article is to build a mathematical model to optimize the placement of variable radius circle and on its basis - the development of methods of solution. We propose an approach to obtaining a local extremum of covering problem.

THE MAIN RESULTS OF THE RESEARCH

There is a polygon P, defined by a set of vertices p_k, $k = 1,2,...,n$ and a set of circles C_i, $i = 1,2,...,N$, with varying radius $r_i < r$ and centers $v_i = (x_i, y_i)$. Suppose $u = (v_1, r_1, ..., v_N, r_N)$ – vector of variables, $F(u)$ - the objective function,

$$\Xi(u) = \bigcup_{i=1}^{N} C_i(u_i, r_i).$$

By definition $\Xi(u)$ – coverage of polygon P if:

$$P \subset \Xi(u) \Leftrightarrow \Xi'(u) \bigcap P = \varnothing,$$

where: $\Xi'(u) = R^2 \setminus \operatorname{int} \Xi(u)$.

Note 1. In this study, we consider only such coverings, which met the following conditions

$$\operatorname{int} C_i \not\subset \Xi_i(u),$$

$$\Xi_i(u) = \bigcup_{j=1}^{i-1} C_j(v_j, r_j) \bigcup_{k=i+1}^{N} C_k(v_k, r_k) \text{ and}$$

$$\operatorname{int} C_i(v_i, r_i) \bigcap \operatorname{int} P \neq \varnothing,\ i = 1,2,...,N.$$

Problem of circular coverage of polygon. The start point – vector

$$u^0 = (v_1^0, r_1^0, ..., v_N^0, r_N^0),$$

where: $\Xi(u^0)$ covers a polygon P.

The task – to determine the vector

$$u^* = (v_1^*, r_1^*, ..., v_N^*, r_N^*),$$

in which $F(u)$ reaches the extreme and $\Xi(u^*)$ is coverage of a polygon P.

The problem of covering polygon by circles. Mathematical model of the problem of circular coverage can be represented as follows:

$$\underset{u \in W}{extr}\, F(u), \tag{1}$$

where:

$$W = \{u \in R^{3N} : \Xi'(u) \bigcap P = \varnothing\} \tag{2}$$

As a criterion of covering for a fixed u can be used phi-function method [24]:

$$\Xi'(u) \bigcap P = \varnothing \Leftrightarrow \Phi^{\Xi' P} \geq 0,$$

where: $\Phi^{\Xi' P}$ – phi-function of objects $\Xi'(u)$ and P [29].

Since the description of admitted region of the form (2) in an analytical form is extremely difficult theoretical problem and requires significant computational cost, in this study we propose the coverage criteria based on the following statement.

Statement. In order $\Xi(u)$ to cover the polygon P, it is necessary and sufficient that the vector $u = (v_1, r_1, ..., v_N, r_N)$ satisfies the condition:

1) $\forall p_k\ k \in I_n$, exists such circle C_i, that

$$p_k \in C_i,\ C_i \not\subset P;$$

2) if there is a point

$$t \in frC_i \bigcap frP,\ C_i \not\subset P,$$

then there are a circle C_j and a point $v_{ij}, i \neq j$, such that

$$v_{ij} \in C_i,\ v_{ij} \in C_j,\ v_{ij} \in R^2 \setminus \operatorname{int} P;$$

3) if there is a point $t = frC_i \bigcap frC_j$ and where in $t \in frP$, there is C_s and a point $v_{ijs}, s \neq i, s \neq j$, such that

$$v_{ijs} \in C_i,\ v_{ijs} \in C_j, v_{ijs} \in C_s;$$

4) if there is a point $t_q = frC_i \bigcap frC_j$ and $t_q \in \operatorname{int} P$, $q = 1,2, i \neq j$, then there is a circle C_s and a point $v_{ijsq}, s \neq i, s \neq j$, such, that

$$v_{ijsq} \in C_i,\ v_{ijsq} \in C_j, v_{ijsq} \in C_{sq}.$$

On the Fig. 1 there is an example of a polygon coverage by the set of circles with the points of type $v_{ij}, v_{ijs}, v_{ijs1}, v_{ijs2}$.

With this in mind, the inequalities describing the admitted region of the problem based on the information about the start point can be written as:

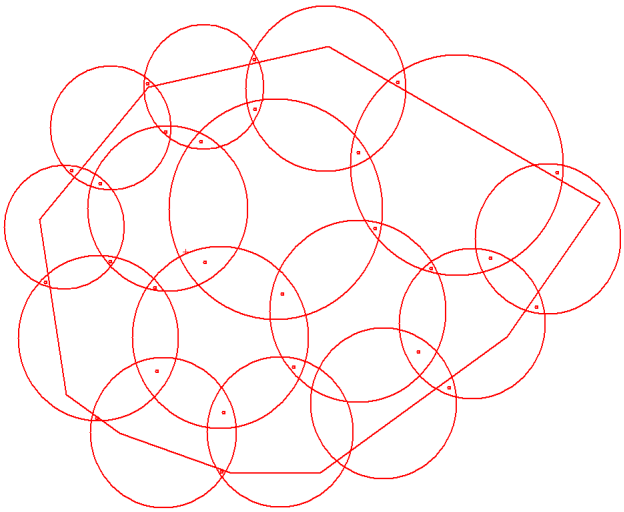


Fig.1. Example of coverage by circles with system of auxiliary points

1) for the vertices of the polygon $\forall p_k\ k \in I_n$, and the corresponding circles C_i, $p_k \in C_i$, $C_i \not\subset P$, inequality:

$$(x_{i_1} - x_k)^2 + (y_{i_1} - y_k)^2 \leq r_{i_1}^2,$$

$$(i_1, k) \in \Xi_1, \qquad (3)$$

2) for points $t \in frC_i \bigcap frP$, circles $C_i \not\subset P$ and the corresponding circles C_j is the inequalities system in the form:

$$\begin{cases} (x_{i_2} - x_{i_2 j_2})^2 + (y_{i_2 i_2} - y_{i_2 j_2})^2 \leq r_{i_2}^2 \\ (x_{j_2} - x_{i_2 j_2})^2 + (y_{j_2} - y_{i_2 j_2})^2 \leq r_{j_2}^2 \\ f_{i_2 j_2}(x_{i_2 j_2}, y_{i_2 j_2}) \geq 0 \end{cases},$$

$$(i_2, j_2) \in \Xi_2, \qquad (4)$$

where: $f_{i_2 j_2}(x_{i_2 j_2}, y_{i_2 j_2}) \geq 0$ – the membership function of the set $R^2 \setminus \operatorname{int} P$ of points $v_{i_2 j_2}$ (maximum of k linear functions);

3) for points $t = frC_i \bigcap frC_j$, $t \in frP$ and the corresponding circles C_s – the inequalities system in the form:

$$\begin{cases} (x_{i_3} - x_{i_3 j_3 s})^2 + (y_{i_3} - y_{i_3 j_3 s})^2 \leq r_{i_3}^2 \\ (x_{j_3} - x_{i_3 j_3 s})^2 + (y_{j_3} - y_{i_3 j_3 s})^2 \leq r_{j_3}^2 \\ (x_s - x_{i_3 j_3 s})^2 + (y_s - y_{i_3 j_3 s})^2 \leq r_s^2 \end{cases},$$

$$(i_3, j_3, s) \in \Xi_3, \qquad (5)$$

4) for points $t_q = frC_i \bigcap frC_j$ and $t_q \in \operatorname{int} P$, $q = 1,2, i \neq j$ and the corresponding circles C_{sq} – the inequalities system in the form:

$$\begin{cases} (x_{i_4} - x_{i_4 j_4 s_1})^2 + (y_{i_4} - y_{i_4 j_4 s_1})^2 \leq r_{i_4}^2 \\ (x_{j_4} - x_{i_4 j_4 s_1})^2 + (y_{j_4} - y_{i_4 j_4 s_1})^2 \leq r_{j_4}^2 \\ (x_{s_1} - x_{i_4 j_4 s_1})^2 + (y_{s_1} - y_{i_4 j_4 s_1})^2 \leq r_{s_1}^2 \end{cases},$$

$$(i_4, j_4, s_1) \in \Xi_{41}, \qquad (6)$$

and

$$\begin{cases} (x_{i_4} - x_{i_4 j_4 s_2})^2 + (y_{i_4} - y_{i_4 j_4 s_2})^2 \leq r_{i_4}^2 \\ (x_{j_4} - x_{i_4 j_4 s_2})^2 + (y_{j_4} - y_{i_4 j_4 s_2})^2 \leq r_{j_4}^2 \\ (x_{s_2} - x_{i_4 j_4 s_2})^2 + (y_{s_2} - y_{i_4 j_4 s_2})^2 \leq r_{s_2}^2 \end{cases},$$

$$(i_4, j_4, s_2) \in \Xi_{42}. \qquad (7)$$

Thus, the mathematical model of the problem coverage area can be formulated as a problem of local optimization:

$$\min_{u \in W \subset R^\delta} F(u) \qquad (8)$$

$$u = (u_1, u_2, ..., u_N, v_{i_2 j_2}, (i_2, j_2) \in \Xi_2,$$
$$v_{i_3 j_3 s}, (i_3, j_3, s) \in \Xi_3, v_{i_4 j_4 s_1}, (i_4, j_4, s_1) \in \Xi_{41},$$
$$v_{i_4 j_4 s_2}, (i_4, j_4, s_2) \in \Xi_{42})$$

in the area of feasible solutions W, taking into account the limitations of the system (3)-(7). Here:

$$\sigma = 3N + 2|\Xi_2| + 2|\Xi_3| + 2|\Xi_{41}| + 2|\Xi_{42}|,$$

Ξ - cardinality of the set Ξ, Ξ_1 - set of indexes of pairs of numbers of vertices polygon and circles, satisfying the conditions of paragraph 1 of the criterion of the existence of covering the polygon by the circles, Ξ_2 - set of indexes of pairs of numbers of vertices polygon and circles, satisfying the conditions of paragraph 2 of the criterion of the existence of covering the polygon by the circles, Ξ_3 is set of indexes of pairs of numbers of vertices polygon and circles, satisfying the conditions of paragraph 3 of the criterion of the existence of covering the polygon by the circles, Ξ_{4q}, $q = 1,2$ - set of indexes of triples of numbers of vertices polygon and circles, satisfying the conditions of paragraph 4 of the criterion of the existence of covering the polygon by the circles,

$$u_i = (x_i, y_i, r_i) = (v_i, r_i),\ i = 1,2,...,N;$$

$v_{i_2 j_2} = (x_{i_2 j_2}, y_{i_2 j_2})$, $v_{i_3 j_3 s} = (x_{i_3 j_3 s}, y_{i_3 j_3 s})$, $v_{i_4 j_4 s_q} = (x_{i_4 j_4 s_q}, y_{i_4 j_4 s_q})$ is the coordinates of auxiliary points that are used to formalize the terms of covering.

Search of local optimal solution is performed using nonlinear of package of open source IPOPT. It should be noted that at the last iteration of the algorithm point of local extremum in the subregion is the points of local extremum of the initial problem.

Given a starting point - a vector

$$u^0 = (u_1^0, r_1^0, ..., u_N^0, r_N^0),$$

in which $F(x_1^0, y_1^0, r_1^0, ..., x_N^0, y_N^0, r_N^0)$ is a covering P (Fig. 2a).

It is necessary to define a vector $u^* = (x_1^*, y_1^*, r_1^*, ..., x_N^*, y_N^*, r_N^*)$, in which $F(u)$ is a covering P, and the radii of the circles have reached the minimum value (at zero - the circle is removed). On Fig.2b is an example of problem solving.

An algorithm for solving the problem of location of observation terrestrial systems video monitoring forest fires [30], the main stages of which are as follows:

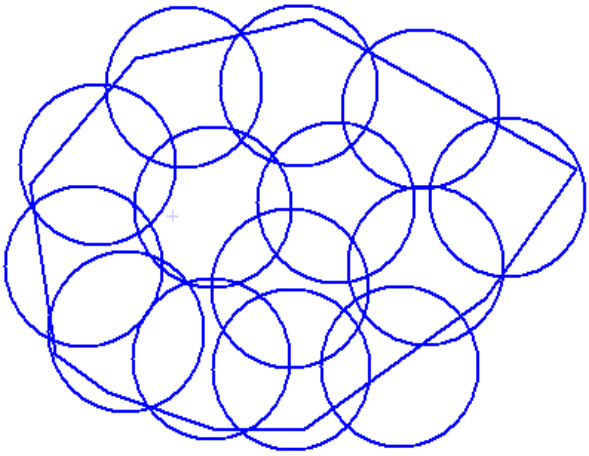
1. Construction start permissible coverage and corresponding function tables gridded values based on the analysis of the relief and fire safety zones.

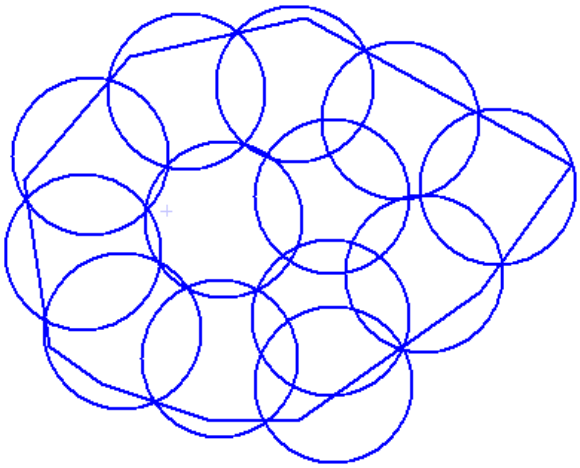
2. Selection on the basis of the analysis of the tabulated values in the vicinity of each of the towers interpolation areas for which interpolation polynomial satisfies the constraints on the maximum permissible error, the transformation of the selected area to the square of the size of the unit (if appropriate transformation of the detector coordinates) and the construction of the coefficients of interpolating polynomials.

3. Generation of a system of nonlinear inequalities describing the range of permissible solutions of the problem.

4. Search locally optimal solutions generated subdomain of feasible solutions for the methods described above. Contact coordinate transformation fire detectors. If you receive improved value of the objective function, then a transition to the second point, otherwise the completion of the algorithm.

Conclusion. An approach to the placement of towers terrestrial video monitoring of forest fires, the main stage of which is set forth search method local extremum in the problem coverage area circles of varying radius.





a) b)

Fig. 2. Covering of polygon by circles: a) the initial covering of area; b) optimization result

CONCLUSIONS

The constructed model of covering the polygon by the circles of variable radii and a method for obtaining local extremum is basic for a wide range of practical problems, in particular for the problem of locating points of video surveillance, which arises when designing ground video monitoring systems.

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Impact of the biomass pyrolysis parameters on the quality of biocarbon obtained from rape straw, rye straw and willow chips

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Abstract. In the article the results of studies conducted regarding the thermal processing of rape straw, rye straw and willow chips applying various parameters of the pyrolysis process are presented. Samples of biomass were subject to thermal processing at various temperatures and process durations, assessing the impact of the applied conditions on physicochemical parameters of the obtained pyrolysis products. The contents of phosphorus, potassium, magnesium, carbon and nitrogen were analysed. The studies have indicated that the pyrolysis process can be used to refine biomass, among others obtained from straw and chips, in the context of using it for fertilization. Modification of the pyrolysis process parameters (temperature, time) significantly impacted the concentration of the analysed macroelements. It has been stated that the highest content of phosphorus, potassium and magnesium in biocarbon (rape straw, rye straw and willow chips) can be obtained performing pyrolysis at the temperature of 5000C for 10 minutes. A significant impact of the pyrolysis parameters – temperature and time on the total content of macroelements in the obtained biocarbon was observed. The highest contents of phosphorus, potassium and magnesium were observed in the case of biocarbon obtained at the temperature of 5000C during 10 minutes, while the temperature of 4000C and duration of 10 minutes allowed to obtain the maximum content of carbon and nitrogen.

Key words: biomass, straw, willow chips, pyrolysis, biocarbon, macroelements.

INTRODUCTION

Due to the physical and chemical properties of biocarbon, it can be used in sequestration of carbon in the soil, production of fertilizers, as well as soil recultivation [13]. Biocarbon has a positive impact on fertility and productivity of the soil and it can protect plants from infections causing diseases [17]. Introduced into the soil, it can contribute to an increase of water capacity of the terrain and decrease soil acidity [8]. One characteristic of biocarbon is its capacity for retention and exchange of nutrients which translates into an increased availability of nutrients for plants and improvement of soil properties [6, 13]. Biocarbon properties also allow its use in remediation of polluted soils, therefore limiting bioavailability of pollution for living organisms [3].

The purpose of the presented study was to examine the impact of parameters of the pyrolysis process on the properties of the obtained biocarbon regarding the content of phosphorus, potassium, magnesium, carbon and nitrogen.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIOS

The study material included rape straw, rye straw and willow chips, which were subject to thermal processing. In order to prepare samples for analysis, homogenization of the study material was conducted, which was later divided into equal parts according to the following standards: PN-EN 14780:2011(U) and PN-EN 14778:2011(U). The pyrolysis process was conducted using the LECO TGA 701 thermogravimetric analyser. Thermal conversion of biomass was conducted at the temperatures of 400 and 500oC for 5, 10 and 15 minutes in the nitrogen (99.99% pure) atmosphere. The gas flow was 10l/min, and the level of temperature increase was 30oC/min. The pyrolysis products obtained from rape straw, rye straw and willow chips were subject to studies in the TrueSpec device in order to determine the content of carbon and nitrogen (CHN module) according to standard PN-EN 15104:2011(U). The analysis conducted using the TrueSpec device for simultaneous marking of carbon and nitrogen was based on the principles of the Dumas method, also determined as the method of high-temperature combustion in oxygen. Application of this method allowed to mark elements within a time period not exceeding 4 minutes. The analysed material was also subject to microwave digestion with the concentrated nitrogen acid under increased pressure in Teflon containers in the Milestone ETHOS ONE microwave digestion system. The digestion of the studied material was conducted in three parallel repetitions. Marking the total content of phosphorus, potassium and magnesium in the analysed samples was conducted by means of the optical emission spectrometry of the inductively coupled plasma (ICP-OES) using the Thermo Scientific iCAP Dual 6500 device. To calculate the content of the analysed macro-elements, calibration curves were used,

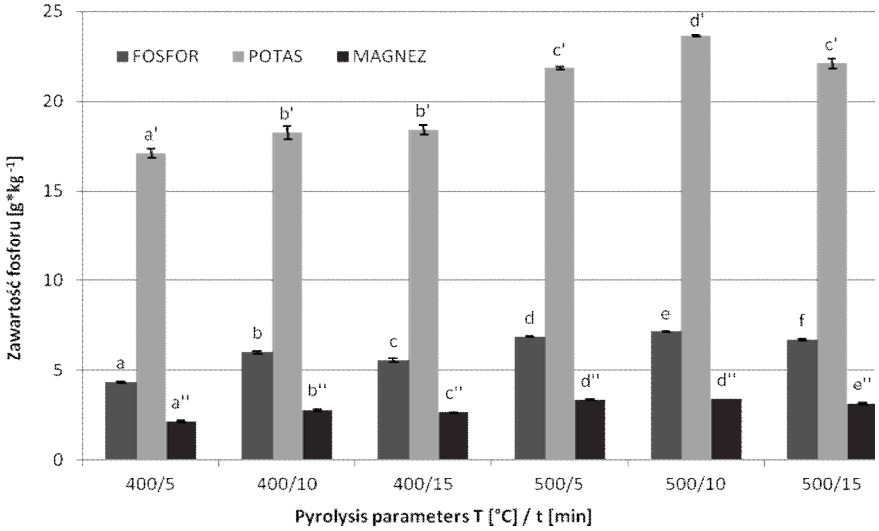
which were prepared using the patterns of the studied compounds.

The obtained results were subject to statistical analysis in the Statistica 10 program. Average values were compared using the Duncan test at the significance level of p=0.05 for n=3.

THE MAIN RESULTS OF THE RESEARCH

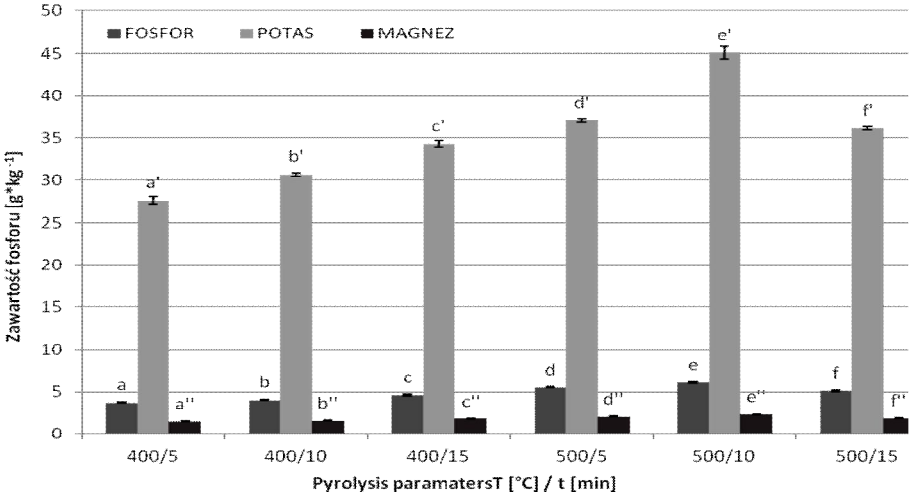
In Fig. 1 the content of phosphorus, potassium and magnesium in biocarbon obtained from rape straw applying various temperature and pyrolysis time parameters was presented. The content of phosphorus, potassium and magnesium in the pyrolysis products suited the relevant ranges: 4.4 – 7.1 g*kg^{-1}; 17.1 – 23.6 g*kg^{-1}; 2.1 to 3.4 g*kg^{-1}. An increase of temperature and extension of duration significantly impacted an increase of the content of the analysed elements. The highest values of phosphorus, potassium and magnesium were observed in biocarbon (rape straw) which occurred at the temperature of 500^{0}C applied for 10 minutes.

In Fig. 2 the impact of the applied rye straw pyrolysis parameters on the content of phosphorus, potassium and magnesium in the obtained products was presented. The content of phosphorus, potassium and magnesium was observed, accordingly, at the levels of 6.1 g*kg^{-1}, 45.1 g*kg^{-1}, 2.3 g*kg^{-1}. Together with an increase of temperature and duration of the process the content of the studied macro-elements increased significantly reaching the highest values at the temperature of 5000C and in the period of 10 minutes. Further extension of duration of pyrolysis resulted in a significant decrease of the elements' levels.



Legend: Fosfor: Phosphorus, Potas: Potassium, Magnez: Magnesium, Zawartość fosforu: The content of phosphorus

Fig. 1.The content of phosphorus, potassium and magnesium in biocarbon obtained from rape straw depending on the pyrolysis parameters (temperature, time). Various letters indicate statistically significant differences between average values within group x, x', x'' (for $p \leq 0,05$)



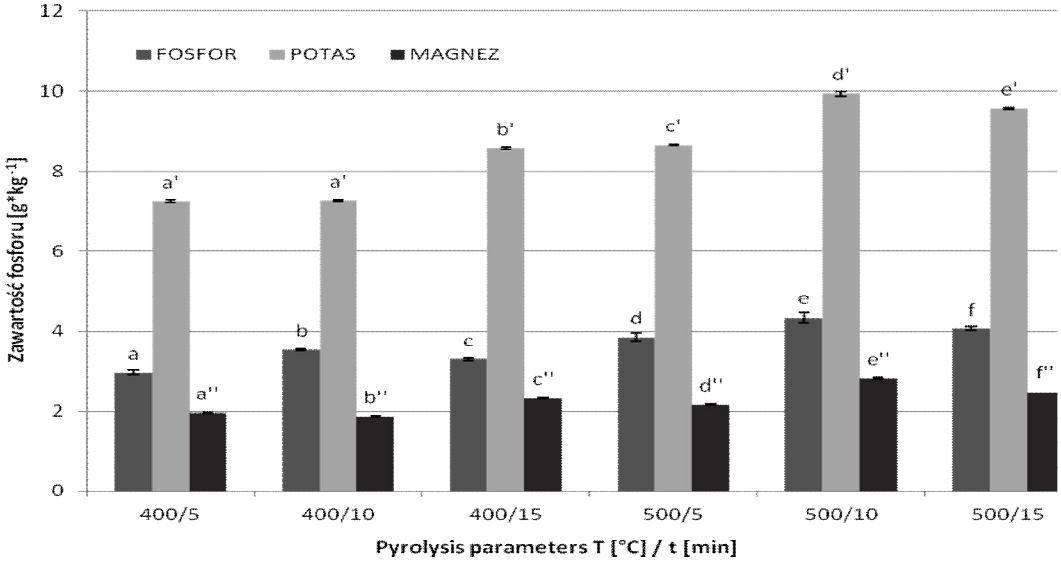
Legend: Fosfor: Phosphorus, Potas: Potassium, Magnez: Magnesium, Zawartość fosforu: The content of phosphorus

Fig. 2.The content of phosphorus, potassium and magnesium in biocarbon obtained from rye straw depending on the pyrolysis parameters (temperature, time). Various letters indicate statistically significant differences between average values within group x, x', x'' (for $p \leq 0,05$)

In Fig. 3. The results regarding the content of phosphorus, potassium and magnesium in the studied biocarbon obtained from willow chips depending on temperature and duration of the pyrolysis process were presented.

The maximum values for P, K and Mg, accordingly, at the level of 4.3 g*kg^{-1}; 9.9 g*kg^{-1}; 2.8 g*kg^{-1} were determined for the pyrolysis process at the temperature of 500^{0}C and in the period of 10 minutes. The highest content among the analysed elements was observed in the case of potassium – 9.9 g*kg^{-1}, similar as in the case of the pyrolysis products obtained from rape straw – 23.6 g*kg^{-1} and rye straw – 45.1 g*kg^{-1}. While the lowest content was observed in the case of magnesium: rape straw – 2.1 to 3.4 g*kg^{-1}, rye straw – 1.9 to 2.3 g*kg^{-1}, willow chips – 1.9 to 2.8 g*kg^{-1}.

In Tab. 1. the impact of the applied pyrolysis parameters on the content of carbon and nitrogen in the obtained biocarbon was presented. The highest contents of carbon and nitrogen were obtained in the pyrolysis process conducted at the temperature of 400^{0}C and in the period of 10 minutes. Biocarbon obtained from willow chips was characterized by the highest level of carbon, the value of which reached between 67.6 to 73.6%, while in the case of rye straw and rape straw these values were at the levels of 69.5 and 59%. The maximum concentration of nitrogen in the pyrolysis products was obtained from rye straw, rape straw and willow chips and it was 1.1, 1.9 and 1.6%, respectively. Analysing the substrates used in the pyrolysis process we can determine that biocarbon obtained from rape straw was characterized by the highest concentration of nitrogen. According to [2], the content of carbon in the products obtained in thermal processing at the temperatures 220-300^{0}C was 52-64%, while the content of nitrogen was between 0.2-2%.



Legend: Fosfor: Phosphorus, Potas: Potassium, Magnez: Magnesium, Zawartość fosforu: The content of phosphorus

Fig. 3. The total content of phosphorus, potassium and magnesium in biocarbon obtained from willow chips applying various pyrolysis parameters (temperature, time).Various letters indicate statistically significant differences between average values within group x, x', x'' (for $p \leq 0,05$)

Table 1.The content of carbon and nitrogen in biocarbon obtained applying various pyrolysis parameters (temperature, time)

	T [°C] / t [min]					
	400/5	400/10	400/15	500/5	500/10	500/15
	C [%]					
Rye straw	65.61 ± 0.09	69.52 ± 0.65	64.35 ± 0.36	67.13 ± 0.04	65.23 ± 0.06	65.98 ± 0.66
Rape straw	58.43 ± 034	59.01 ± 0.21	57.63 ± 0.60	57.14 ± 0.64	56.84 ± 0.42	57.89 ± 0.49
Willow chips	67.65 ± 0.54	73.60 ± 0.02	67.70 ± 0.16	71.50 ± 0.09	73.15 ± 0.33	70.79 ± 0.22
	N [%]					
Rye straw	0.71 ± 0.01	1.12 ± 0.01	0.87 ± 0.11	0.80 ± 0.04	1.03 ± 0.01	0.84 ± 0.07
Rape straw	1.28 ± 0.05	1.92 ± 0.06	1.42 ± 0.01	1.45 ± 0.12	1.54 ± 0.03	1.42 ± 0.01
Willow chips	1.18 ± 0.02	1.60 ± 0.06	1.07 ± 0.01	1.35 ± 0.01	1.45 ± 0.07	1.47 ± 0.12

The authors stated that modifications of parameters (temperature and time) in the torrefaction process of chips of apple tree branches can cause changes in the contents of carbon and nitrogen by 16 and 0.5%,

respectively. [10] argue that the pyrolysis products obtained from straw and chips at the temperature of 350°C are characterized by the content of carbon at the level of 64, and 74%, respectively and nitrogen at the level of 1.3 and 0.3%. [19] note that an increase of temperature in the torrefaction process of oat straw results in higher carbonization of the material, the maximum level of which – 57.1% was determined for the product obtained at the temperature of 300^0C. Similar results were obtained by [5], who conducted pyrolysis of oak and pine wood at the temperatures 300, 400, 500 and 600^0C and observed significant changes of the content of carbon in the obtained pyrolysis products, the maximum value of which was 75%..

In Tab. 2. the highest marked concentrations of elements in biocarbon obtained using various pyrolysis parameters were presented in comparison to other natural fertilizers. It was stated that the temperature of 500^0C and duration of 10 minutes are the optimal pyrolysis conditions which allow to obtain the maximum contents of phosphorus, potassium and magnesium in biocarbon obtained from rape straw, rye straw and willow chips. In the case of carbon and nitrogen, the maximum contents of these elements in all the analysed materials were marked in the biocarbon obtained at the temperature of 400^0C during 10 minutes. The biocarbon obtained from rape straw was characterized by the highest concentration of phosphorus, magnesium and nitrogen, respectively, at the level of 7.1, 3.4 g*kg^{-1} and 1.9 %. In the pyrolysis products obtained from rye straw the maximum content of potassium was observed at the level of 45.1 g*kg^{-1}, while the highest content of carbon – 73.6% was identified in biocarbon obtained from willow chips. Biocarbon in comparison to biomass ash was characterized by a lower content of phosphorus, potassium and magnesium, but a higher concentration of carbon and nitrogen. In comparison to another natural fertilizer, such as cattle manure, the obtained biocarbon was characterized by a much higher content of the analysed elements.

Tab. 3. presents the values of the calculated correlation coefficients between the selected elements of analysed materials. A high positive correlation was determined between the contents of phosphorus and magnesium, as well as magnesium and carbon. The values of the correlation coefficients were 0.74 and 0.63, respectively.

Table 2.The highest contents of the analysed elements in biocarbon obtained from rape straw, rye straw and willow chips in comparison with other natural fertilizers.

	Rape straw	Rye straw	Willow chips	Biomass ash[1]	Cattle manure [1]
	[g*kg^{-1}]				
Phosphorus	7.1 ± 0.04*	6.1 ± 0.11*	4.3 ± 0.13*	14.7 ± 0.45	2.3 ± 0.12
Potassium	23.6 ± 0.07*	45.1 ± 0.72*	9.9 ± 0.05 *	70.5 ± 0.42	4.9 ± 0.21
Magnesium	3.4 ± 0.01*	2.3 ± 0.04*	2.8 ± 0.02*	27.2 ± 0.61	1.1 ± 0.05
	%				
Carbon	59.01 ± 0.21**	69.5 ± 0.65**	73.6 ± 0.02**	1.22 ± 0.03	19.2 ± 0.32
Nitrogen	1.9 ± 0.06**	1.1 ± 0.01**	1.6 ± 0.06**	0.2 ± 0.02	3.35 ± 0.07

* - biocarbon obtained at the temperature of 500^0C during 10 minutes.
** - biocarbon obtained at the temperature of 400^0C during 10 minutes.
[1]–authors' own studies

Table 3. Correlation coefficients between selected elements in the analysed materials.

	Phosphorus	Potassium	Magnesium	Carbon	Nitrogen
Phosphorus	1	0.48	0.74	0.48	0.22
Potassium		1	-0.18	-0.12	0.05
Magnesium			1	0.63	0.32
Carbon				1	-0.22
Nitrogen					1

CONCLUSIONS

1. The conducted studies indicated that the pyrolysis process of biomass significantly impacted the quality of the obtained biocarbon.
2. The obtained biocarbon was characterized by a high total content of phosphorus, potassium and magnesium, respectively, at the level of 7.1, 45.1, 3.4 g*kg^{-1} and it can be used as a valuable natural fertilizer.
3. A significant impact of the pyrolysis parameters – temperature and time on the total content of macroelements in the obtained biocarbon was observed.
4. The highest contents of phosphorus, potassium and magnesium were observed in the case of

biocarbon obtained at the temperature of 500^0C during 10 minutes, while the temperature of 400^0C and duration of 10 minutes allowed to obtain the maximum content of carbon and nitrogen.

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