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AN ARCHITECTURE AND EMPIRICAL RESEARCH OF DEDICATED KNOWLEDGE PROCESSING INTERPRETER

Ivan V. Savchenko

Abstract: *Developing of architectures of computer systems, which effectively support knowledge processing, remains a relevant problem. Architecture and empirical research of performance of dedicated knowledge processing interpreter are suggested in the paper. The studies were made by using the methods of mathematical statistics. The results proved reasonability of using dedicated knowledge processing interpreters. The knowledge processing interpreter can be used to develop high-performance knowledge processing systems.*

Keywords: *knowledge processing interpreter, performance, architecture, processor, instruction set, prototyping board.*

ACM Classification Keywords: *C.1.3 Other Architecture Styles*

Introduction

Knowledge processing systems play an important role in human life and their using is constantly growing. The systems are used in such application areas [Rossitza Setchi at al., 2010]: management and control of production processes; diagnostics, trouble-shooting; robotics; image processing; computer vision; medical systems; monitoring and forecasting of the financial and stock markets, etc.

The volume and complexity of the tasks that solve knowledge processing systems are constantly growing. This causes hardware developers to find ways to create faster, more reliable and at the same time energy-conserving architectures of computer systems. The major tasks in this area are [Stallings, 2010]: increasing processor performance, increasing memory speed and increasing input-output speed of ports. In this paper a focus is concentrated on increasing processor performance task.

Modern knowledge processing systems use such hardware architectures of their processors [Stallings, 2010]: multi-core, multithreading, superscalar and very long instruction word. Today increasing architecture performance is achieved by [Stallings, 2010]: reduction in the size and density of gates; increasing size and speed of cache memory; implementation of changes to architecture and organization of the processor (using various forms of parallelism, instruction pipelining and an integration of additional sets of instructions). However, semantic gap, lack of architectural flexibility, inefficient use of memory and high hardware cost make it necessary to develop dedicated hardware architectures to efficiently support problem of knowledge processing [Kurgaev, 2008].

The first attempts to solve the problem of the semantic gap were made in the 60's and 70's. Their essence was to develop non-von Neumann architecture of computer systems, suitable for direct interpretation of the programs written in high or intermediate level. Well-known works of such famous scientists in this area are: Glushkov V.M., Skurihin V.I., Palagin A.V., Morozov A.O., Malinowski B.M., Boyun V.P., Klimenko V.P., Yakovlev Y.S., Amamiya M., Tanaka Y. et al. However, a huge implementation complexity of these architectures forced to abandon the approach [Amamiya at al., 1993].

Rapid development of modern system-on-a-chip technologies, suggest the developing of a new dedicated architectures for solving problems in subject area. Dedicated system structure (fig. 1) contains the following main modules: general-purpose processor, random-access memory (RAM), problem-oriented coprocessor (dedicated coprocessor), processor and peripheral bus. Depending on the location of the general-purpose processor to dedicated coprocessor, there are two types of coupling [Hauck, 2008]: 1) tightly coupling – general-purpose processor and dedicated logic are placed in the same module (general-purpose processor) or general-purpose processor and dedicated coprocessor are placed on the same processor bus; 2) loosely coupling – general-purpose processor and dedicated coprocessor are placed in various busses (processor and peripheral buses). Selecting of the type of connection depends on the intensity of the data exchange between general-purpose processor and dedicated coprocessor.

The main principle of operation of dedicated architecture is reducing sequential logic with combinational logic (fig. 2) in a system. The system has a number of independent dedicated arithmetic logic units (ALU) which operates simultaneously. Thanks to this adaptation the systems can provide a much more performance. However, this increases the amount of equipment that is involved in the system, and as a result increases energy consumptions [Hauck, 2008].

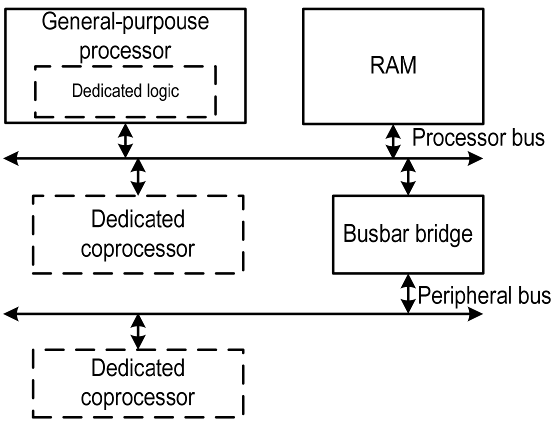

Figure 1. Structure of dedicated system

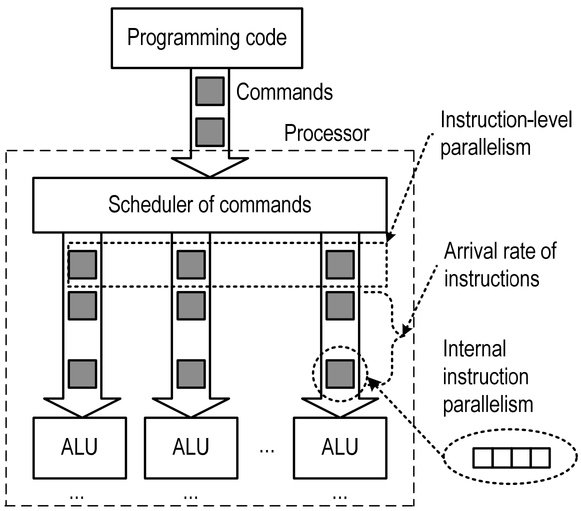

Figure 2. The main principle of operation of dedicated architecture

Systems based on system-on-a-chip technologies are widely used for creation of dedicated hardware which increasing performance of knowledge processing systems (systems based on neural networks, genetic algorithms, database search, word-processing, logical conclusion).

In [Poznanovic, 2006] suggested FPGA based non-von Neuman processor which achieving performance through harnessing parallelism of data-flow processing, utilizing multi-core fixed logic technology, increasing chip capacity and higher clock rates and delivering power efficient performance. In [Salapura at al., 1994] suggested an economic architecture (cost of hardware resources) and fast topology map, which allows for large neural network. The proposed topology allows for a variety of models of neural networks. In [Netin at al., 2003] suggested FPGA implementation of an expert system, according to which the knowledge base is transformed into an equivalent hardware network whose nodes are the facts, and the connections between nodes – relationships. Results of experiments show a significant advantage of the expert system. In [Kokosinski at al., 2002] proposed architecture and multi-operand associative processor, which is capable of simultaneously and efficiently perform 16 operations logical search operation, including the operations (= ≠, <,>, ≤, ≥). In monograph [Teodorescu at al., 2001] presented broad overview of the architectures of hardware implementations of intelligent systems that using: reconfigurable logic, genetic algorithms, fuzzy logic, neural networks and parallel algorithms. In [Galuzzi at al., 2008] suggested increasing performance of architecture of computer system by expanding instruction set of processor with new instructions.

Among the main limitation of the existing architectures for knowledge processing systems are [Kurgaev, 2008]: 1) the need to implement a large number of operations for symbolic computations; 2) lack of effective knowledge representation in memory and lack of effective information processing of complex structures such as: nested, iterative and recursive.

Research task of the paper are suggesting an effective architecture of dedicated knowledge processing interpreter and empirical study of its performance.

2 Knowledge processing interpreter functioning principles

The functional structure (fig. 3) of the knowledge processing interpreter includes [Kurgaev, 2008]: compiler, interpreter of knowledge base, interpreter of terminal programs, glossary of terms, input and output arrays.

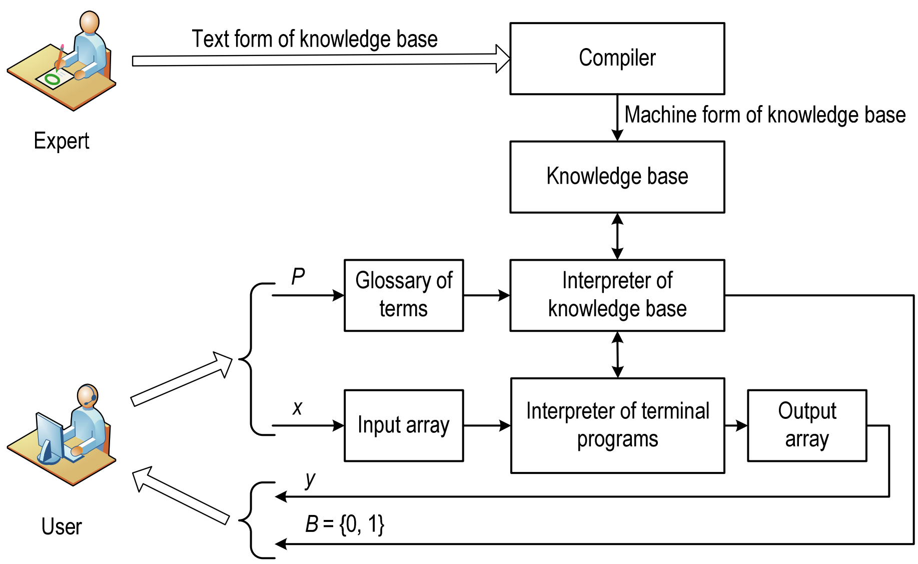

Figure 3. Functional structure of knowledge processing interpreter

The knowledge base of any structurally complex problem can be represented formally [Kurgaev, 2008]:

$$KB = \langle A_{TR}, A_{CON}, C, S \rangle, \quad (1)$$

where KB – knowledge base, A_{TR} – a set of terminal programs defined outside the knowledge base; A_{CON} – set of nonterminal concepts; C – set of concepts of high complexity; S – data structures of concepts in set C which describing the relevant concepts as an alternative or a sequence of some of the concepts, each of which may be information structure iteration, terminal program or constant.

Knowledge base contains related concepts of some subject area. Each concept is defined as an alternative or a sequence of some concepts (concept also may include itself). Each concept can be an iteration of structures of definitions or set definitions. Any simple concept (with lowest level of complexity) is defined in the form of a constant or a procedure (terminal program) and is executed by main processor or dedicated hardware unit [Kurgaev, 2008].

Compiler converts the text representation of the knowledge base in a machine form.

The input and output arrays in the form of ASCII code contain such data accordingly: subject *x* of categorical statement *P*(*x*) which is necessary to prove; subject *y* obtained as a result of this proving.

Interpreter of terminal programs contains a set of terminal programs that execute on the request of the interpreter of knowledge base. Its input data is received from the input array. Output results are generated in the form of the truth value and in the form of data written to the output array.

Glossary of terms contains a set of records, each of which consists of two fields: «Name of concept» and «Address of concept». «Name of concept» in symbolic form contains name of a concept *P*. And «Address of concept» contains an address *A* of a concept *P* in knowledge base. Converting of name of a concept *P* in the address *A* is based on search function F_{CON}:

$$F_{CON}(P) \rightarrow A \qquad (2)$$

Interpreter of knowledge base derive categorical statement *P*(*x*) according to the algorithm of interpretation F_{INT}:

$$F_{IHT}(x, P) \rightarrow y, B, \qquad (3)$$

where $B = \{0, 1\}$ – the logical result of proving of categorical statement *P*(*x*), *y* – the subject (set of characters) obtained as result of proving *P*(*x*).

The process of the knowledge processing consists of four stages: 1) an expert creates knowledge base in text form; 2) knowledge base is compiled into machine form; 3) user formulates the problem in subject-predicate form *P*(*x*); 4) searching for the problem solution.

3 Knowledge processing interpreter architecture

The structure of knowledge processing interpreter, which is based on prototyping board M1AGL-DEV-KIT-SCS of Actel corp., is presented in fig. 4.

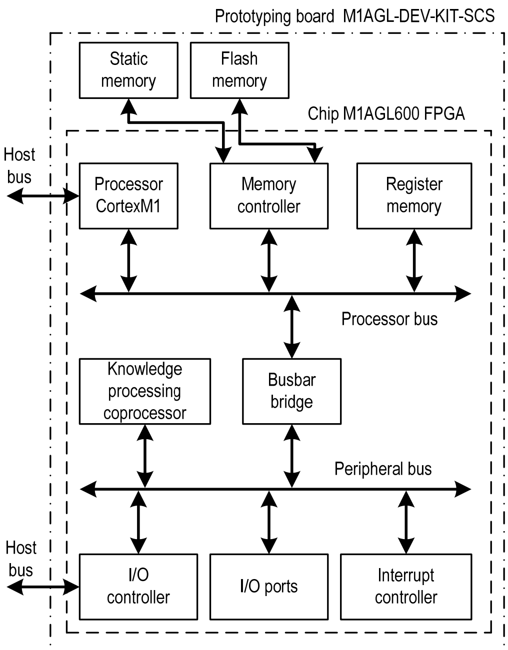

Figure4. Structure of the knowledge processing interpreter

The core of the interpreter is a chip M1AGL600 FPGA, which is located on prototyping board (fig. 4). The main modules of the interpreter are: static memory, flash memory, main processor (CortexM1), memory controller, register memory, processor bus (AHB), peripheral bus (APB), knowledge processing coprocessor, busbar bridge, I/O controller, I/O ports and interrupt controller. The interpreter also includes a host computer for problem statement and for reading the solved problem from interpreter. Host computer interacts with the interpreter through host busses. In order to extend an instruction set of the main processor, knowledge processing coprocessor was integrated into the interpreter.

Main processor performs following functions: initialization of knowledge processing interpreter; obtaining problem from host computer and transferring it to knowledge processing coprocessor; transferring result of solved problem to host computer; execution of a terminal programs by request of knowledge processing coprocessor.

Flash memory is intended for permanent storage of: program memory, knowledge base, glossary of terms, input and output arrays. Since flash memory is quite slow, but volatile, a data stored in it only when power is turned off. During the system initialization the data from flash memory is copying to faster memory – static memory.

Static memory is continuously using while the knowledge processing interpreter solving stated problem. And it also stores: program memory, stack of main processor (Cortex-M1), glossary of terms.

Register memory is used by main processor for storing local data (variables, arrays, constants). This provides maximum access to the local data.

Knowledge processing coprocessor performs interpretation of a knowledge base in accordance with the assigned problem stated by the host computer. It also maintains such memories: trace memory, stack memory, input and output array.

Interrupt controller is used for synchronizing the processes of exchanging of commands and data between the main processor and all functional modules of the interpreter. Interrupt controller also performs a major role in an exchange of data between the host computer and the interpreter.

I/O controller performs a function of a high-performance bridge between the interpreter and the host computer.

Timer and I/O ports are used to visually inform user about a current status of the interpreter.

The address space of the interpreter is divided into separated segments, so main processor has access to individual modules of the interpreter. The structure of knowledge processing interpreter memory, based on prototyping board, is shown in fig. 5.

Static memory includes program memory and glossary of memory of terms (fig. 5). Program memory contains program (algorithm) which controls interpreter functioning. The program provides interpreter functioning according to an algorithm (fig. 6). Consider the algorithm in more details.

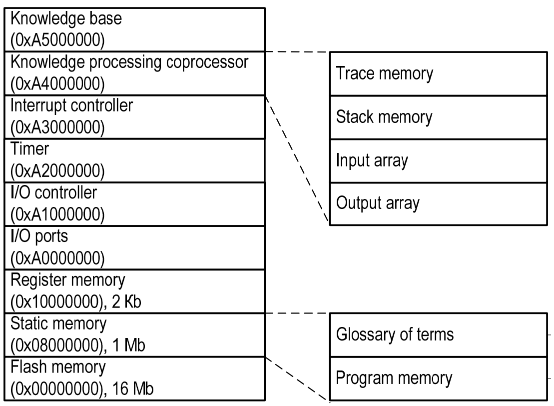

Figure 5. Structure of memory of knowledge processing interpreter

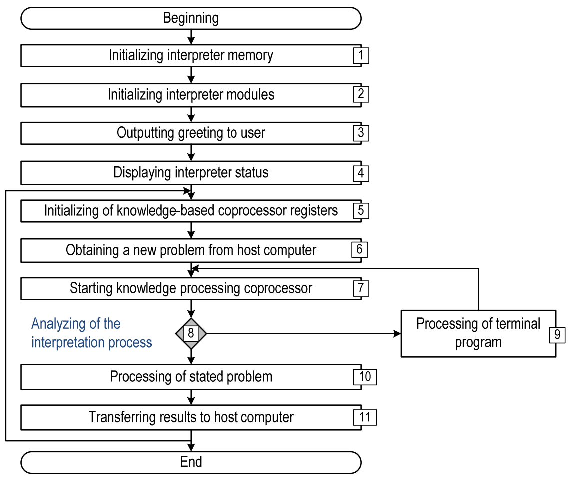

Figure 6. Algorithm of knowledge processing interpreter functioning

1. Initializing interpreter memory. The procedure begins by applying a power to the interpreter or after pressing the «RESET» button on the prototyping board. The information that is stored in flash memory is automatically rewriting to a static memory.

2. Initializing interpreter modules. Main processor writes specific data to the registers of all functional modules (input-output ports, I/O controller, interrupt controller, I/O ports, timer and knowledge processing coprocessor).

3. Outputting greeting to user. Main processor sends the host computer a message that indicates the interpreter is ready for problem execution.

4. Displaying interpreter status. Main processor reads data from registers (COUNTER, input and output array) of knowledge processing coprocessor and refers them to the host computer.

5. Initializing of knowledge processing coprocessor registers. Main processor initializing the registers (R_{02}–R_{03}, R_{06}–R_{09}, R_{OI}, R_{LM}) to zero in order to prepare of the interpreter to solve next problem.

6. Obtaining a new problem from host computer. Main processor receives from the host computer a new problem which comes as three parameters: a function argument, a function name and a mode of interpretation. The function argument (sequence of characters) stores in the input array. Then function name is searching in glossary of terms. If function name is found, then the address of function name in knowledge base is stored in knowledge processing coprocessor register R_{01}. In other case, you are prompted to re-enter the correct function name. Registers R_{10} and R_{11} are initializing depending on the mode of interpretation (table 1).

Table 1. Interpretation modes

№	Regime	R_{10}	R_{11}
0	Analysis without tracing	0	0
1	Analysis with tracing	1	0

7. Starting knowledge processing coprocessor. Main processor sending «START» message to knowledge processing coprocessor and it becomes solve the stated problem.

8. Analyzing of the interpretation process. If next to be done is terminal program, then go to Point 9, otherwise, go to Point 10.

9. Processing of terminal program. Knowledge processing coprocessor terminates its work and transfers control to the main processor. When processing of the terminal program is finished, control and results of processing are transferred to the knowledge processing coprocessor and go to Point 7.

10. Processing of stated problem. Knowledge processing coprocessor solves an interpretation problem according with its algorithm and current data in its registers and memories.

11. Transferring results to host computer. The main processor reads data from knowledge processing coprocessor registers, input, output arrays and forward them to the host computer. Next go to Point 5.

4 Knowledge processing coprocessor architecture

Since all functional modules of the knowledge processing interpreter are standard (we can find them in CAD system library), besides knowledge processing coprocessor, then let us discuss its architecture.

Knowledge processing coprocessor interprets knowledge base presented in the form of meta-language.

Knowledge processing coprocessor consists of (fig. 7): knowledge-based processor, knowledge base, trace memory, stack memory, input and output arrays [Kurgaev, 2008].

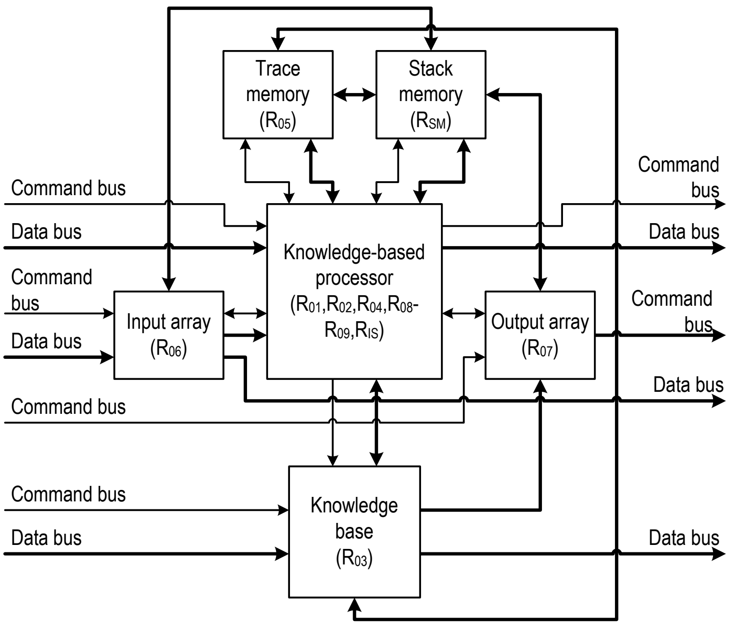

Figure 7. Structure of the knowledge processing coprocessor

Knowledge-based processor consists of control unit and processing unit. The control unit is designed as a Moore finite state machine. Processing unit contains such registers: R_{01}, R_{02}, R_{04}, R_{08}–R_{09} and R_{IS}. Detailed list of knowledge processing coprocessor register list are represented in table 2.

Table 2. Set of registers of knowledge processing coprocessor

Register		Description	Width, bits
R_{01}		Name of structure register	16
R_{02}		Number words frame register	16
R_{03}		Address knowledge base register	16
R_{04}		Coordinates trace register	16
R_{05}		Top trace register	16
R_{06}		Address register in the input array	16
R_{07}		Address register in the output array	16
R_{08}		Iteration register	16
R_{09}		Truth register	16
R_{IS}	R_{10}	Trace signs register	1
	R_{11}	Production signs register	1
	R_{12}	Inversion 1 register	1
	R_{13}	Inversion 2 register	1
	R_{14}	Type frame register	3
	R_{15}	Sign last element register	1
R_{SM}		Stack memory register	16

Stack memory contains the current state of interpretation process. States are stored in fixed-length records. Each record contains data about: input and output array index position, trace iteration register, the number of successful iterations and mode of interpretation.

The trace memory contains an array of records with fixed-length, which reflects the progress the interpretation of concepts in the form of derivation tree. Each record can contain data of two types of data: physical address of successfully interpreted alternatives or a number of successful executed iterations.

Knowledge base contains information structure of a knowledge, which consists of a set of frames. Each frame contains head and frame elements that are related with each other by ratio: conjunction, disjunction or iteration.

Head of frame and any frame elements occupy several adjacent locations in memory. The frame elements are located in following memory locations. Head of a frame is the first in this sequence and frame size (number of elements in a frame) can be various. Iteration frame consists of two components: a head and an iterated element. Iterated element is represented by a reference frame, which is the main component of a description of this item. This ensures connectivity of different frames in a single multiply nested structure that allows recursive structures. Difficulty of the description can be arbitrary and limits by resources of a particular implementation.

Instruction set of knowledge-based processor is showed in table 3.

Table 3. Instruction set of knowledge-based processor

№	Command name	Bin value	Description
1	NOP	000000 $_b$	No operation
2	INC_PC	000001 $_b$	Incrementing R_{02}
3	TDEEP_PC	000011 $_b$	Loading R_{02} to R_{03}
4	PUSH_REG	000100 $_b$	Pushing (R_{04}, R_{05}, R_{06}, R_{07}, R_{10}, R_{11} and R_{14}) into stack memory
5	POP_REG1	000101 $_b$	Popping (R_{04}, R_{05}, R_{06}, R_{07}, R_{10}, R_{11} and R_{14}) from stack memory
6	POP_REG2	000110 $_b$	
7	GET_TRUTH	000111 $_b$	Getting R_{09} data from terminal program
8	SET_TRUTH	001000 $_b$	Setting R_{09} to «1» value
9	INV_TRUTH	001001 $_b$	Inverting R_{09} value

Table 3 prolongation. Instruction set of knowledge-based processor

10	WR_TRACE_ALT	001010 $_b$	Recording the address of successfully interpreted alternative into trace memory
11	WR_TRACE_ITER	001011 $_b$	Recording the number of successfully interpreted iterations into trace memory
12	SAVE_TR_WR_ADDR	001100 $_b$	Saving (R_{04}, R_{05}) data into trace memory
13	REST_TR_WR_ADDR	001101 $_b$	Loading (R_{04}, R_{05}) data from trace memory
14	SET_TR_WR_ADDR	001110 $_b$	Loading (R_{05}) data from trace memory
15	SET_TRACE_REG	001111 $_b$	Setting R_{10} to «1» value
16	CLR_TRACE_REG	010000 $_b$	Setting R_{10} to «0» value
17	SET_PROD_REG	010001 $_b$	Setting R_{11} to «1» value

18	CLR_PROD_REG	010010 $_b$	Setting R_{11} to «0» value
19	INIT_NUM_ITER	010011 $_b$	Setting iteration counter register to «0» value
20	INC_NUM_ITER	010100 $_b$	Incrementing iteration counter register
21	DEC_NUM_ITER	010101 $_b$	Decrementing iteration counter register
22	LOAD_NUM_ITER	010110 $_b$	Loading iteration counter register from trace memory
23	SET_TR_RD_ADDR	010111 $_b$	Loading R_{04} from trace memory
24	RD_TR	011000 $_b$	Reading data from trace memory
25	SET_KB_WR	011001 $_b$	Setting knowledge base in writing mode
26	SET_KB_RD	011010 $_b$	Setting knowledge base in reading mode
27	TERMINAL	011011 $_b$	Requesting terminal program
28	REQUEST	011100 $_b$	Requesting for main processor resources
29	CLR_ALL	011101 $_b$	Clear all the registers of knowledge processing coprocessor
30	IDLE	011110 $_b$	Knowledge processing coprocessor is ready for processing
31	RESTORE_REG	011111 $_b$	Restoring (R_{04}, R_{05}, R_{06}, R_{07}, R_{10}, R_{11} and R_{14}) from stack memory
32	WR_OUT_MAS	100000 $_b$	Write data to output array
33	WR_TR_NUL	100001 $_b$	Write «0» data to trace memory

A simplified example of an algorithm of knowledge-based processor functioning in a form of directed graph is showed in fig. 8. The algorithm solves only analysis task. Analysis with the tracing and analysis with generation tasks is omitted for simplicity. Consider the algorithm in more details.

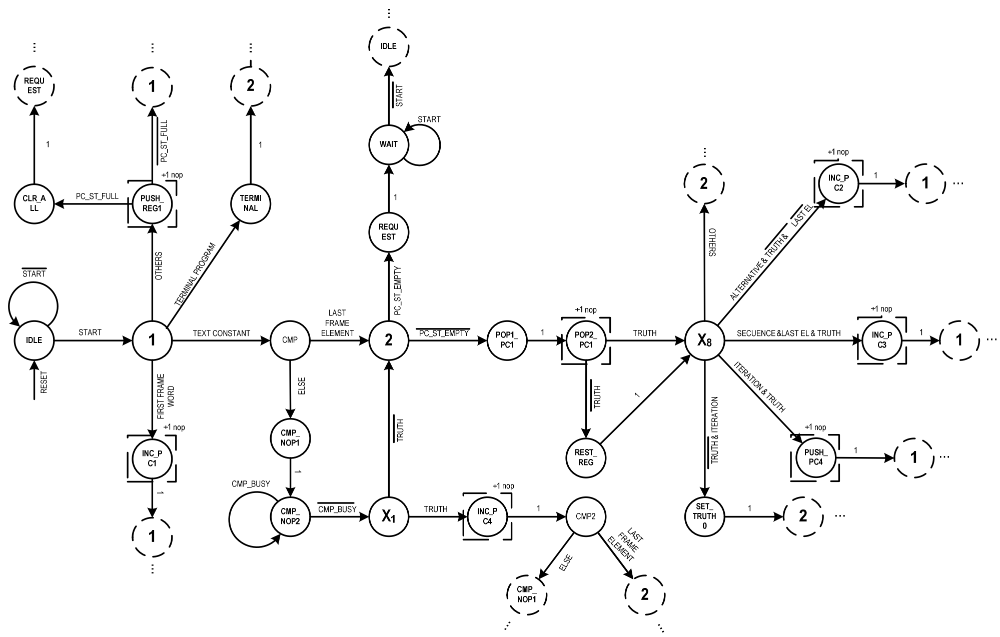

Figure 8. Algorithm of knowledge-based processor functioning

IDLE. Knowledge-based processor waits for «START» signal from main processor and sends instruction «IDLE». When «START» signal arrives then it goes to the state 1.

STATE №1. Knowledge-based processor sends instruction «NOP». If current word of frame is: 1) terminal – then it goes to the state «TERMINAL»; 2) text constant – then it goes to the state «CMP»; 3) first frame word – then it goes to the state «INC_PC1»; 4) else – then it goes to the state «PUSH_REG1».

PUSH_REG1. Knowledge-based processor sends instruction «PUSH_REG». Then it sends instruction «NOP». If memory stack is full then it goes to the state «CLR_ALL» else it goes to the state «STATE №1».

CLR_ALL. Knowledge-based processor sends instruction «CLR_ALL». Then it goes to the state «REQUEST».

TERMINAL. Knowledge-based processor sends instruction «TERMINAL». Then it goes to the state «STATE №2».

CMP. Knowledge-based processor sends instruction «TERMINAL». If current frame element is last then processor goes to the state «STATE №2» else it goes to the state «CMP_NOP1».

CMP2. Knowledge-based processor sends instruction «TERMINAL». If current frame element is last then processor goes to the state «STATE №2» else it goes to the state «CMP_NOP1».

CMP_NOP1. Knowledge-based processor sends instruction «NOP» while the terminal program is executing. When terminal program is executed then it goes to the state «X1».

STATE №2. Knowledge-based processor sends instruction «NOP». If memory stack is empty then processor goes to the state «REQUEST» else it goes to the state «POP_PC1».

REQUEST. Knowledge-based processor sends instruction «REQUEST». Then it waits until signal «START» is reset. Then it goes to the state «IDLE».

POP_PC1. Knowledge-based processor sends a sequence of instruction «POP_REG1», «POP_REG2» and «NOP». If signal «TRUTH» arrived then processor goes to the state «X8» else it goes to the state «REST_REG».

REST_REG. Knowledge-based processor sends instruction «RESTORE_REG». Then it goes to the state «X8».

X1. Knowledge-based processor sends instruction «NOP». If signal «TRUTH» arrived then processor goes to the state «INC_PC4» else it goes to the state «STATE №2».

X8. Knowledge-based processor sends instruction «NOP». If current frame element is «ALTERNATIVE» and signals «TRUTH» and «LAST FRAME ELEMENT» is turned off then processor goes to the state «INC_PC2». If current frame element is «SEQUENCE» and signals «TRUTH» and «LAST FRAME ELEMENT» is turned on then processor goes to the state «INC_PC3». If current frame element is «ITERATION» and signals «TRUTH» is turned off then processor goes to the state «SET_TRUTH0».

INC_PC1. Knowledge-based processor sends instruction «INC_PC» and after that sends instruction «NOP». Then it goes to the state «STATE №1».

INC_PC2. Knowledge-based processor sends a sequence of instruction «INC_PC» and «NOP». Then it goes to the state «STATE №1».

INC_PC3. Knowledge-based processor sends a sequence of instruction «INC_PC» and «NOP». Then it goes to the state «STATE №1».

INC_PC4. Knowledge-based processor sends a sequence of instruction «INC_PC» and «NOP». Then it goes to the state «STATE №1».

SET_TRUTH0. Knowledge-based processor sends instruction «SET_TRUTH». Then it goes to the state «STATE №2».

5 Empirical research of knowledge processing interpreter performance

Empirical research was investigated by comparing an efficiency of software-based knowledge processing interpreter (SBKPI) and hardware-based knowledge processing interpreter (HBKI). HBKI was implemented on the prototyping board M1AGL-DEV-KIT-SCS. SBKI was compiled in an environment Microsoft Visual Studio 2010 using the library Boost/Spirit [Boost Spirit About, 2011] and implemented in two configurations – SBKI2 and SBKI4. SBKI2 operates on a PC with following features: operating system – MS Windows XP Professional 32-bit SP3; processor – Intel Mobile Core 2 Duo T8100 2.10 GHz; processor cores – 2; RAM size – 2GB. SBKI4 operates on a PC with the following features: operating system – Windows Server 2008 R2 Standard SP 1; processor – Intel Xeon CPU E5504 2.00 GHz; processor cores – 4, RAM size – 12 GB.

In order to eliminate the influence of the technological features of the HBKI, SBKI2 and SBKI4 implementations, it is useful to compare not absolute time in seconds but in the number of processor clock cycles.

During of the empirical research was used a knowledge base which contains two concepts: Identifier (4) and Sentence (5). The knowledge base has been implemented in accordance with the syntax of interpreter and loaded into SBKI2, SBKI4 and HBKI. During the empirical research, the experimental data was generated automatically or obtained from a literature. All the data were analyzed in turn on SBKI2, SBKI4 and HBKI and written in a spreadsheet for analysis. The analysis of the experimental data proved that the algorithmic complexity of interpretation algorithm is linear. The main empirical results are shown in fig. 9-10.

Identifier $=_{df}$ *Letter (Letter/Numeral);* (4)

Letter $=_{df}$ *A/B/C/D/E/F/G/H/I/J/K/L/M/N/O/P/Q/R/S/T/U/V/W/X/Y/Z/a/b/c/d/e/f/g/h/i/j/k/l/m/n/o/p/q/r/s/t/u/v/w/x/y/z;*

Sentence $=_{df}$ *NP* Aux_1 *VP;* (5)

NP $=_{df}$ Art_1 AP_1 *N* PP_1;

VP $=_{df}$ *Verb* NP_1 PP_1 Adv_1;

PP $=_{df}$ *Prep NP;*

AP $=_{df}$ *Adj* PP_1;

Aux_1 $=_{df}$ *Aux/1;*

Art_1 $=_{df}$ *Art/1;*

AP_1 $=_{df}$ *AP/1;*

PP_1 $=_{df}$ *PP/1;*

NP_1 $=_{df}$ *NP/1;*

Adv_1 $=_{df}$ *Adv/1;*

Adj $=_{df}$ *old/red/slimy/white/new/hungry;*

Adv $=_{df}$ *slowly/now/quite_quick;*

Art $=_{df}$ *the/an/a;*

Aux $=_{df}$ *will/can/might;*

N $=_{df}$ *tree/wind/children/toys/toy/box/boy/ball/house/shorts/letter/jon/man/fish/toby/book/dogs/swimmer;*

Prep $=_{df}$ *at/in/to/with/out_of;*

Verb $=_{df}$ *swayed/put/found/kicked/was reading/gave/saw/read/fed/was/pulled/have_been_reading;*

In fig. 9 are showed the results of empirical research of SBKI and HBKI during interpretation of the concept «Identifier».

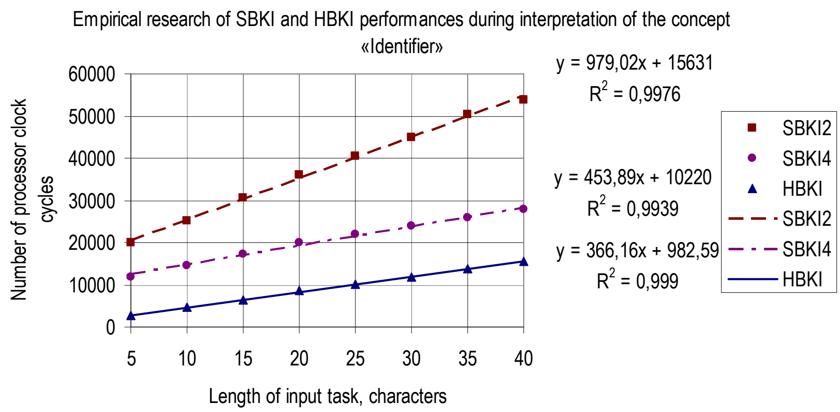

Figure 9. Empirical research of SBKI and HBKI during interpretation of the concept «Identifier»

These results represent dependence of the run duration of interpreting task on length of the task. The functions of approximations are got for SBKI2, SBKI4 and HBKI, which are accordingly equal: $y_{SBKI2}(x) = 979{,}02x + 15631$, $y_{SBKI4}(x) = 453{,}89x + 10220$ and $y_{HBKI}(x) = 366{,}16x + 982{,}59$. It is possible to make conclusion, that algorithmic complexity of problem of interpreting of concept «Identifier» is linear. Otherwise: $y_{HBKI2}(n) = O(n)$, $y_{HBKI4}(n) = O(n)$ and $y_{SBKI}(n) = O(n)$. In comparison with functions $y_{HBKI2}(x)$ and $y_{SBKI4}(x)$, rate of function $y_{HBKI}(x)$ is least (366,16 < 453,89 < 979,02). Middle run time of interpretation of concept «Identifier» on SBKI2, SBKI4 and HBKI accordingly equals: 37658,775; 20483,15 and 9221,15 processor clock cycles. The middle advantage of HBKI in comparison with SBKI2 and SBKI4 accordingly equal 4,08 and 2,22 times faster.

In fig. 10 are showed the results of empirical research of SBKI and HBKI during interpretation of the concept «Sentence». Middle run time of interpretation of concept «Sentence» on SBKI2, SBKI4 and HBKI accordingly equals: 27510,556; 15284,556 and 2272,2 processor clock cycles. The middle advantage of HBKI in comparison with SBKI2 and SBKI4 accordingly equal 12,11 and 6,73 times faster.

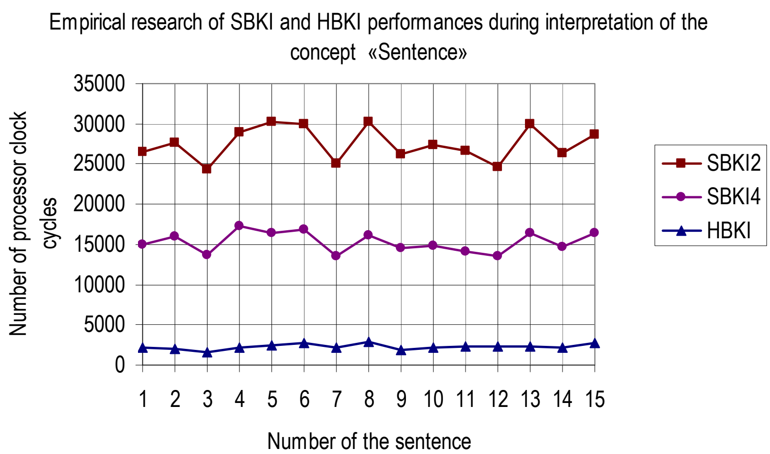

Figure 10. Empirical research of SBKI and HBKI during interpretation of the concept «Sentence»

Conclusion

The empirical researches of dedicated knowledge processing interpreter proved that architecture of modern computer is not effective for knowledge processing. The main reason is semantic gap between the concepts of relations and their objects in the high-level languages of representation of knowledge and concepts of operations and data which are determined by architecture of modern computer.

It is necessary to develop dedicated architectures of computer systems, which will be more efficient for knowledge interpretation. Advisability of this tendency is stipulated by modern system on chip technologies, which allow fast and cheap realization of new dedicated architectures.

It is shown that dedicated knowledge processing interpreter provides advantage in performance in comparison with the programmable interpreters, which function on the base of universal architecture. The middle advantage in performance varies from 2 to 12 times faster.

Advanced research of the paper can be developing of a knowledge processing interpreter with multiple independent processing cores based the suggested architecture.

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SPECTRAL COEFFICIENT OF CONSISTENCY OF FUZZY EXPERT INFORMATION AND ESTIMATION OF ITS SENSITIVITY TO FUZZY SCALES WHEN SOLVING FORESIGHT PROBLEMS

Nataliya Pankratova, Nadezhda Nedashkovskaya

Abstract: *An estimation of sensitivity of a new measure of consistency of interval pairwise comparison matrix, i.e. interval spectral coefficient of consistency to fuzzy fundamental scales which are the most often used in fuzzy AHP methods is carried out. This coefficient of consistency may be more valid for solving some foresight problems than other known indexes and methods. The coefficient of consistency is theoretical, but not empiric attribute of consistency of pairwise comparison matrix in the sense that on determination of consistency are not used randomly filled pairwise comparison matrices. For determination of admissible level of inconsistency of interval pairwise comparison matrices application and detection thresholds are developed. To estimate the sensitivity of interval spectral coefficient of consistency a computer simulation study was performed. Spectral coefficient of consistency of FPCM is proposed as combination of ISCC in all* α *-levels using linear, multiplicative and min combination rules of the AHP. For determination of admissible level of inconsistency of FPCM necessary and sufficient conditions are proposed. The AHP method and spectral coefficient of consistency were used to evaluate critical technologies of energy conservation and power efficiency in Ukraine.*

Keywords: *interval pairwise comparison matrix, fuzzy pairwise comparison matrix, spectral coefficient of consistency, admissible level of inconsistency, interval weights, fuzzy fundamental scales, foresight problems.*

ACM Classification Keywords: *H.4.2. INFORMATION SYSTEM APPLICATION: type of* system strategy

Introduction

Technological foresight is a decision making relative to complex systems with human factor concerning their potential behaviour in future [Zgurovskiy & Pankratova, 2007]. Reliability of expert estimation of information in problems of technological foresight is of importance under modern conditions of high dynamism of world globalization. Foresight problems have innovation character. Mainly information of qualitative character in a form of expert estimates, which is often fuzzy, contradictory and incomplete, serves as input data for these problems, therefore, technique of decision making support must include methods for processing information of the mentioned character and, moreover, means of estimation of validity and degree of consistency for the obtained results.

One of the methods, which are applied in the technique of scenario analysis [Zgurovskiy & Pankratova, 2007] for solving problems of technological foresight, is the Analytic Hierarchy Process (AHP). Elaborated by T.Saaty AHP and its generalization Analytic Network Process are popular decision tools used to weight items based on pairwise comparisons in terms of multiple criteria [Saaty, 1980]. Nowadays AHP and its extensions are used to determine relative weights (priorities) of items and probabilities of scenarios for solving foresight problems [Pankratova & Nedashkovskaya, 2007 a, b].

In general, estimates, which are given by experts, will not be consistent. T.Saaty [Saaty, 1980] defines the consistency index CI and ratio CR for a crisp pairwise comparison matrix. The CR value is calculated using the average of the CI values for random matrices. Other consistency coefficients have been developed: the harmonic consistency index [Stein & Mizzi, 2007], which can be viewed as an approximation to the CI, the determinant to measure consistency [Pelaez & Lamata, 2003]. Another type of consistency measure is the distance from a specific consistent matrix. The sum of squared deviations of the log of the elements of a matrix from the log of the matrix elements generated by the row geometric mean solution is used as a measure of consistency [Aguaron & Moreno-Jimenez, 2003].

Problems of technological foresight are characterized by the presence of conceptual uncertainty and multiple-factor risks. Inaccuracy in expert estimates and connected with it risks can be expressed in two ways: 1) by means of crisp estimates and probability distribution function; 2) by means of interval estimates without distribution of probabilities. Probabilistic representation of crisp estimates and distribution functions provides creation of several modifications of AHP, which are called stochastic AHP, while the second way of representation of inaccuracy of expert estimates results in necessity of application of interval and fuzzy methods of weights calculation. Methods for obtaining weights from interval pairwise comparison matrixes (IPCM) may be classified as follows: methods, which make it possible to obtain weights from both consistent and inconsistent IPCM [Saaty&Vargas, 1987; Wang & Elhag, 2007], as well as methods, which work only with consistent IPCM [Arbel, 1989] or do not guarantee solution obtaining in the case of inconsistent IPCM [Sugihara et al, 2004].

New measure of consistency of IPCM the interval spectral coefficient of consistency (ISCC) k_y^{interv} was introduced [Pankratova & Nedashkovskaya, 2007 b]. This spectral coefficient is theoretical, but not empiric attribute of consistency of IPCM in the sense that on determination of consistency we do not use random matrices. An application and detection thresholds of the ISCC are developed [Pankratova & Nedashkovskaya, 2007 b] for determination of admissible level of inconsistency of IPCM in the AHP method.

One of the problems when formalizing expert judgment in a form of fuzzy number and linguistic variable is to choose the type and parameters of a membership function. The lognormal [Laininen & Hämäläinen, 2003], logit and probit multinomial [Hahn, 2003] and other [Lipovetsky & Conklin, 2002] distributions of expert judgments are used in modified AHP methods. But justification of the distribution law of expert judgments needs further investigations. In fuzzy AHP methods [Wang & Chen, 2008; Amy Lee et al, 2008; Wu et al, 2008; Amy Lee, 2009; Kreng & Wu, 2007; Kulak& Kahraman, 2005] different fuzzy fundamental scales are used to formalize expert judgment.

In present paper we perform an estimation of sensitivity of ISCC to fuzzy fundamental scales which are the most often used in fuzzy AHP methods.

Problem statement

Let us consider definition of fuzzy pairwise comparison matrix, which is to be used further.

Fuzzy pairwise comparison matrix (FPCM) is a pairwise comparison matrix $A^{fuzzy} = \{(a_{ij}^{fuzzy}) \mid i = \overline{1,n}, j = \overline{1,n}\}$, for which $a_{ij}^{fuzzy} = (x, \mu_{ij}(x))$ is a normal convex fuzzy set (fuzzy number) reflecting the result of paired comparison of objects O_i and O_j, $x \in \Re$, where $\Re$ is the set of real numbers. The value of the membership function $\mu_{ij}(x)$ of the fuzzy set a_{ij}^{fuzzy} is the degree of realization of preference $O_i \succeq O_j$ [Pankratova & Nedashkovskaya, 2007 a].

Let it be given: FPCM A^{fuzzy}; the vector of fuzzy weights $w^{fuzzy} = \{(w_i^{fuzzy}) \mid i = \overline{1,n}\}$, which reflects preferences written in FPCM A^{fuzzy}; coordinate w_i^{fuzzy} of this vector is a fuzzy set.

It is necessary to determine a degree of consistency of FPCM and admissible level of inconsistency of FPCM.

Problem solving. Interval spectral coefficient of consistency (ISCC)

For estimating consistency of expert information we decompose FPCM A^{fuzzy} by sets of level $A(\alpha)$, where $A(\alpha) = \{(a_{ij}(\alpha)) \mid i = \overline{1,n},\ j = \overline{1,n}\}$ is a matrix of sets of level $\alpha \in [0,1]$, $a_{ij}(\alpha) = \{x : \mu_{ij}(x) \geq \alpha\}$, $\mu_{ij}(x)$ is a membership function of fuzzy set a_{ij}^{fuzzy}, $x \in \Re$.

Since elements a_{ij}^{fuzzy} of FPCM serve as estimates for some parameters (in this case as estimates of paired comparisons), then it is convenient to use triangular fuzzy values $a_{ij}^{fuzzy} = (a_{ij}^l, a_{ij}^m, a_{ij}^u)$, $a_{ij}^l \leq a_{ij}^m \leq a_{ij}^u$ for their representation. Then we pass from the initial FPCM A^{fuzzy} to consideration of the set of IPCM $\{A(\alpha) \mid \alpha \in [0,1]\}$, where $A(\alpha) = \{(a_{ij}(\alpha)) \mid i, j = \overline{1,n}\}$, $a_{ij}(\alpha) = [a_{ij}^m - x1_{ij}(\alpha), a_{ij}^m + x2_{ij}(\alpha)]$, a_{ij}^m is the value of interval with the greatest degree of realization of preference, $x1_{ij}(\alpha) = (1-\alpha)(a_{ij}^m - a_{ij}^l)$, $x2_{ij}(\alpha) = (1-\alpha)(a_{ij}^u - a_{ij}^m)$, $x1_{ij}(\alpha) \geq 0$, $x2_{ij}(\alpha) \geq 0$ are values of deviations from the value a_{ij}^m, $i = \overline{1,n}$, $j = \overline{1,n}$.

We state that necessary condition for FPCM A^{fuzzy} to be consistent is as follows: all IPCM $A(\alpha)$ of sets of levels $\alpha \in [0,1]$ are consistent. Thus the problem is reduced to determination of consistency of IPCM. Let us consider IPCM

$$A = \{(a_{ij}) \mid a_{ij} = [l_{ij}, u_{ij}], i = \overline{1,n}, j = \overline{1,n}\},$$

where $l_{ij} = m_{ij} - x1_{ij}$, $u_{ij} = m_{ij} + x2_{ij}$, m_{ij} is the value of the interval with the greatest degree of realization of preference. Values $x1_{ij} \geq 0$ and $x2_{ij} \geq 0$ show the degree of uncertainty associated with approximate equality $m_{ij} \approx w_i / w_j$.

Let $\{A^h \mid h = \overline{1,n}\}$ be the set of matrices generated by rows [Pankratova & Nedashkovskaya, 2007 b] of the matrix A. Suppose every object O_k, $k = \overline{1,n}$ is characterized by n estimates of interval weights $W^k = \{(w^{kh}) \mid h = \overline{1,n}\}$, where $w^{kh} = [w^{khl}, w^{khu}]$ is interval weight of the object O_k, obtained from the matrix A^h using two-staged method, described in [Pankratova & Nedashkovskaya, 2007 a].

Further we assume that estimates of weights are numbers of marks of certain scale $S = \{s_j \mid j = \overline{0,m}\}$ with $(m+1)$ marks. The number of scale marks can be determined, if we set admissible error of attribution of weight estimate to either this or another mark. The zero, first and the last scale marks are equal correspondingly to $s_0 = 0$, $s_1 = 1/m$ and $s_m = 1$. Scale mark s_j is equal to j/m.

We construct mapping $F^k: W^k \underset{F^k}{\rightarrow} S$, $F^k(w^{kh}) = s_j$. The mapping F^k is composition of mappings G and D^k, where $G(d^{kh})$ defines scale mark, which is the least remote from d^{kh}. $D^k = \{d^{kh} \mid d^{kh} \in \Re, h = \overline{1,n}\}$ is the set of distances from interval weights w^{kh} to scale mark s_0. In the case of interval weights we realize attribution of weight w^{kh} to either one or another scale mark according to distance $d^{kh} = D(w^{kh}, O) = \sqrt{\left(\frac{w^{khu} + w^{khl}}{2}\right)^2 + \frac{1}{3}\left(\frac{w^{khu} - w^{khl}}{2}\right)^2}$. Advantage of this method of determination of distance between intervals consists in the fact that we take into account all points in both intervals in contrast to the majority of existing techniques, which are often based only on the left or right boundaries of intervals.

Next, the set W^k is represented by spectrum, which is a vector $R^k = \{(r_j^k) \mid j = \overline{1,m}\}$, where r_j^k is the number of interval weights belonging to scale mark s_j.

To construct ISCC of IPCM we initially determine the ISCC $k_y^{interv}(R^k)$ of spectrum for the set W^k of object O_k interval weights [Pankratova & Nedashkovskaya, 2007 b]:

$$k_y^{interv}(R^k) = \left(1 - \frac{\frac{1}{n}\sum_{j=1}^{m} r_j^k \mid j - a^k \mid - \sum_{j=1}^{m} \frac{r_j^k}{n} \ln\left(\frac{r_j^k}{n}\right)}{G\sum_{j=1}^{m}\left|j - \frac{m+1}{2}\right| + \ln(m)}\right) z,$$

where a^k is mean value of the set of interval weights W^k, $G = n / \ln(n) m \ln(m)$ is scale coefficient, z is Boolean function, which sets necessary and sufficient conditions of equality to zero for ISCC.

Coefficient $k_y^{interv} = \inf_{k \in [1;n]} k_y^{interv}(R^k)$ is called the ***interval spectral coefficient of consistency (ISCC) of IPCM** A* [Pankratova & Nedashkovskaya, 2007 b].

For determination of admissible level of inconsistency of IPCM the criterion is proposed.

Criterion of admissible level of inconsistency of IPCM:

- If $k_y^{interv} < T_0^{interv}$, where T_0^{interv} is detection threshold, then IPCM does not contain information and it is necessary to make paired comparisons again;
- If $T_0^{interv} \le k_y^{interv} < T_u^{interv}$, where T_u^{interv} is application threshold, then IPCM contains useful information, but this IPCM is strongly inconsistent and it is necessary to use methods for increase of its consistency;
- If $k_y^{interv} \ge T_u^{interv}$, then the degree of inconsistency of IPCM is supposed as admissible.

Detection threshold T_0^{interv} on estimate of consistency of interval judgements is the ISCC $k_y^{interv}(R^0)$ of the spectrum R^0, which is constructed from spectrum, in which every scale mark was selected exactly by one expert. In spectrum R^0 estimate being at first scale mark is excluded and placed supplementary on scale mark

$[\varepsilon m+1]$, where $[.]$ is operation of taking integer part, $\varepsilon = 0.5$ is minimally registered quantity in terms of the scale.

Application threshold T_u^{interv} on estimate of consistency of interval judgements is the ISCC $k_y^{interv}(R^u)$ of consistency of the spectrum R^u, which contains only two estimates distant for b scale marks, $b=1$.

Spectral coefficient of consistency of fuzzy pairwise comparison matrix

Decomposing FPCM A^{fuzzy} by sets of levels $\alpha_1,...,\alpha_s,...\alpha_S \in [0,1]$ we obtain a set of IPCM $A=\{A(\alpha_s)\,|\, s=\overline{1,S}\}$ and a set of ISCC:

$$k_y^{interv} = \{k_y^{interv}(\alpha_s)\,|\, s=\overline{1,S}\},$$

where $k_y^{interv}(\alpha_s)$ is ISCC of IPCM $A(\alpha_s)$.

Using triangular fuzzy values $a_{ij}^{fuzzy}=(a_{ij}^l, a_{ij}^m, a_{ij}^u)$ we have $A(\alpha_s)=\{(a_{ij}(\alpha_s)= =[l_{ij}(\alpha_s), u_{ij}(\alpha_s)])\,|\, i,j=\overline{1,n}\}$, $l_{ij}(\alpha_s)=a_{ij}^m-(1-\alpha_s)(a_{ij}^u-a_{ij}^m)$, $u_{ij}(\alpha_s)=a_{ij}^m+(1-\alpha_s)(a_{ij}^u-a_{ij}^m)$.

A low value of α_s corresponds to IPCM with wide intervals, whose bounds have low memberships in the fuzzy set a_{ij}^{fuzzy}. Therefore, a lower value of α_s corresponds to less reliable IPCM with a high level of uncertainty. A greater value of α_s corresponds to IPCM with narrow intervals, whose bounds have higher memberships in the fuzzy set a_{ij}^{fuzzy}. Therefore, a higher value of α_s corresponds to more reliable IPCM. Level $\alpha_s=1$ results in the crisp pairwise comparison matrix, whose elements are the values a_{ij}^m of initial fuzzy judgments a_{ij}^{fuzzy} with the greatest degree of realization of dominance.

In this paper spectral coefficient of consistency of FPCM A^{fuzzy} is defined as combination of $k_y^{interv}(\alpha_s)$ in all levels α_s, $s=\overline{1,S}$ using combination rules of the AHP method. Linear, multiplicative and min combination rules of the AHP method are known in literature of the subject [Pankratova & Nedashkovskaya, 2011]. Let us consider calculation of spectral coefficient of consistency k_y^{fuzzy} of FPCM using these combination rules. Suppose α_s^* are normalized values, $\alpha_s^* = \alpha_s / \sum_{s=1}^{S}\alpha_s$.

Spectral coefficient of consistency k_y^{fuzzy} ***of FPCM*** A^{fuzzy} ***using linear combination rule*** is as follows:

$$k_y^{fuzzy(1)} = \sum_{s=1}^{S}\alpha_s^* k_y^{interv}(\alpha_s).$$

Spectral coefficient of consistency k_y^{fuzzy} ***of FPCM*** A^{fuzzy} ***using multiplicative combination rule*** is as follows:

$$k_y^{fuzzy(2)} = \prod_{s=1}^{S}\left(k_y^{interv}(\alpha_s)\right)^{\alpha_s^*}.$$

Spectral coefficient of consistency k_y^{fuzzy} ***of FPCM*** A^{fuzzy} ***using min combination rule*** is as follows:

$$k_y^{fuzzy(3)} = \min_{s=1,..,S} \alpha_s^* k_y^{interv}(\alpha_s) .$$

For determination of admissible level of inconsistency of FPCM necessary and sufficient conditions are proposed. The necessary condition requires admissible level of IPCM at each level $\alpha_1,...,\alpha_s,...\alpha_S \in [0,1]$. The sufficient condition deals with combined spectral coefficient of consistency k_y^{fuzzy} obtained by one of above combination rules.

Necessary condition of admissible level of inconsistency of FPCM:

- If $k_y^{interv}(\alpha_s) < T_0^{interv}$ at each level $\alpha_s \in [0,1]$, $s = \overline{1,S}$, then FPCM does not contain information and it is necessary to make paired comparisons again.
- If $T_0^{interv} \le k_y^{interv}(\alpha_s) < T_u^{interv}$ at each level $\alpha_s \in [0,1]$, $s = \overline{1,S}$, then FPCM contains useful information, but this FPCM is strongly inconsistent and it is necessary to use methods for increase of its consistency.
- If $k_y^{interv}(\alpha_s) \ge T_u^{interv}$ at each level $\alpha_s \in [0,1]$, $s = \overline{1,S}$, then the degree of inconsistency of FPCM is supposed as admissible.

Sufficient condition of admissible level of inconsistency of FPCM has the same formulation, but combined value k_y^{fuzzy} obtained by one of above combination rules is used instead of $k_y^{interv}(\alpha_s)$.

Estimation of sensitivity of ISCC to fuzzy fundamental scales

In AHP the fundamental scale of relative importance [Saaty, 1980] is the most commonly used numerical scale to quantify the pairwise comparisons. Marks of this scale (linguistic terms) are as follows: “equal importance” (corresponding scalar value is equal to 1), “moderate preference” (3), “strong preference” (5), “very strong preference” (7), “absolute preference” (9) and intermediate marks. This scale is one of the advantages of AHP over other expert methods since it optimally takes into account psychophysiological features of a human being [Arbel, 1989].

We consider fuzzy fundamental scales [Wang & Chen, 2008; Amy Lee et al, 2008; Wu et al, 2008; Amy Lee, 2009; Kreng & Wu, 2007; Kulak& Kahraman, 2005], which are the most often used in fuzzy AHP methods. Linguistic terms of the fuzzy scales are the same as the terms of traditional (crisp) fundamental scale and their numerical values are represented as triangular fuzzy numbers (see Table 1). The fuzzy numbers of different fuzzy scales have different parameters. Let us perform an estimation of sensitivity of ISCC to the fuzzy fundamental scales shown in the Table 1.

Table 1. Fuzzy fundamental scales (FFSs)

	Triangular fuzzy numbers					
Linguistic terms	FFS 1 [Wang & Chen, 2008]	FFS 2 [Amy Lee et al, 2008]	FFS 3 [Wu et al, 2008]	FFS 4 [Amy Lee, 2009]	FFS 5 [Kreng & Wu, 2007]	FFS 6 [Kulak& Kahraman, 2005]
Equal $\widetilde{1}$	$\widetilde{1} = (1,1,3)$	$\widetilde{1} = (1,1,1)$	$\widetilde{1} = (1,1,1)$	$\widetilde{1} = (1,1,2)$	$\widetilde{1} = (1,1,1)$	$\widetilde{1} = (1/2,1,3/2)$

Moderate preference $\tilde{3}$	$\tilde{3}=(1,3,5)$	$\tilde{3}=(2,3,4)$	$\tilde{3}=(2,3,4)$	$\tilde{3}=(2,3,4)$	$\tilde{3}=(1,3,5)$	$\tilde{3}=(1,3/2,2)$
Strong preference $\tilde{5}$	$\tilde{5}=(3,5,7)$	$\tilde{5}=(4,5,6)$	$\tilde{5}=(4,5,6)$	$\tilde{5}=(4,5,6)$	$\tilde{5}=(3,5,7)$	$\tilde{5}=(3/2,2,5/2)$
Very strong preference $\tilde{7}$	$\tilde{7}=(5,7,9)$	$\tilde{7}=(6,7,8)$	$\tilde{7}=(6,7,8)$	$\tilde{7}=(6,7,8)$	$\tilde{7}=(5,7,9)$	$\tilde{7}=(2,5/2,3)$
Absolute preference $\tilde{9}$	$\tilde{9}=(7,9,9)$	$\tilde{9}=(9,9,9)$	$\tilde{9}=(8,9,10)$	$\tilde{9}=(8,9,9)$	$\tilde{9}=(7,9,11)$	$\tilde{9}=(5/2,3,7/2)$
Intermediate terms: $\tilde{2}$, $\tilde{4}$, $\tilde{6}$, $\tilde{8}$	$\tilde{2}=(1,2,4)$ $\tilde{4}=(2,4,6)$ $\tilde{6}=(4,6,8)$ $\tilde{8}=(6,8,9)$	$\tilde{2}=(1,2,3)$ $\tilde{4}=(3,4,5)$ $\tilde{6}=(5,6,7)$ $\tilde{8}=(7,8,9)$	$\tilde{2}=(1,2,3)$ $\tilde{4}=(3,4,5)$ $\tilde{6}=(5,6,7)$ $\tilde{8}=(7,8,9)$	$\tilde{2}=(1,2,3)$ $\tilde{4}=(3,4,5)$ $\tilde{6}=(5,6,7)$ $\tilde{8}=(7,8,9)$	$\tilde{2}=(1,2,4)$ $\tilde{4}=(2,4,6)$ $\tilde{6}=(4,6,8)$ $\tilde{8}=(6,8,10)$	$\tilde{2}=(3/4,5/4,7/4)$ $\tilde{4}=(5/4,7/4,9/4)$ $\tilde{6}=(7/4,9/4,11/4)$ $\tilde{8}=(9/4,11/4,13/4)$

The ***ISCC*** k_y^{interv} ***of IPCM is sensitive to fuzzy scale*** if there are different results about admissible level of inconsistency of IPCM according to above Criterion when different fuzzy scales are used. Inadmissible level of inconsistency means that IPCM do not contain information and it is necessary to make paired comparisons again ($k_y^{interv} < T_0^{interv}$) or IPCM is strongly inconsistent and it is necessary to use methods for increase of its consistency ($T_0^{interv} \le k_y^{interv} < T_u^{interv}$).

To estimate a sensitivity of ISCC to fuzzy scale a computer simulation study was performed. Random test FPCM were examined while dimentions of the FPCM were varied. Lenguistic terms which represented elements of one triangular part of these test FPCM were chosen randomly from the set $\{\tilde{1}, \tilde{2},..., \tilde{9}\}$. Then FPCM were formed in six different FFS shown in the Table 1. Elements of another triangular part of the FPCM were calculated according to the property of reciprocity as follows: $1/\tilde{x} = (1/c, 1/b, 1/a)$. $1/\tilde{x}$ is an element of lower triangular part of the FPCM, where $\tilde{x} = (a, b, c)$ is symmetric element of upper triangular part of the FPCM. Elements on a diagonal of the FPCM are equal to a fuzzy number $\tilde{1} = (1, 1, 1)$. Each FPCM was decomposed by sets of level $\alpha \in [0, 1]$ and IPCM were built. Level α was possessed the values $\alpha_1 = 0$, $\alpha_2 = 0.1$, ..., $\alpha_{11} = 1$. Interval weights were calculated for each of the matrices generated by rows of the IPCM using two-staged method [Pankratova & Nedashkovskaya, 2007 a]. ISCC k_y^{interv} of IPCM was determined. Random test FPCM's were formed with 10000 replications per each case in order to derive statistically significant results. Cases of sensitivity of the ISCC of IPCM to fuzzy scale were recorded.

The results reveal that in general the ISCC is not sensitive to the considered fuzzy scales.

To better understand method of estimation of sensitivity of ISCC to fuzzy fundamental scales, the following test decision problem with four alternatives is considered. Pairwise comparisons of these alternatives in linguistic terms are shown in Fig.1. Let two different FFS from the Table 1, for instance FFS 1 and FFS 2 are chosen to form FPCM. These FPCM A^{FFS_1} and A^{FFS_2} are shown in Fig. 2. Let us consider sets of the level $\alpha_2 = 0.1$ of the FPCM that result in two IPCM, i.e. $IPCM^{FFS_1}(\alpha_2)$ and $IPCM^{FFS_2}(\alpha_2)$ shown in Fig.3.

$$A=\begin{pmatrix} \tilde{1} & \tilde{3} & \tilde{2} & \tilde{4} \\ 1/\tilde{3} & \tilde{1} & \tilde{4} & \tilde{7} \\ 1/\tilde{2} & 1/\tilde{4} & \tilde{1} & \tilde{9} \\ 1/\tilde{4} & 1/\tilde{7} & 1/\tilde{9} & \tilde{1} \end{pmatrix}$$

Figure 1. Pairwise comparison matrix in linguistic terms

$$A^{FFS_1}=\begin{pmatrix} (1,1,1) & (1,3,5) & (1,2,4) & (2,4,6) \\ (1/5,1/3,1) & (1,1,1) & (2,4,6) & (5,7,9) \\ (1/4,1/2,1) & (1/6,1/4,1/2) & (1,1,1) & (7,9,9) \\ (1/6,1/4,1/2) & (1/9,1/7,1/5) & (1/9,1/9,1/7) & (1,1,1) \end{pmatrix}$$

(a)

$$A^{FFS_2}=\begin{pmatrix} (1,1,1) & (2,3,4) & (1,2,3) & (3,4,5) \\ (1/4,1/3,1/2) & (1,1,1) & (3,4,5) & (6,7,8) \\ (1/3,1/2,1) & (1/5,1/4,1/3) & (1,1,1) & (9,9,9) \\ (1/5,1/4,1/3) & (1/8,1/7,1/6) & (1/9,1/9,1/9) & (1,1,1) \end{pmatrix}$$

(b)

Figure 2. FPCMs on the FFS 1 (a) and on the FFS 2 (b)

$$IPCM^{FFS_1}(\alpha_2)=\begin{pmatrix} [1, 1] & [1.2, 4.8] & [1.1, 3.8] & [2.2, 5.8] \\ [0.21, 0.93] & [1, 1] & [2.2, 5.8] & [5.2, 8.8] \\ [0.28, 0.95] & [0.18, 0.48] & [1, 1] & [7.2, 9] \\ [0.18, 0.48] & [0.11, 0.19] & [0.11, 0.14] & [1, 1] \end{pmatrix}$$

(a)

$$IPCM^{FFS_2}(\alpha_2)=\begin{pmatrix} [1, 1] & [2.1, 3.9] & [1.1, 2.9] & [3.1, 4.9] \\ [0.26, 0.49] & [1, 1] & [3.1, 4.9] & [6.1, 7.9] \\ [0.35, 0.95] & [0.21, 0.33] & [1, 1] & [9, 9] \\ [0.21, 0.33] & [0.13, 0.16] & [0.11, 0.11] & [1, 1] \end{pmatrix}$$

(b)

Figure 3. IPCMs for FPCM on the FFS 1 (a) and on the FFS 2 (b) when $\alpha_2 = 0.1$

Then matrices generated by rows of these IPCM are formed. For instance, IPCM generated by *h*-th row of the $IPCM^{FFS_1}(\alpha_2)$, *h*=1 is shown in Fig 4. Weights for two matrices generated by *h*-th rows of the $IPCM^{FFS_1}(\alpha_2)$ and $IPCM^{FFS_2}(\alpha_2)$, *h*=1 are calculated using two-staged method [Pankratova & Nedashkovskaya, 2007 a] and are as follows: $w^{h\ FFS_1} = (0.40, 0.36, 0.16, 0.07)$, $w^{h\ FFS_2} = (0.35, 0.44, 0.14, 0.07)$.

Also weights for matrices generated by other rows of the IPCM are calculated.

$$IPCM^{h\,FFS_1} = \begin{pmatrix} [1,1] & [1.2, 4.8] & [1.1, 3.8] & [2.2, 5.8] \\ [0.21, 0.93] & [1,1] & [0.8, 0.9] & [1.2, 1.8] \\ [0.28, 0.95] & [1.11, 1.25] & [1,1] & [1.5, 2.0] \\ [0.18, 0.48] & [0.56, 0.83] & [0.50, 0.67] & [1,1] \end{pmatrix}$$

Figure 4. IPCM generated by *h*-th row of the $IPCM^{FFS_1}(\alpha_2)$ when *h*=1

Values of ISCC of the $IPCM^{FFS_1}$ and $IPCM^{FFS_2}$, detection and application thresholds are equal correspondingly to $k_y^{interv}(IPCM^{FFS_1}) = 0.851$, $k_y^{interv}(IPCM^{FFS_2}) = 0.784$, $T_0^{interv} = 0.398$ and $T_u^{interv} = 0.878$. Since $T_0^{interv} \le k_y^{interv} < T_u^{interv}$ for both IPCMs, then both IPCMs contain useful information, but are strongly inconsistent and it is necessary to use methods for increase of their consistency. Hence ISCC of IPCM when using different scales, namely FFS 1 and FFS 2, leads to the same conclusion about strong inconsistency of IPCM. Therefore ISCC is not sensitive to the considered fuzzy scales. This result holds for majority of the random FPCM.

Evaluation of critical technologies (CTs) of energy conservation and power efficiency in Ukraine

The AHP method and ISCC were used to calculate consistent relative priority values for critical technologies (CTs) of energy conservation and power efficiency in Ukraine. Quantitative information of passports of CTs and qualitative information in a form of expert estimates serves as input data for this problem. A list of 14 CTs and their technical passports were presented by leading organizations in energy sector of Ukraine on a first stage of foresight process. Then the CTs were clustered as follows: energy conservation CTs, renewable energy CTs and eco-house CT. Energy conservation CTs include energy conservation while producing energy (cogeneration technologies and power machine building) and in energy networks (electrical power engineering and technologies of burning). Renewable energy CTs include geothermal, wind, solar and bioenergetics technologies. Problem of power efficiency is included in a notion of eco-house only as a part along with building materials production, construction of eco-house and waste utilization. Therefore the technology of effective eco-house was considered separately.

Using information of passports of CTs and estimates of 12 experts about different factors of risk for CTs and importance of decision criteria (Fig.5), consistent relative priority values for CTs were calculated. On basis of these priority values rating of CTs of energy conservation and power efficiency in Ukraine was determined.

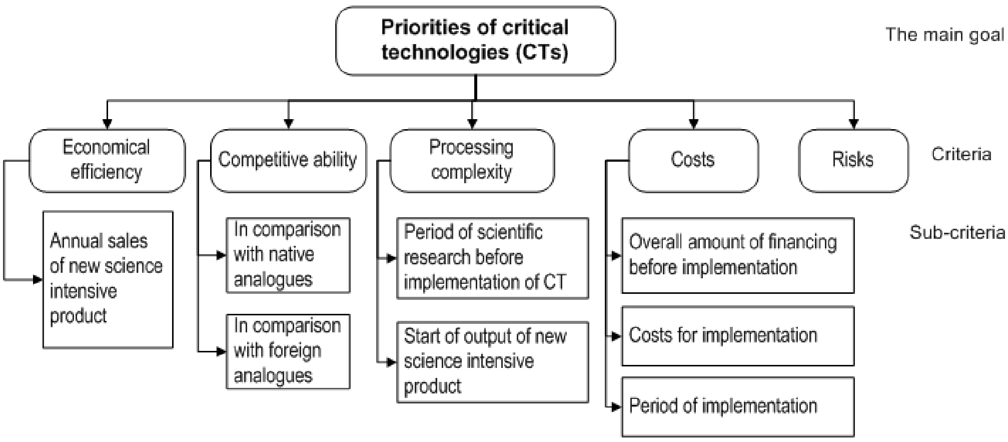

Figure 5. Hierarchy of criteria for choice of priority CTs

Economical efficiency includes annual sales of new science intensive product in value indicator (millions of dollars). Competitive ability of CTs is evaluated in comparison with native and foreign analogues. Processing complexity of CTs is measured by two parameters: period of scientific research before implementation of CT (years) and start of output of new science intensive product (in x years). Costs include costs in terms of money and time, namely: overall amount of financing before implementation (thousands of grivnas), costs for implementation (thousands of grivnas), period of implementation (years).

Table 2. Relative priority values (weights) of decision criteria

Criterion	Sub-criterion	Weight
Economical efficiency(0.486)	Annual sales of new science intensive product (1)	0.486
Competitive ability (0.137)	Competitive ability in comparison with native analogues (0.125)	0.017
	Competitive ability in comparison with foreign analogues (0.875)	0.120
Processing complexity (0.066)	Period of scientific research before implementation of CT (0.833)	0.054
	Start of output of new science intensive product (0.167)	0.011
Costs (0.149)	Overall amount of financing before implementation (0.481)	0.072
	Costs for implementation (0.405)	0.060
	Period of implementation (0.114)	0.017
Risks (0.162)	Risks (1)	0.162

Global Priorities of clusters of CTs, calculated on basis of judgements of 12 experts are shown in Table 3 (values without sign *). Spectral coefficients of consistency of individual global priorities spectrums for clusters “Energy conservation CTs”, “Renewable energy CTs” and “Eco-house” (Fig. 6) which are equal to 0.682, 0.737 and 0.658 respectively, indicate that expert judgements for these clusters are strongly inconsistent ($k_y<T_u$), T_0=0.398, T_u=0.790 and it is necessary to use methods for increase of its consistency. Revised values are marked in Table3 with sign *. Spectrums of revised values are more consistent, spectral coefficients take values 0.758, 0.771 and 0.770 respectively (Fig.7).

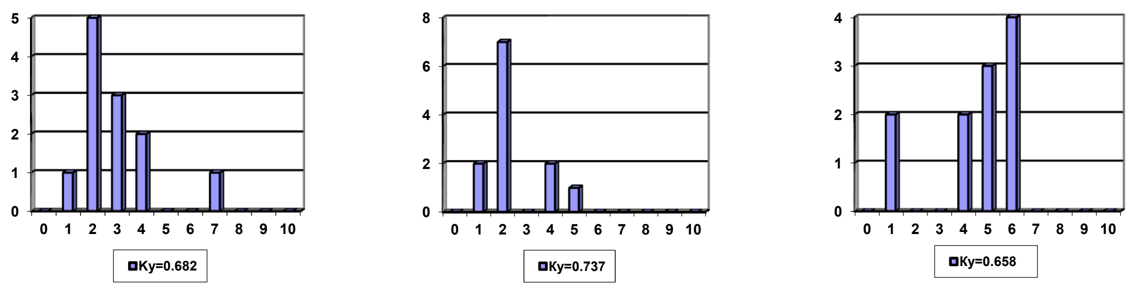

Figure 6. Spectrums of individual global priorities for clusters “Energy conservation CTs” (a), “Renewable energy CTs” (b) and “Eco-house” (c)

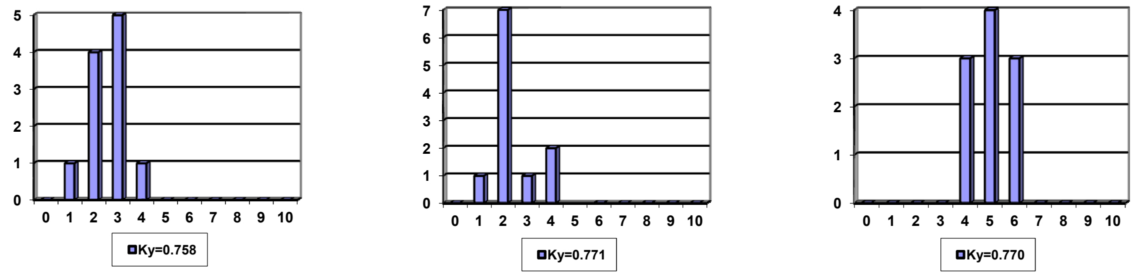

Figure 7. Spectrums of revised individual global priorities for clusters “Energy conservation CTs” (a), “Renewable energy CTs” (b) and “Eco-house” (c)

Table 3. Individual global priorities of clusters of CTs

Expert's No	Individual global priorities			Expert's No	Individual global priorities		
	Energy conservation CTs	Renewable energy CTs	Eco-house		Energy conservation CTs	Renewable energy CTs	Eco-house
1	0.247/0.257*	0.115/0.225*	0.638/0.519*	7	0.251	0.165	0.584
2	0.186/0.254*	0.210/0.269*	0.604/0.477*	8	0.358	0.176	0.466
3	0.677/-	0.230	0.093/ -	9	0.229	0.391	0.380
4	0.223	0.416	0.361	10	0.160	0.240	0.600
5	0.143	0.248	0.609	11	0.319	0.179	0.502
6	0.322	0.535/-	0.143/-	12	0.441/0.216*	0.102	0.457/0.379*

Group global priorities (Table 4) result in cluster “Eco-house” as the most priority cluster of CTs of energy conservation and power efficiency in Ukraine (corresponding priority value equals 0.426). Clusters “Energy conservation CTs” and “Renewable energy CTs” receive lower priority values. Cluster “Eco-house” contains only one technology “Technology of power efficient eco-house with renewable energy”. This CT receives the highest priority value, i.e. the first rank, thus, cluster “Eco-house” and CT “Technology of power efficient eco-house with renewable energy” are not considered in further analysis. Then, CTs with second, third and other ranks, which form clusters “Energy conservation CTs” and “Renewable energy CTs” are founded during further analysis.

Consistent normalized relative priority values of CTs, obtained as aggregated values in terms of clusters with group global priorities of clusters as weighted coefficients are shown in Table 5.

Table 4. Group global priorities of clusters of CTs

Clusters of CTs	Group global priorities
Energy conservation CTs	0.284
Renewable energy CTs	0.290
Eco-house	0.426

Table 5. Normalized consistent group global relative priority values of CTs

No	CTs	Relative priority values, *10
1	Technology of power efficient eco-house with renewable energy	4.260
2	Technology of improvement and structural optimization of energy networks in accordance with a purpose of harmonization with energy system of countries of the European Union	0.764
3	Technology of effective usage of soil and groundwater heat in complex thermal pump systems	0.571
4	Technology of diverse renewable energy sources usage in integrated thermal pump systems	0.568
5	Technology of steam compressor thermal pumps	0.557
6	Technology of usage of high-temperature conductivity in electrical machines and devices	0.545
7	Technology of magneto-liquid sealing for considerable increasing energy equipment's service life	0.499
8	Technology of production of generative power capacities on basis of integrated co-generation and thermal pump plants	0.443
9	Technology of energy loss saving in transit power networks	0.437
10	Technology of production of thermostable and corrosion-proof heat-insulating materials for thermal networks	0.420
11	Technology of synthetic fuel (gas) production	0.415
12	Technology of heating and housing and domestic hot-water supply on basis of usage of solar energy	0.380
13	Technology of production of engine oil and methanol on basis of Ukrainian deposit(s) of brown coal, peat, shales, coal and other carbon raw materials	0.377
14	Technology of usage of modular systems in low wind power engineering	0.299

Thus, first rank, i.e. the highest priority has cluster “Eco-house” and technology “Technology of power efficient eco-house with renewable energy”. Second rank has technology “Technology of improvement and structural optimization of energy networks in accordance with a purpose of harmonization with energy system of countries of the European Union”. Three thermal pump technologies “Technology of effective usage of soil and groundwater heat in complex thermal pump systems”, “Technology of diverse renewable energy sources usage in integrated thermal pump systems” and “Technology of steam compressor thermal pumps” receive third rank, differences between their priority values are rather small. Other technologies have lower priorities (Table 5).

Conclusion

In the present paper we provide a research of a new measure of consistency of interval pairwise comparison matrix, i.e. interval spectral coefficient of consistency. This coefficient is theoretical, but not empiric attribute of consistency of pairwise comparison matrix in the sense that on determination of consistency we do not use randomly filled pairwise comparison matrices. For determination of admissible level of inconsistency of IPCM application and detection thresholds are developed.

A computer simulation study was performed to estimate a sensitivity of interval spectral coefficient of consistency to fuzzy fundamental scales, which are the most often used in fuzzy AHP methods. The results reveal that in general the ISCC of interval pairwise comparison matrices is not sensitive to the considered fuzzy scales. This means that this coefficient of consistency leads to the same conclusion about inconsistency of interval pairwise comparison matrix when using different fuzzy scales to represent linguistic terms.

Spectral coefficient of consistency of FPCM is proposed as combination of ISCC in all α -levels using linear, multiplicative and min combination rules of the AHP. For determination of admissible level of inconsistency of FPCM strong and weak criteria are proposed.

The AHP method and spectral coefficient of consistency were used to evaluate critical technologies of energy conservation and power efficiency in Ukraine.

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METHODS FOR SOLVING OF SOME TASKS WITHIN THE PROBLEM OF OPTIMAL SYNTHESIS OF INFORMATION NETWORKS IN THE COURSE OF THEIR EVOLUTION

Galyna Gayvoronska, Svetlana Sakharova, Maxim Solomitsky

Annotation: *Possible methods for solving particular problems arising from the decomposition of the problem of optimal synthesis of information networks in the course of their evolution are considered. The contribution of the scientific collective of the Information-communication Technologies Department of Odessa State Academy of Refrigeration is analyzed. The efforts of this collective allowed to come close to the formalized statement of this problem.*

Keywords: *synthesis, information network, infocommunication services, access network, load, calls and messages streams.*

Keywords classification of ACM: *C.2. Computer-communication networks, H. Information Systems - H.1 Models and Principles, K. Computing Milieux - K.6 Management of computing and information system*

«… sentient beings live only to enrich the awareness …»

C. Castaneda

The status of the issue

Problems of development of the existing information networks (IN) with a rational redistribution of information streams and the most appropriate using of funds allocated for the network equipment's modernization contain elements of both analysis and synthesis [Roginsky, 1981].

In the context of this problem the difference between the concepts of information and telecommunication networks must be taken into account, since the information network involves a set of telecommunication networks (TN) and information technologies (IT), designed to provide infocommunication services (ICS). Earlier the concept of electrical communications was widely used. It was defined as the correspondent's tool for delivering to one or more correspondents information of any kind in any form (written or printed document, fixed or moving image, speech, music, visual or audible signals, control signals, etc.) using any electromagnetic system (wire transfer, radio transfer, optical transmission, or a combination of these systems) [Davydov, 1977].

However, the answer to the question: "What exactly is transmitted by electromagnetic systems?", - may be straightforward: "Electrical signals are transmitted by electromagnetic systems". To do this, information of any kind and form is converted into electrical signals for transmission and reception by electromagnetic systems. With the advent of optical telecommunication systems, the term electrical communication has ceased reflect the essence of the process of information transmission over communication networks longer, and was replaced by the term -"telecommunications". However, the term telecommunications does not reflect the fact that communications is moving kind of information too, because the tele- simply means "far", "at a distance." That is, telecommunications literally means "the movement at a distance". Plumbing, electrical networks, other tools designed to move anything may be included to communications. And hence it does not follow that we are talking about electrical communications, but in fact the concept of electrical communications and telecommunications are very similar if not identical.

With this came the concept of infocommunications [Gayvoronska, 2008] that combines the processes of communication, information and the provision of ICS to users, by which we understand modern information-communication infrastructure of society that provides not only the transmission and reception of information, but also its processing and storage. Infocommunications include as one of the components of the user's terminal, in which information intended for transmission over the network converts into an electrical signal and its inverse transformation [Varakin, 2001]. That is, the user terminal can be seen as a means of information technology and telecommunication technology, as it supports aligns with the electrical parameters of the network, enters the service signals, etc. The question then arises: "What is Information Technology?" This term refers to a set of methods and hardware - software tools, combined in the processing chain, providing collection, processing, storage, distribution and display of information to reduce the complexity of the processes of using information resources and improve the reliability and efficiency. The main purpose of information technologies - providing information services (IS). It is necessary to settle on the concept of information-communication technologies, or simply infocommunication technologies (ICT). It implies a set of processes required to render that part of IS, which is associated with the transfer of information, i.e. infocommunication services (ICS) [Davydov, 1985].

Scientists from different countries are united in their opinion that we have entered an era of global information society, characterized by a new "information economy". This is due to the fact that, on the one hand, the services offered by modern IN can be viewed as a mass commodity for common using, having its price and its share in GDP of any country, on the other, infocommunications are an integral part of almost social processes and play very important role in the global economy. This thesis is supported by the fact that the total share of the world's infocommunications is more than 10% of total world GDP. As a rule, where is the higher the GDP - there is the higher proportion of infocommunications in it. This percentage is higher than the combined figures oil and automobile industries [Parliament hearings, 2005].

In the beginning of 21st century, there was a crisis in the global infocommunication sector, associated with the reassessment of the potential consumer demand. As a result there were excessive investments in steel industry and the very high rate of long-term debt. Currently, the world's infocommunications has emerged from the crisis and are strategically positioned not only in economics but also in politics and social life. For example, in the USA only 1 USD invested in telecommunications provides 6.2 USD of GDP growth, and one job in telecommunications generates 5.4 jobs in other industries. Telecommunications employing over 20 million professionals who provided 70-80 million jobs. At the same time there is a redistribution of jobs in various fields. For example, the banking system is experiencing an information revolution: banks use about 80% of its profits for their computerization. The transition to computer exchange of information has reduced employment in the banking sector by 30%. All this occurs against the backdrop of globalization, which requires establishment of an information infrastructure that provides the transmission and processing of information [Parliament hearings, 2005].

From this point of view the problem of optimal synthesis of switched IN, takes on a new extremely important meaning because of its decisions are depended not only by the cost of network and service quality, but without exaggeration, by the development of society as a whole. It caused by the fact that in the twenty-first century the spontaneous market mechanism of world civilization development is being replaced by the global order, when the power of the state is not determined by the number of iron and steel, tanks and missiles, but by the ability to produce knowledge and modern technologies, to manage the socio-economic processes and to exchange information rapidly, creating the conditions for the prosperity of its citizens.

In September 2005, in Ukraine, there were parliamentary hearings on the development of information society. The major tasks of the information society were identified in December 2003, in Geneva, at the World meeting on the creating of information society. In such a society, everyone should be able to create information and knowledge, to have access to them, to use and share them to individuals, societies and peoples were able fully realize their potential, adhering to the Universal Declaration of Human Rights. Education, knowledges, information and communication are the basis of human development. At the same time ICT have an enormous impact on practically all aspects of our lives. The rapid progress of ICT offers new prospects for the development of society, however, ICT should be seen as a tool but not as an goal in itself.

When the conceptual basis of the information society has just started to form, Ukraine was among the undisputed leaders and ideologists of its construction (see Table 1 [Parliament hearings, 2005]).

Table 1. Formation of the conceptual foundations of the Information Society of Ukraine

1925	The idea of mechanization of formalizing logical operations was formulated, mechanical thinking machine was built
1941	V.E. Lashkarev experimentally opened p-n junction. American scientists used it later for the creation of the transistor.
1948	S.O. Lebedev justified principles and structure of an universal digital computer with a recorded program (regardless of the American and British scientists). USSR Academy of Sciences.
1951	At first the digital electronic computer SECM (S.O. Lebedev) was introduced in the Soviet Union and continental Europe
1953	The principles of building, architecture and structure of the matrix-vector processor of the first Ukrainian specialized electronic computer (SEVM) for solving systems of linear algebraic equations was based, and introduced in 1955.
1954 - 1957	The base principles of construction, structure and architecture for the first Ukraine asynchronous computer "Kiev" with "address" of the language were developed.
1961	The theoretical basis for the design of computer was developed. V.M. Glushkov
1966	The idea of the circuit realization of high-level languages was proposed. Computer implementation of the project "Ukraine".
1958 - 1968	The principles of construction, structure and architecture of the first Soviet semiconductor general-purpose control computer "Dnepr" were developed. A full-scale production was launched into.
1964 - 1967	The principles of construction, structure and architecture, and the first in Ukraine information and control complex "Dnepr-2" for the automated control systems were developed. NPO "Electronmash."
1965	The principles of construction were developed, and the first Soviet digital regulator "Avtooperator" Severodonetsk NPO «IMPYLS» was created.
1959 - 1975	Principles of building, structure, and the architecture were developed, and the first production cars in the USSR for engineering calculations "Promin" and "MIR" - the forerunners of future PC - were implemented.
1961	V.M. Glushkov suggested brain-like structures of computers.

1963	An inventor's certificate to a step microprogram control was received and implemented as a family of vehicles "Mir". V.M. Glushkov
70-ties	A complex computer systems design was developed and used in many organizations of the USSR. Ukraine's first mini-computer M 180 Falcon was established, and released as series in 1972.
1972	Ukraine's first mini-computer M 180 Falcon was established, and released as series in 1972.
1975	The first domestic ideology of the family of micro-computers "Electronics C5-01" was developed.
1975	The first in Ukraine complex microprocessor means "Neuron" and setup tools for it were designed and produced.
1965 - 1970	Unique specialized computers Kiev 67 and Kiev 70 for the automation of design and manufacture of IPOs with Elyon technology were developed.
1972	Gage Complex Bars was created and released.
1972	The first World's "Encyclopedia of Cybernetics" has been prepared and published.
1973	The powerful control VC M4030 was developed, designed and made ready for commercial production.
1974	Ukraine, the Soviet Union and Europe for the first time launched mass production of large-scale integrated circuits at the NGO "Crystal".
1974	The principles of constructing a recursive (non-von Neumann) computers were proposed.
1976	Specialized computer "Neva" for digital communication systems was developed in cooperation with the GDR and the GDR has arranged industry production.
70-ties	Specialized mini computers - Iskra, Mriya, Chyka, Moscow, Scorpion, Romb, Orion - were developed and produced by industry.
80-ties	Unique specialized on-board computer systems for spacecraft control without reckoning were developed and produced by the Defense Ministry enterprises.
1983 - 1987	The family of specialized industrial computer for pre-flight testing and pre-mooring WIG, ships, hydrofoil ships, seaworthy for complex testing of ships of the Navy for testing and diagnostics of aircraft were developed, designed and produced.
1978 - 1987	Superproductive macroconveyor complexes ES-2701 and ES-1766, which have no analogues were developed, designed and created. The maximum number of processors 256. The maximum productivity of 500 mln. oper. / Sec.
1965 - 1980	A lot of great digital media industrial systems engineering were developed, designed and created (machine of control and communication with the object of management), to ensure the creation of wide range of control systems in industry and power for the entire former Soviet Union. Multi-processor systems for heavy duty systems, geophysical prospecting of mineral resources and a number of unique military systems were created and produced.
1967 -	12 types of on-board computers (including steady from influence radiations) for space-rocket complexes

1989	strategic were developed designed and organized its production.
1969 - 1989	Ultra-reliable computer specialist «Carat» (17 models) for weapon systems and management of surface and underwater, including nuclear power, the courts of the Navy, and for solving problems of navigation in the merchant navy ships and nuclear power drifting ice was developed, designed and implemented its mass production.
1969	Implemented mass production of computers «Kashtan» for automated cutting of chestnut tissue according to the specified range.
1981	Serial production of the computer systems of small computers was mastered.
1984 - 1988	The principles of construction and developed a unique computer ultra speed system - complex «Star» to detect submarines.
1997	International Computer Society (IEEE Computer Society) awarded to S.O. Lebedev medal "Pioneer of computer technology" with the inscription: S.O. Lebedev, 1902-1974. The developer and designer of the first computer. The founder of computer.
1997	International Computer Society (IEEE Computer Society) awarded to V.M. Glushkov medal "Pioneer of computer technology" for the foundation of the first in the USSR Institute of Cybernetics and creation the theory of digital automat and work in the industry macroconveyor computing architectures.

New ways of communications and communication systems blur the boundaries between nations and peoples. Digital technologies have fundamentally changed not only connectivity but also the technology of exchange of goods, services, knowledge management, production, socio-economic and political processes in society. In the development of electronic union and the information co-operation gap among countries which have already made the transition to an information society, and others, for various reasons backward from this process, is becoming increasingly obvious. A detailed analysis of the level of global competitiveness of individual sectors shows that there are the most competitive country in which co-exist successfully hi-tech production and management of their own natural resources, knowledge, and information technology [Parliament hearings, 2005].

In this regard, the role of infocommunications and information networks, in particular, is immeasurably increased, and certainly increases the importance and relevance of their scientific support. Methods of synthesis of IN created in the last century and no longer meet any of networks, or the needs of society.

The statement of the problem

Detailed formulation of the problem of synthesis of developing switched network is performed in [Gayvoronska, 2007]. The basic problems and the appropriate methods for their solving were formulated and analyzed in this paper too. However, during the five years since its publication, information networks are developing so rapidly that the formulation of the problem of optimal synthesis of developing switched networks no longer meets the current situation in the field of infocommunications sphere. In this connection, it took some refinement of the overall problem, the introduction of new tasks and more careful formulating of the tasks that were identified in the decomposition of the general problem of synthesis.

In addition, over these years a number of objectives set out in [Gayvoronska, 2007] are more or less solved. All of this required a revision of the formulating of some statements of the developing switched IN synthesis problem. This article is aimed at the consecration of the possible approaches to solving of some aspects from the complex of tasks, mentioned in the decomposition of the overall problem.

Overview of problems solved by collective of the ICT department within the general problem of synthesis of developing switched information network

In [Gayvoronska, 2007] it is showed that in terms of the topological structure, parameters and principles of information exchange in the network under research it can be divided into two subnets: access network and core network [Sokolov, 1999, Gayvoronska, 2008, Gayvoronska, 2010]. Thus, the overall problem is divided into: synthesis of the access network and synthesis of the core network. Formulated set of tasks in the problem of optimal synthesis of switched information network in the course of their evolution in recently is being solved by the collective of the information-communication technologies (ICT) department of Odessa State Academy of Refrigeration. Solving of separate problems is being studied by lecturers and post-graduates, supervised by Galyna Gayvoronska, namely: Alexander Ryabtsov [Ryabtsov, 2010-2012], Semen Pavlov [Pavlov, 2007-2012], Alexandra Kotova [Kotova, 2009-2012], Svetlana Sakharova [Sakharova, 2010-2012], Anna Kryzhanovskaya [Kryzhanovskaya, 2010-2012], Illya Gannitsky [Gannitsky, 2007-2011], Anton Bondrenko [Bondarenko, 2011-2012], Maxim Solomitsky [Solomitsky, 2011-2012], Yuri Grynkov [Grynkov, 2011-2012], Eugene Konyshev [Konyshev, 2012], Oleg Domaskin [Domaskin, 2012]. Masters' works, performed at the ICT department are devoted to the same topic.

In [Gayvoronska, 2007] all tasks within the researched problem of information networks' synthesis are grouped in such way that they are interrelated and stem from one another within each group of tasks.

The first group of problems, in particular, includes:

- analysis of users' needs in communications services, which are to be satisfied by the created network;
- definition of the requirements for network services and equipment for speed connectivity, bandwidth and volume of transmitted information, the absolute value of the allowable information delay and its variations in the network, the allowable error rate, etc.;
- development of recommendations for the necessary parameters of access parameters for the information services rendering in accordance with the requirements specified in the preceding paragraphs.

The first of this group of tasks includes the determination of projected volumes of information streams and their distribution in space and time. Existing algorithms that allow solving this problem by means of computers tools for the existing telephone networks or data transfer networks (DT) should be updated taking into account the specifics of integrated services and the convergence process of separate TN into unified information Next Generation Network (NGN). There are very strong expected fluctuations of the traffic in the network with mixed traffic (voice, dates, images). Interactive traffic often changes spasmodically (from periods of high to the low activity periods and vice versa) and those of its features should also be taken into account at the synthesis of the network structure. Here planning is clarifying types and volumes of traditional and new communication services, selecting the right relationship between the volume and nature of the distribution of streams generated by these services. Works in the field of economics, sociology, and other service sectors are accounted at the forecasting of the services.

Semen Pavlov's work is addressed to the relevant objectives of the study requirements for networks and network equipment from the ICS. There are analyzed properties and characteristics of the ICS, highlighted main factors affecting the provision of these services and the international documents governing the provision of ICS in this study. As the result of the done analysis there were denoted main characteristics of services, which became the base of the proposed classification of all possible ICS, both existing and those that may occur in the future. The main purpose of this work is to identify the main characteristics of ICS. Its accounting is required for the synthesis of IN, the evaluation of correlation among them and the formalization of these characteristics with the way when they can be put into a general model of the synthesis of IN. To solve this problem there were analyzed the existing classification methods appropriate to apply to the ICS, identified advantages and disadvantages of these methods. The necessity of applied statistics methods' usage for classifying ICS is proved. With the help of factor, cluster and discriminant analysis the relationship between the parameters of providing ICS was revealed. The effect of ICS on the development of IN was researched, and revealed that both qualitative and quantitative changes in the parameters of service affect the development of IN. By using statistical methods for processing ICS parameters and reducing feature space classification of ICS was proposed. It is taking into account five parameters of these services rendering. The reliability of the process and the results of ICS classification are proved. Parameters are analyzed to provide services to the real IN. For each of the ICS classes requirements for IN and its equipment were definite. The method for classification of any existing or planned ICS to a particular class is developed. A model of the ICS classes' presentation is built. It is shown how this model can be extended with additional parameters of service rendering. Two types of formal description of the ICS for convenient human and computer perception are proposed. The formalized description of the services makes it easy to build interfaces and data entry programs into the various models of IN analysis and synthesis. It is unified representation of the service and it is characterized by the parameters of service's rendering. Software complex which automates the assignment of a specific service to a definite class and definition of requirements for the network equipment from service groups is developed. The implemented software improves the efficacy of IN design and modernization as compared to known methods by about 12-17%. The effectiveness of the program complex experimentally evaluated on real IN. That is evidenced by the introduction of the relevant statutes. Semen Pavlov has presented the research of this problem in the form of dissertation work and was awarded with the academic degree of Ph.D. after its main results' defense.

Alexandra Kotova's work is devoted to solving the problem of increasing the efficiency of the development of perspective access networks (AN) by upgrading existing subscriber networks. The solution of the problem allows to identify cost-effective options for the access network's organization, one of which is the usage of the existing subscriber network as the basis for its construction. Studies conducted in the work allowed detection of the structural characteristics of existing subscriber lines, value of which determine the ability of digital information transfer over the analog network and assessing the suitability of xDSL equipment and other access technologies of existing networks. A large amount of processed statistical information allows evaluation of the structure and technical condition of the existing subscriber network in Ukraine. Methods used to process of statistic allow determination of the possibility of extending these results to other areas that have not been participated in the study. The developed method for calculating the structural characteristics of the access lines (AL) for perspective AN allows determination of the most advantageous location and capacity of the access point (AP) from the standpoint of minimizing the cost, length and bandwidth of access lines in the transport and the local segments, taking into account the current configuration of the service area. The proposed method takes into account the existing principles of organization of subscriber access lines only to the PSTN, as well as possible connections to other core networks. Research was presented in the form of dissertation work. After the defense of its main theses academic degree of Ph.D. was awarded to Alexandra Kotova.

Besides it researches are conducted by post-graduates of ICT department in the following areas:

- improvement of the functioning of information networks by unifying the calculation method of network equipment - Illya Gannitsky;

- the method and model of accounting of inclination at the implementation of access networks - Anna Kryzhanovskaya;
- the model of optimal synthesis of access networks - Anton Bondarenko;
- peculiarities of optical switching in the access networks - Yuri Grynkov;
- the model of information network's user as badly formalized object - Anastasia Smirnova.

Registration of errors in the course of access networks parameters' forecasting

The problem of AN designing efficiency's increasing by taking into account the sensitivity of networks' characteristics to forecasted parameters is being solved in Svetlana Sakharova`s work.

To solve the problem of estimating the sensitivity the simulation model of the development of perspective AN, taking into account their concept, structure and design principles was developed. Research and analysis of the parameters involved in the process of AN creating allowed identifying that parameters which variation had the most significant impact on the characteristics of these networks. Forecasted parameters, which are the subject of the study, are highlighted. They are the number of AN users, the list of requested by them ICS, the surface density and the distribution of users in the territory served by the network, the load created by these users and several other variables. Taking in account the concept, structure and functions of perspective AN, generalized scheme of the process of these networks' creating was developed. It differs by the analytical methods and program procedures. Developed scheme defines sequence of stages, each of which solves set of goals of AN creating. Existing methods are partially used to solve these problems. But for the most purposes author developed new methods and software procedures which were presented in the thesis. The method for optimizing the number, capacity, location of AP and size of areas served by them, by criterion of the network total cost was developed. To minimize the cost of the line facilities in the course of overcoming obstacles to the laying of access lines, it is proposed method of adaptation of access lines ways' construction and choose of AP places to the structure of the network. It allows taking into account the influence of local conditions on the choice of the optimal location of the AP.

Simulation model of AN, which allowed implementation of proposed methods for optimization of AN structural characteristics is developed. The modeling process has allowed for the first time to reveal the range of impact of input forecasting parameters' variation on the cost of the network and its structural characteristics.

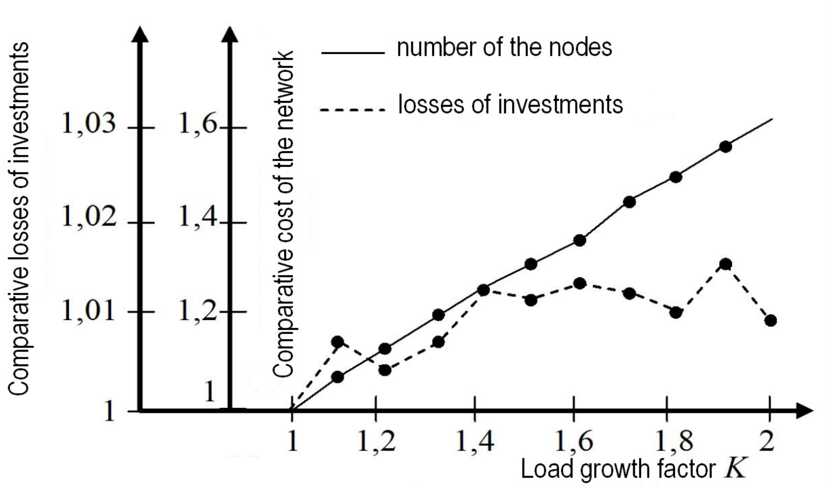

Figure1. Impact of carried load value forecasting on the network cost

Impact of load variation was investigated taking into account the cost of AN, quality of service and network structure. Let's denote load stream created by users of selected group i to the service rendering point of one of the core network j as F_{ij}, and the load stream, which occurs as a result of unanticipated changes in advance - $F_{ij}^{'}$. Then it can be determined by multiplying by a constant $F_{ij}^{'} = KF_{ij}$. For instance, here it is given the research of forecasting faults of the values of two AN parameters when the factor that accounts deviation of the load's actual value from the forecasted, from 1 to 2 with step of 0.1. Parameters under research are cost of the network optimized for the original load structure and cost of the network optimized for the varied load. The latter case suggests that the capacity of AP is fixed, and bandwidth of local and transport segments of AL are calculated anew, to meet the quality of service standards. Fig. 1 shows the obtained results. The solid line shows the cost of the network, based on the original value of the load, and the dotted shows the loss of investment due to the difference between the calculated parameters, averaging about 1.1%.

Besides it the effect of the load distribution prediction fault is determined. Here it is suggesting that the total amount of load is calculated exactly. Load varying element $F_{ij}^{'}$ is calculated as $F_{ij}^{'} = F_{ij}(1+R)$, where R - is uniformly distributed random variable in the range $[-a,+a]$ $a \in [0,1]$. The results are shown in Fig. 2.

At the same time here marked both the more expensive and less expensive than the original cost cases, depending on the nature of the error. Nevertheless, we can conclude that additional investment should be needed, as the average value of the network in all cases is higher than the calculated values. If the cost of the network becomes too high, the medium-and long-term planning may need to change the AP placement both with their service areas.

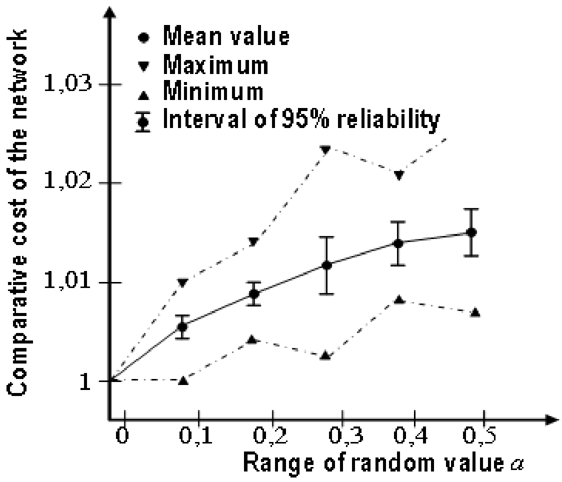

Figure 2. Impact of connections paths' load distribution's forecasting fault on the network cost

Created software implementing the model for estimation of the AN characteristics' sensitivity to variations of predicted initial parameters is being used for the design of modern TN. This fact is evidence of the introducing act of the research results by the enterprise "Ukrsvyazproekt", which states the following. The analysis has revealed that the cost of AN with increasing of the prediction error of the requirements for connection of new users increases linearly; the prediction error of the geographical distribution of requirements for connection of new users, while maintaining the overall forecast of network capacity growth leads to an increase in the total cost of the network up to 20%; minimum change of the node location increases the value of a network of about 8%. Fluctuations in the cost parameters lead to change of AP number more than ten times or until the loss in value to 16% in the worst case. Manual changes in the distribution of nodes and the boundaries of their service, as a rule, are inevitable at the last stage of network planning. As a result of the investigations it has been shown that the optimal network configuration is insensitive to variations of number of parameters. In order to optimize the location and boundaries of AP servicing the most important was the cost of AP hardware. Forecasting error of users' number, the load created by the ICS users and the coefficients of the inclination influence much less than it is usually indicated. As expected factors of AP cost, local access lines and transport segments have a dominant influence on the configuration and cost of the optimal network.

Development of messages stream's model of convergent telecommunication network

Before to speak about information network's synthesis it is necessary to solve a problem of the analysis of users' requirements in communication services for which satisfaction the network is being established. Such analysis includes determination of predicted volumes of information streams, their distribution in space and time. Here it is necessary to specify kinds and volumes of traditional and new infocommunication services, to choose proper correlations between volumes and behaviour of streams' distribution established by these services.

The decision of the majority of problems of the information distribution theory is based on the law of stream preservation, saying that intensity of requirements number's growth in the system is defined by a difference of intensity of inlet and outlet streams. The stream of requirements, demands or calls is a set of the moments of these requirements' arrival in the system. The call is a requirement of connection between two network users for a message transfer. The message is the information converted to electromagnetic signals. Considering a difference between the call and the message it is possible to speak about the calls stream as arriving in the network, and the messages stream as circulating in networks for the users information transfer. Nowadays there is no common theory of distribution and calculation of quantitative and quality parameters for messages streams in the TN. The messages stream between points i and j is a sequence of messages transferred from the one point to another. Except the effective information network provides transfer of control handling and signalling messages which do not have values for the user. Callbacks as result of connection's deny for primary call essentially load networks without giving useful effect too.

At the network synthesis it is also necessary to solve problem of information streams' distribution. Existing algorithms allowing by means of computer computing tools to solve this problem for existing telephone networks or data networks should be modernised taking into account specificity of integrated service. In the network with the mixed traffic (speech, data, images) it should be expected very strong oscillations of traffic. Dialogue traffic often varies spasmodically (from the periods of high to the periods of low activity and on the contrary) and these features also should be considered at the network architecture's synthesis. It is not enough to speak only about need of information delivery: it is necessary to know what these information is (both from quantitative and qualitative positions), what information value is to be transferred and in what way it would be carried out. This information is to be known from the point of view of information transformation both in time and in space.

The model of messages stream allows defining quantitative parameters of the streams circulating in the TN at: interaction between the TN and an information metastructure in the context of processes of network service, transmission of messages streams through bypaths instead of the main ones, etc. Thus, it is possible to determine characteristics of mainly stochastic processes of convergent TN at the different moments and time intervals on different segments of the network that is especially important, for example, at realisation of interoperators interaction within the limits of common physical network's sharing. Such special case can be result not only of market relations in infocommunication sphere, but also can be a pressing need of providers in the conditions of monopoly. Proceeding from these assumptions principles of the description and the model of messages stream should differ essentially from the model of calls stream, however now there is no common theory of distribution and calculation qualitative and quantitative parameters for messages streams in the TN. Therefore the problem of making up of the messages stream's model in the network, and the method of these streams characteristics' registration at the designing of convergent TN is essential, actual and nontrivial at all.

The volume of transferred messages is rather important characteristic at the designing of the messages stream's model. Instead of duration of calls streams' service it is characterised not only by the message transfer time, but by volume and value of the information transmitted in this message. That is much more important. Besides, it is necessary to consider presence and level of priority of each message and number of other parameters.

Hence, a common problem of creation of the messages stream's model circulating in the network can be splitted into following subtasks.

1. An estimation of distribution function of the moments of messages' receipt in the network.

2. Research of correlation between duration of message transfer and volume of the information transmitted in it.

3. An estimation of influence of the transmitted information value on type of the transmitted message and a method of its account at designing of the messages stream's model.

4. A method of the message priorities' forming depending on its volume and value of the containing information.

5. A method of the registration of callbacks and other factors which are important for provision of qualitative message transfer service through the network.

6. Development of the generalised formalized messages stream's model circulating in the convergent TN.

7. Research of the offered model by imitating modelling.

The problem of development of messages stream's mathematical model circulating in the convergent telecommunication network (CTN) (fig. 3) and designing of based on it imitating model of CTN messages streams is being decided in work of Maxim Solomitsky.

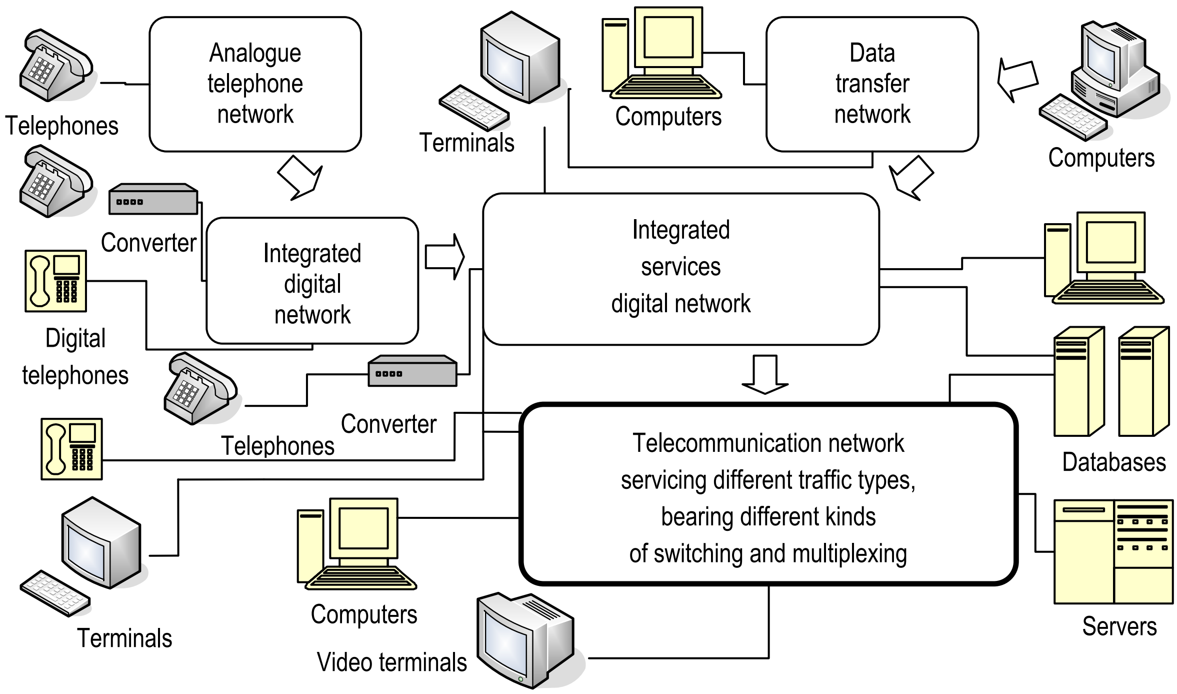

Figure 3. Stages of the convergent telecommunication network's development

Determination of CTN is given in the production paper [Solomitsky, 2011], where CTN is considered from system positions. Some formal representations and approach for decision of problems of CTN analysis and synthesis are formulated in this paper too. It is established that it is impossible to carry CTN directly to one of such well known classes of networks, as data-processing, data transfer, telephone which urged to render services for users only of the defined accurately limited area.

As a result of executed in [Solomitsky, 2011] analyses of possibility of the teletraffic theory mathematical apparatus' usage for the description of interaction between the CTN and environment it is concluded that existing models of networks functioning, networks processes' models and methods of calculation of the network equipment in their initial kind are unsuitable for the decision of problems of the CTN analysis and designing.

To develop the messages stream model in CTN first of all it is necessary to understand what is the CTN and what are its fundamental differences from other kinds of communication networks. The formal description of CTN architecture in the form of the environment and network medium is developed for its research [Solomitsky, 2012]. Each of these mediums is represented in their turn in the form of two mediums: environment - generation and distribution mediums, network medium - interaction and processing mediums (fig. 4).

Extraction of the generation medium allows to describe influence of users on the network, i.e., streams of their requests for the network resources; the distribution medium allows to reflect influence of any external prevent factors on propagation of physical signals in the network; the interaction medium gives the possibility to describe the network as a whole; the processing medium - possibility to describe the basic structural network elements processing the digital information.

An approach to formal determination of points of interaction between the CTN and information metastructure, processes of network service is offered in [Solomitsky, 2012]. That is important for adequate modeling of the messages streams circulating in CTN. The interaction medium is presented as some homogeneous data-processing medium consisting from SN and service nodes. Apparatus of hierarchical connectivity matrixes (CM) is offered for the description and analysis of the interaction medium features. Thus the configuration of nodes is set in a matrix form with usage of square CM for the given level nodes (dimension is N_i x N_i, where N_i – number of nodes of corresponding i-level) and rectangular CM for the adjacent levels nodes (dimension is N_i x N_{i-1}, where N_{i-1} – number of nodes of the bottom level). In CM there can be as the designations pointing presence or absence of connection between nodes, and designations of numerical value of some parameters characterizing corresponding connections. Interlevel CM are being made for displaying communications between nodes of the next levels. They can be primary, displaying physical connections between nodes, and secondary, showing internodes logic connections.

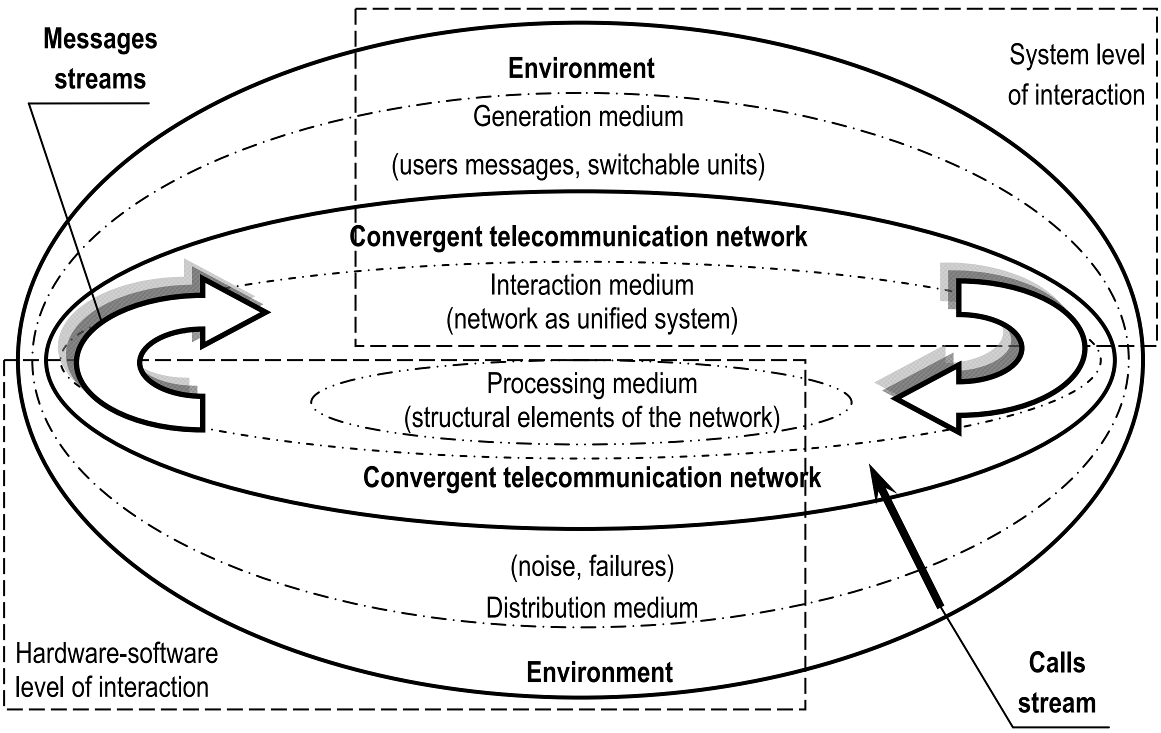

Figure 4. Formal conception of CTN architecture

According to the given decomposition of the problem of messages stream model's development, being based on the received results, further it is planned: development of the apparatus of the formal description of information content in the messages stream; determination of a distribution function of the messages stream in time and distribution function of information content of the messages stream; development of the apparatus of the formal description of control information in the CTN messages streams and the formalized apparatus of determination, whether is the separate message the finished semantic unit or represents a part of the whole; development of formalistic approach to determination of information value and function and/or set of functions of information value; development of the mechanism of formal determination of the messages stream's priority, including conditions of fuzzy statement. That is a direction of the further research.

Conclusion

The formulated set of problems is being successfully solved by the collective of information-communication technologies department. However, nowadays it is impossible to formalize common problem of synthesis of optimum variant of information network as a whole in a general view. Furthermore this problem is the NP-difficult problem which does not have both the analytical decision and any solution at all. Possibility of use of analytical methods is coupled to introduction of some assumptions. Therefore in process of the decision of problems of separate network segments' topological structure's synthesis, algorithms of management and information exchange particular problems are being formulated and solved. Combination of these problems' decisions by analytical methods and by imitating modeling will allow to approach closely in due course to creation of general imitating model reflecting process of switched information network evolution. The similar model will allow to approach closely to the decision of a problem of these networks' optimum synthesis. There are assumptions to hope, that these works can be useful both scientists in the field of information technologies and at the practical planning and designing of information networks.

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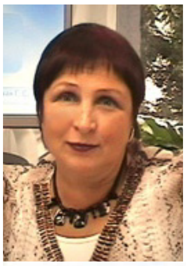

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Major fields of scientific research: problems of convergent telecommunication networks' creation

SOME FEATURES OF INFORMATION TECHNOLOGY DEVELOPMENT OF EXPERT SYSTEMS USED IN UKRAINE

Olena Domaskina, Oleg Domaskin

***Abstract**: In this paper the analysis of the various functions in the view of features of information technology development of expert systems used in Ukraine is given.*

***Keywords**: information systems, artificial intellect, expert systems, ACS.*

***ACM Classification Keywords**: I. Computing Methodologies - I.2 ARTIFICIAL INTELLIGENCE - I.2.1 Applications and Expert Systems.*

The tendency and function

Characteristic feature of the progress of computer information systems that are relevant to Ukraine is an absolute priority to development of expert systems based on the using of artificial intellect Institute. This trend is substantiated by a factor that expert systems allow the manager or specialist to get expert advice on any problems which have accumulated knowledge of these systems. Artificial intellect is usually described as the ability of computer systems to such actions, which would be called intelligent if it came from the man.

Of course, the solution of special problems requires special knowledge. However, not every company can afford to keep a staff of experts on everything related to her work, problems, or even invite them each time the problem occurred. This, at first glance, the only economic problem, which is inherent in almost every young and poor country such as Ukraine, was the main reason for this: main idea of using the technology of expert systems is to obtain from the expert's knowledge, and download them to your computer, use whenever the need arises.

As one of the major applications of artificial intellect, expert systems are computer programs that transform the experience of experts in any field of knowledge in the form of heuristics rules. Heuristics do not guarantee optimal results with the same confidence as usual algorithms used to solve problems through decision support technologies. However, they often provide sufficiently acceptable solutions to their practical use. All this makes it possible to use expert systems technology as advising systems.

The similarity of the information technologies used in expert systems and decision support systems is that they both provide a high level of support for business decision-making in Ukraine. However, there are three significant differences, rather the features.

The first is that the solution to the problem in the decision support systems reflects the level of understanding of the Ukrainian particular user, his mentality and the ability to obtain and interpret the optimal solution. The technology of expert systems, on the contrary, asks the user to decide which exceeds its capabilities.

The second difference between these technologies is reflected in the ability of expert systems to explain their reasoning in the process of receiving the decision. Very often, these explanations are more relevant to users than the decision itself.

The third difference involves the use of a new component of information technology - general knowledge and expertise.

The main components of information technology used in the expert system

The main components of information technology expert systems are: the user interface, knowledge base, the interpreter, module for creation system.

To enter data and commands in an expert system and receiving output information from her manager (specialist) uses the interface. Teams include the parameters that guide the processing of knowledge. The information is usually issued in the form of values assigned to certain variables.

The manager can use the four methods of data entry menus, commands, natural language and its own interface.

The technology of expert systems provides an opportunity to get as output information is not only a solution, but also the necessary explanations.

We distinguish between the two most important kinds of explanations:

- explanation issued on request. The user may at any time require the expert system to explain their actions;
- explanation of the solution of the problem.

After receiving the decision, you can demand an explanation of how it was obtained. The system should explain every step of his reasoning, leading to the solution of the problem. Although the technology to work with the expert system is not simple, the user interface of these systems is friendly and usually does not cause difficulties in the dialogue.

Facts describing the problem area, as well as the logical relationship of these facts, contains a knowledge base. Of course, central to the knowledge base belongs to the rules. This is usually determines what should be done in this particular situation, and consists of two parts: a condition that can be executed or not, and the action that should be performed if the condition.

All materials used in the expert system rules and form a system of rules, even for relatively simple systems may contain thousands of rules.

All kinds of knowledge depending on the specific subject area and qualification of the designer (knowledge engineer) with varying degrees of adequacy may be represented by one or several semantic models. The most common models are logical, production, and frame-based semantic network.

Part of an expert system that produces in a certain order processing knowledge, which are in the knowledge base, we called the "interpreter". The technology of interpreters` activity reduced to a consistent set of rules of consideration (rule after rule). If the condition contained in the rule is observed, then the appropriate action must be done, and users have the option to solve the problem.

Besides that, in many expert systems it is appropriate to introduce additional blocks: the database, the unit of calculation, the block entry and data correction. The block is needed if solution of the conflict situations mast be taken or associated with the adoption of management decisions. An important role is played by a database of planning, physical, settlement, reporting, and other permanent or operational performance. Block entry and data correction is used for quick and timely reflection of current changes in the database.

Create and organize a set of rules are done by module of the system. There are two approaches that can be used as a basis for creating a module of the system: the use of algorithmic programming languages and the use of expert systems shells.

In Russia and Ukraine in order to provide the knowledge base using a specially designed language "Lisp" and "Prologue" are using, although you can use any known algorithmic language.

In most cases, faster and easier compared to programming, to create expert systems using expert systems shell - ready software environment that can be tailored to address specific issues through the creation of a knowledge base.

Decision support systems and stages of their evolution

During its development, decision support systems were the following stages.

The first stage of the evolution of transaction processing systems have appeared (TSP) - a computer system designed to perform routine operations of registration, accumulation, storage and delivery of information in a predetermined manner. As we see, in such decision-making systems provided only information.

The next stage of development of information systems was the concept of automated control system (ACS). In the West, this concept was called MIS. It is a computer system designed to provide timely information for decision-making.

The level of support solutions using this concept - the information, we apply some models and methods for making optimal decisions.

Note, to a large extent the nature of all the generations of systems and their concepts determined by the technical capabilities of processing information available at that time. Office automation systems (OAS) implemented the distributed database. Eliminated excessive centralization. There were local area networks based on the average computer. The level of decision support (information) apply some models and methods for making optimal decisions. OAS - computer system to perform complex operations management system as such.

The next stage - a decision support system (DDS). DDS - interactive computer system, which uses formal rules and the controlled object model in conjunction with the database manager and personal experience to develop and test options for management decisions. As you can see, the system of this kind is not ensured by information and decision-making process, but participate in it.

The peak of the development of information systems are expert system (ES). Expert System - a computer system that uses knowledge of one or more experts, presented in a formal form to decision address (ESS - a variant of DDS decisions to senior management).

There are many members of various types of information systems.

Thus, the decision support system - interactive automated information system that uses rule-making and the corresponding models with databases, and interactive computer modeling process that supports the adoption of independent and unstructured decisions by individual managers and the personal experience of the person making specific implemented solutions to problems which are not amenable to solution by conventional methods.

Recently, DSS are beginning to be applied in Ukraine, in the interests of small and medium-sized businesses (for example, selecting placement of outlets, the choice of candidates for the vacant position, with the option of information, etc.). In general, they are able to maintain an individual style and meet the personal needs of the manager.

Developed and implemented application systems, designed for solving complex problems in large commercial and government organizations in Ukraine, for example: in the airline industry - using a decision support system - Analytical Information Management System. It was created by American Airlines, but its modified versions are used by other companies, aircraft manufacturers, aviation analysts, consultants and associations, including those in Ukraine. This system supports a variety of solutions in this sector by analyzing data collected during the utilization of transport, traffic assessment, statistical analysis of the chart. For example, it allows you to make forecasts for the aviation market for the shares of companies, revenue and profitability. Thus, this system allows management to make decisions about airline ticket prices, demands for transport. Also it is used to study the degree of urbanization, forestry, railway business, agricultural, etc.

Conclusion

Last time, in Ukraine the recent DSS became more and more actual and applied in the interests of large commercial and government organizations, small and medium-sized businesses.

It is very popular for the small and medium-sized businesses: selecting placement of outlets, the choice of candidates for the vacant position, with the option of information, etc. In general, they are able to maintain an individual style and meet the personal needs of the manager.

Developed and implemented application systems, designed for solving complex problems of large companies are using. For example, in the airline industry a decision support system - Analytical Information Management System is using. It was created by American Airlines, but its modified versions are used by other companies, aircraft manufacturers, aviation analysts, consultants and associations, including those in Ukraine. This system supports a variety of solutions in this sector by analyzing data collected during the utilization of transport, traffic assessment, statistical analysis of the chart. As well as, it allows them to make forecasts for the aviation market for the shares of companies, revenue and profitability. Thus, this system allows management to make decisions about airline ticket prices, demands for transport. Also it is used to study the degree of urbanization, forestry, railway business, agricultural, etc.

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CONVOLUTION NETWORKS AS A METHOD OF REALISATION OF CUSTOMS RISK-MANAGEMENT

Boris Moroz, Sergii Konovalenko

Abstract: *The paper discusses the theoretical aspects of the mathematical model of convolutional neural networks as a means of classifying the information was not originally a graphic of origin. The description of this approach was illustrated by the information classification of customs control, which involves the transformation of a set of vectors multitype information graphics (pseudographic patterns).*

Keywords: *convolutional neural network, customs control, risk management*

ACM Classification Keywords: *I.5 PATTERN RECOGNITION – I.5.1 Models – Neural nets.*

Introduction

Application of the customs services of the European Union, modern information technology [WCO] allow to automate customs procedures. They use analytics and decision support have improved the efficiency of customs control and clearance. The use of the mechanism of risk management violations of customs legislation is a key part of their automated information processing systems E-customs [ASYCUDA]. Customs risk management allows for the selective control of the appropriate level of detail where it is needed. This approach allows for the acceleration of customs procedures and effective detection of violation of customs regulations.

In the Ukrainian Customs Service is also actively improving customs control at the expense of upgrading the Unified Automated Information System. The concept of e-Customs [Moroz, 2011] involves the active use of customs risk analysis system. Only the use of effective methods and tools for information processing of customs control will reliably identify potentially dangerous situations. This in turn increases the economic security of Ukraine.

Based on the foregoing, it is possible to select a current area of research as the development of methods and tools to identify risks violation of customs laws. Publications on the use of information processing methods of customs control are relatively few and, for the most part, they are conceptual in nature, highlighting the problems and the relevance of the topic. In the work [Moroz, 2011] it was shown that the use of mathematical models of neural networks such as multilayer perceptron can be pretty good to recognize the input data vector $x = [x_1, x_2, \cdots, x_i]^T$ risk {“Low”,“Moderate”,“High”}. In spite of this fully connected network has some drawbacks, which may reduce their effectiveness. This increase in the dimension of the input vector, which leads to an increase in adjustable parameters and the network as a result of more training time. Additionally, you must take into account the need for E-customs in the recognition of graphic data recorded by technical means of customs control (X-ray, video cameras, etc.). That is, information processing system should have such properties as a relatively small number of adjustable parameters, resistance to distortion, taking into account the topology of the input space and scale. These properties are convolutional neural networks. Convolutional neural network performed well in pattern recognition [Lawrence *et al.*, 1997], closed-circuit television [Fan *et al.*, 2010], scanning systems [Prokhorov, 2010], assessing the quality of digital video [Callet *et al.*, 2006].

This gives us the opportunity to consider the possibility of using convolutional neural networks for recognition of the risks violation of customs laws. In this paper we describe the theoretical aspects of this paradigm of Applications for the needs of the customs service. We ask authors to follow some simple guidelines.

Problem definition

The purpose of this paper is a theoretical consideration of the application of the mathematical apparatus of convolutional neural networks for risk analysis breach of customs legislation, in connection with which there is a need in the following tasks:

- To carry out the transformation of the input data vector to the pseudo-image;
- Form a network architecture of the convolution;
- Draw conclusions about the possibility of using this architecture in the customs risk management.

Customs risk management

Risk Management is a methodology that helps managers make best use of their available resources (Fig. 1). Risk assessment is a feature of many industries, such as insurance, banking, and environmental protection. Risk Management include:

- Good management practice;
- Process steps that enable improvement in decision making;
- A logical and systematic approach;
- Identifying opportunities;
- Avoiding or minimizing losses.

Risk assessment is a technique used to predict adverse outcomes and to contain risks within acceptable limits. Customs Risk Management (CRM) is the name given to a logical and systematic method of identifying, analysing, treating and monitoring the risks involved in any activity or process of customs control.

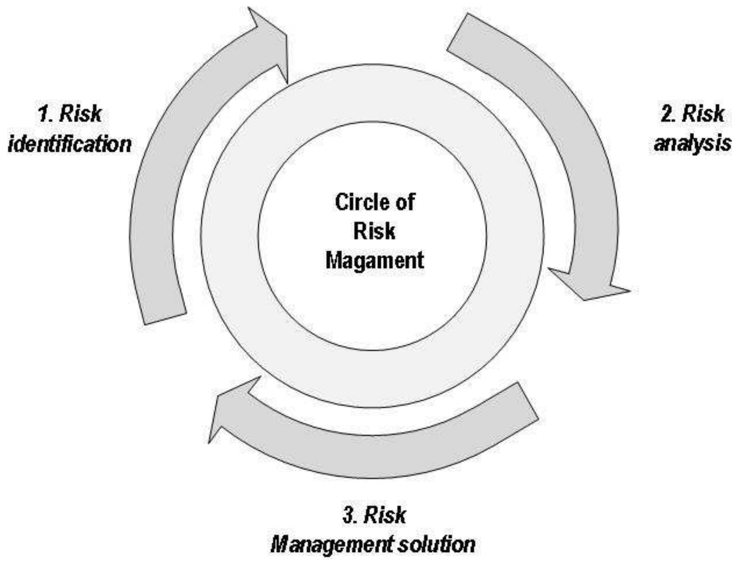

Fig. 1. Risk Management

Risk analysis breach of customs legislation is implemented by means of risk profiles (PR). PR applied at the time of customs control and customs clearance of goods i of vehicles crossing the customs border, and are on target to prevent the Inspector of the risks involved violations of the law at the time of a particular foreign operation. Next, the system gives the inspector recommendations for the use of certain forms of control. The ultimate goal of PR – Customs security software by making management decisions.

Development of PR involves the execution of such actions:

- The definition of an indicator of risk;
- an assessment of selectivity;
- assessment of the importance of PR for filling the state budget;
- determine the effect of negative PR stories, etc.

Using the system of risk analysis methods and tools of effective intellectual processing of information will improve the quality of risk identification of violations of customs rules and smuggling.

Convolutional neural networks and customs risks

Consider the problem of analyzing and identifying risks violation of the customs legislation as a problem of pattern recognition, which in turn is a complex and multidimensional (Fig. 2). It is proposed to use for this purpose the model of information processing based on neural network approach.

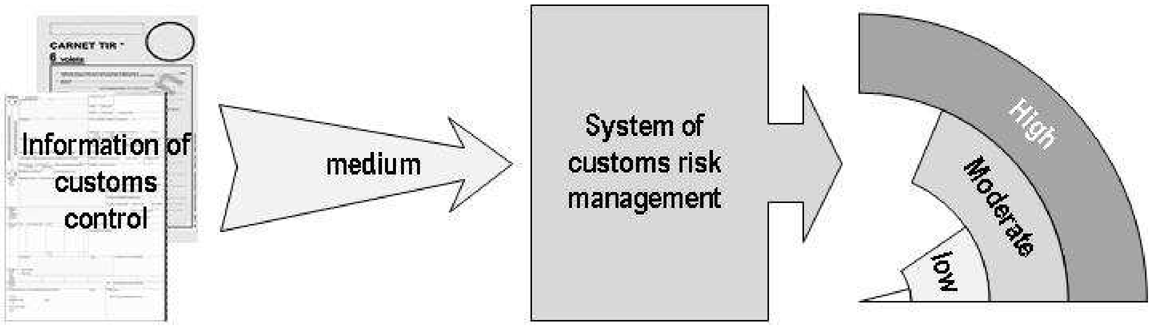

Fig. 2. Customs Risk Managament.

In [Moroz, 2011] were obtained quite good results on the multilayer perceptron Good results were obtained at the expense of low-dimensional input vector and undistorted (adequate) training and testing samples. But in our case it is necessary to ensure effective learning and recognition of the quality of the network by increasing the dimension or change the input vector. This can be achieved by using convolutional neural networks [LeCun and Bengio, 1995]. Convolution neural network is resistant to changes in scale displacements, rotations, changing angles, and other distortions in the input space [Bishop, 2006]. The basis of this paradigm are the following ideas [Haykin, 1998]:

- Invariance to shift with the help of maps of the convolution;
- Reducing the number of free parameters within the overall balance;
- Layers of sub-sample of implementing the local average.

Maps of the convolution implement local perception, i.e. on the input of one neuron is fed is not the whole image (or outputs of the previous layer), but only a portion (area). The use of shared common scale means that for a large number of connections used is very small set of weights (kernel). This kernel is the same for all layers of convolution. With the sub-sample resolution is achieved by reducing the signs of cards, which reduces sensitivity to deformation. Construction of convolutional neural networks lies in the alternation of convolutional layers (C-layers), subsampling layers (S-layers) and the presence of fully connected (F-layers) at the output layer (Fig. 3)

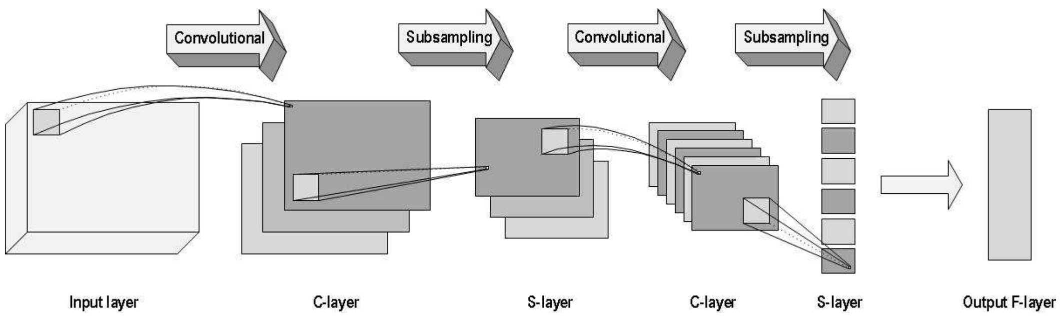

Fig. 3. Convolutional neural network.

The size of the convolution plane is determined in accordance with the following expression:

$$w_c = w_u - K + 1,\\ h_c = h_u - H + 1, \tag{1}$$

where w_c,h_c – width and height of the convolution plane, respectively; w_u, h_u – width and height of the plane of the previous layer; $K(H)$ – width (height) of window scanning.

The state of the convolutional neuron is given by the:

$$y^k_{i,j} = b^k + \sum_{s=1}^{K}\sum_{t=1}^{H} w^{k,s,t} x_{((i-1)+s),(j+t)}, \tag{2}$$

where $y^k_{i,j}$ – k-th neuron of the plane of the convolutional layer; b^k – neuronal bias the k-th plane; K – the size of the receptive field of the neuron; $w^{k,s,t}$ – element of the matrix of synaptic coefficients; x – output neurons of the previous layer.

The process of functioning of the neuron subsampling layer is given by the following relation:

$$y^k_{i,j} = b^k + \frac{1}{np} w^k \sum_{s=1}^{n}\sum_{t=1}^{p} x_{((i+s),(j+s)),(i,j))}. \tag{3}$$

For training the neural network described algorithm error backpropagation [LeCun *et al.*, 1998]. As the neuron activation function used the hyperbolic tangent $f(x) = \tanh(x)$. To assess the quality of recognition usually use the most common in the theory of neural networks is a function of mean-square error:

$$E_p = \frac{1}{2}(D^p - O(I^p, W^p))^2, \tag{1}$$

where E_p – this is an error detection for the p-th training pair, D^p – the desired network output, $O(I^p, W^p)$ – output of the network, depending on the p-th input and the weights W, which includes the convolution kernel, bias, weighting coefficients of S-and F-layers.

Thus, we describe the theoretical model of the recognition of risk breach of customs legislation with the help of the convolution of the neural network. At our disposal is the input vector $x = [x_1, x_2, \cdots, x_i]^T$, which has in its structure, heterogeneous data types in need of normalization and coding, so that our network could work with him [Moroz, 2011]. Because the network is working with two-dimensional convolution of images, the input data should lead to precisely this form. Consider a vector of seven elements and transform them into pseudo-dimension image of 7×7 (Fig. 4). Graphic matrix is horizontally symmetrical range of risk levels $(1; 0.7; 0.3; 0; 0.3; 0.7; 1)$, and vertically - the elements of our input vector $(1...7)$. Each value is the input vector is estimated in accordance with the profile and level of risk (the anomaly) from 0 to 1. And then stained with the cell at the intersection of the corresponding element of the vector and its significance level of risk. The symmetry of the level of risk necessary for a better perception of the network image. Examples are presented in Figure 4 forming the input vector to the pseudoimage, the first column corresponds to a high level of risk, the second and third – the moderate and low. Now, the input vector data suitable for processing by the convolution of the neural network. We project a convolution neural network (Fig. 5) The size of the input layer is equal to 7×7 neurons realizing only way to feed the input to the neural network. Next to the input layer is a convolutional layer C, consisting of a folded card features with its kernel (weight vector W). Each neuron in the map signs to get their inputs locally receptive field dimensions of 2×2. For our problem will be enough to select four maps attributes dimension of 6×6 (1). The next layer implements subsample S and the local average of the layer C. Each plane of S is associated with only one plane of the layer C. The size of each plane of the layer S – 3×3 neurons, which is twice smaller than the size of the plane of the previous layer. Each plane of S has a single factor and neuronal synaptic bias. In our case, then alternate layers of convolution subsample does not make sense because of the small dimension of the input image. Layers $F1$ and $F2$ contain simple neurons. These layers provide the classification after the extraction of features implemented and a reduction in the dimension of the entrance. In the layer 4 neuron $F1$ is, each neuron is fully connected with each neuron only one layer plane S, it performs weighted summation of its nine entries, adds the offset neuron and passes the result through an activation function. Three of the $F2$ layer neuron is fully connected to all neurons in layer $F1$ and perform the final classification. Each neuron corresponds to one of three levels of risk {“Low”,“Moderate”,“High”}. Thus a network, where a total of 143 adjustable parameters $(C - 80, C - 8, F1 - 40, F2 - 15)$, which is several times smaller than similar fully connected networks. This effect is achieved through the principle of sharing of synaptic coefficients. This in turn will only improve the quality of recognition and stability of the network compared to the multilayer perceptron.

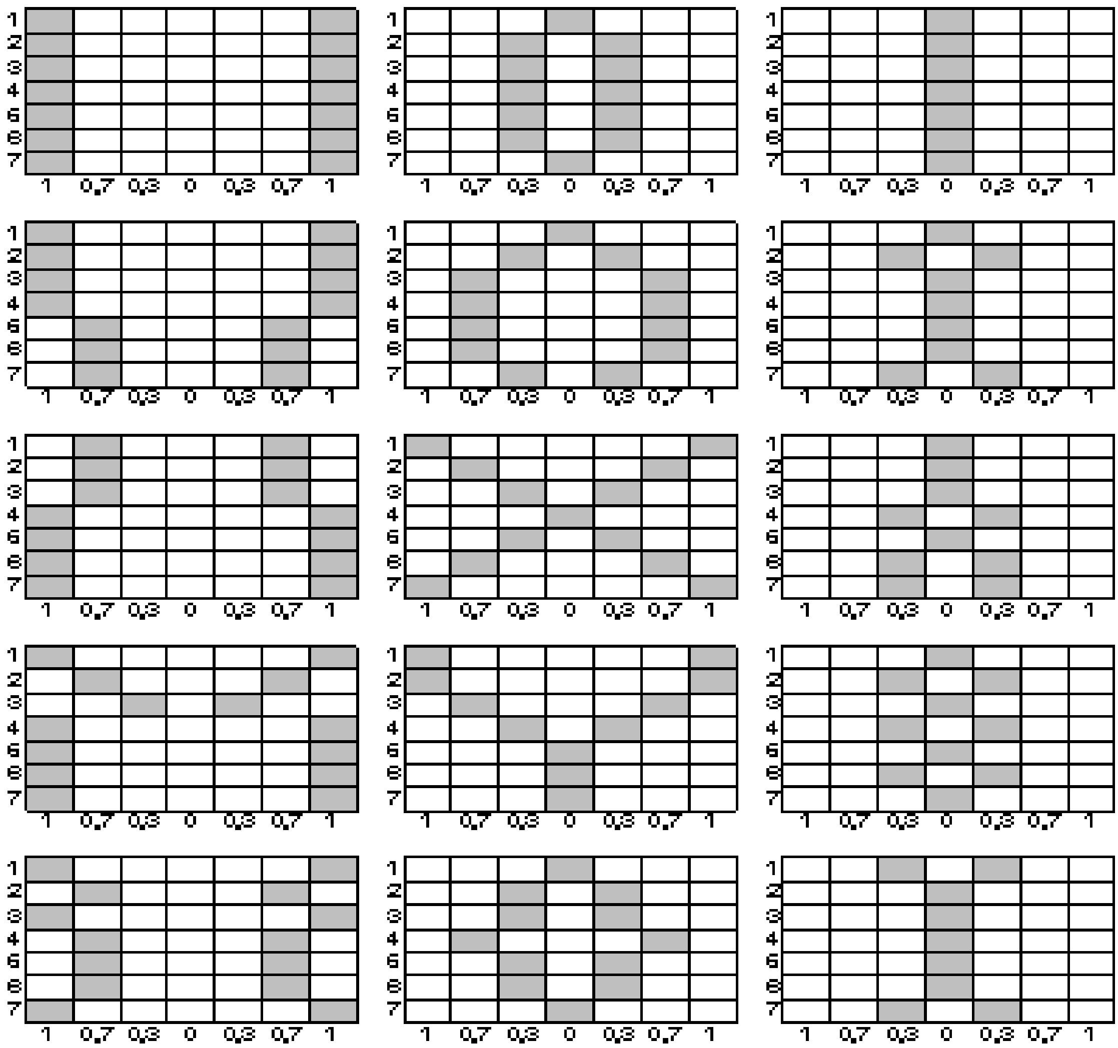

Fig. 4. Pseudographic patterns: {“High”,“Moderate”,“Low”}.

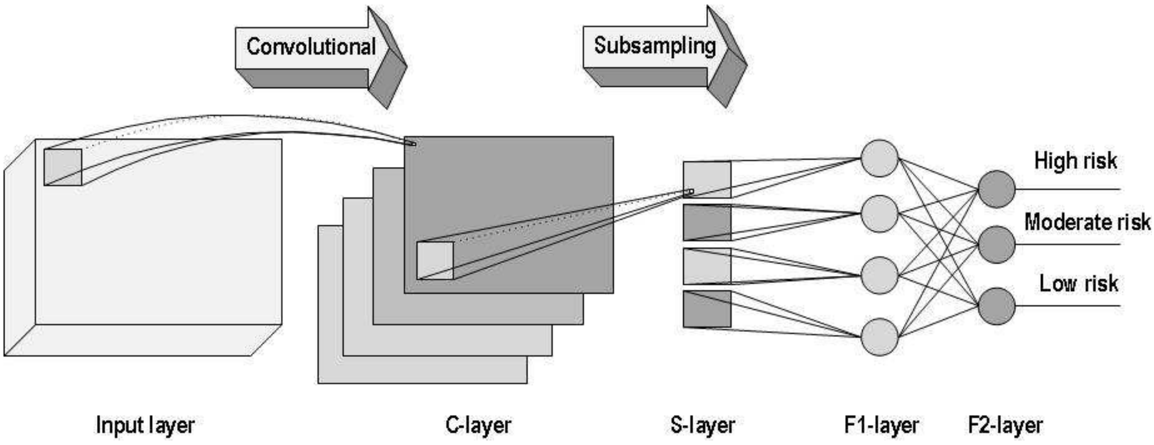

Fig. 5. Convolution model of the recognition of risks.

Conclusion

As a result of this work was theoretically developed models to identify risks breach of customs legislation, based on the convolution of the neural network. The paper shows the mechanism of transformation was not originally a graphic information in a graphical origin of the plane. On the basis of studying and research papers and publications can be argued that the proposed model has not bad processing input recognition quality images than the fully connected network. In addition, the convolution of the neural network model has fewer adjustable parameters than the earlier model by [Moroz, 2011]. The use of convolutional neural networks as a method of classification of information of customs control may be a useful tool in the management of customs risk management. Further research should be devoted to the study of the practical implementation of convolutional neural network models for classification of pseudo-information, and enable them to recognize the numbers of transport crossing the border.

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USING OF PROCESS ONTOLOGIES FOR DECISION SUPPORT IN INFORMATION MANAGEMENT SYSTEMS

T. Atanasova

Abstract: *The use of ontologies for data mining and knowledge discovery in databases is proposed by many researchers. In this paper it is proposed to use a lot of data collected in the information systems, to develop methods for decision support, based on previous experience in implementing similar tasks. It is shown that the investigations are directed towards to reduce the time and the resources, necessary to achieve efficient solutions in the work of enterprises and organizations. In this paper emphasis is placed on the use of problem-oriented thesauri to create ontology of processes. The development will be useful in analyzing the results and the formation of future strategies of management.*

Keywords*: process ontologies, semantics, data sources, information management*

ACM Classification Keywords: *H. Information Systems, H.4 Information Systems Applications*

Introduction

Large databases within information management systems often contain interesting hidden knowledge model that could be extracted using data mining [Mansingh, 2011]. Review of the literature shows that both objective and subjective methods for the extraction of the interesting links have to be applied. Ontologies (as an objective method) allow to reveal hidden implicit knowledge and to make them explicit by means of conceptualization, which can be used in different applications and organizations.

The approach proposed in this paper involves the use of process ontologies for the implementation of decision support, based on previous experience in implementing similar problems in the information management systems.

Ontologies

The term "ontology" in the context of knowledge management is considered as a formal explicit specification of shared conceptualization, which covers the consistent knowledge. Well-formed knowledge representation language can be adopted as ontology.

The main components of the ontology are concepts, relationships, instances, rules and axioms that restrict the interpretation of the components of the ontology. The concept is a class of objects (entities) in the area. Relationships describe the interactions between concepts or properties. The relationships are of two types: taxonomy and the associative relationship. Taxonomies systematize concepts as a hierarchical tree, and the associative relationship disposals the concept on the tree. Instances are specifications of concepts, together with the taxonomy and the relationships they form the knowledge domain.

Axioms are used to restrict the values of classes or objects (examples). Ontology may have logic inference, and then it is so-called formal ontology. Formal ontology must have axioms that restrict the possible interpretations of logical expressions.

Ontologies are created in various forms - from lexicon to dictionary terms, or as first-order logic. In a broad sense, they can be distributed over three categories: general, domain or applied ontology.

General ontologies represent knowledge, applicable in various fields of knowledge. The domain ontology focuses on the refinement of a more narrow meaning of the terms used in a certain area, and may represent a basic reality, in this specific area, but independent of a specific task. Domain ontology has four levels: domain, category, class and instance.

Applied ontology is a specific sub-ontology that contains concepts and relationships which are relevant only to the definite task, such as thesauri, which are semantic relations between lexical units. Usually they contain a small number of concepts with relationships and inference rules, which are defined in detail for solution of particular independent task.

Ontology construction

Ontologies can be expressed in different modelling techniques. The choice of an appropriate semantic model to represent ontology depends on the purpose for which the ontology is build and the underlying assumptions for achieving these goals. The mechanism of the formal description of ontology for information management is proposed in [Загорулько, 2009].

Lot of researches makes extensive engineering efforts in ontologies construction using a relational database as a data source. Construction rules of ontology elements based on relational database, which are used to generate ontology concepts, properties, axioms, instances are put forward. Most approaches are based on converting a database schema (DB) to the ontology as, for example, it is shown in [Zhang and Li, 2011].

Most domain knowledge about domain entities with their properties and relationships is embodied in document collections. On this base in the [Hou et al, 2011] a graph-based formalism to represent ontologies has been proposed. The procedure for ontology construction based on the Concept Map is considered in [Huang and Diao, 2008].

To construct a hierarchy of classes it is necessary not only to use the analysis of the database schema but to make identification of hierarchies in the data itself, that's why machine learning methods have to be involved.

The elicitation of ontology goes through few steps [Santoso et al, 2011]:

1. As the basic knowledge, a hierarchy of concepts gives information about the domain, a hierarchy of concepts is represented as a graph $G = (N, E)$; N - the set of nodes, E - the set of branches, where $N=\{n_1, n_2,\dots n_n\}$, $E=\{e_1,e_2,\dots e_n\}$. The graph can be described using XML Schema Datatype (XSD).

2. The inclusion of basic knowledge in the process of building ontology on OWL (Web Ontology Language) allows to speed up the process of ontologies construction. Metadata from the relational database are displayed in OWL with group of rules for the tables, attributes, and rows: R - set of tables r_i, $R=\{r_1,r_2,\dots, r_n\}$, r_i consists of a set of tuples t, $t_i =\{t_{i1}, t_{i2}, \dots, t_{in}\}$; $p\_a()$ - is predicate to obtain a set of attributes a from r, $p\_a(r_i) =\{a_{i1}, a_{i2}, \dots, a_{in}\}$; $p\_k(r_i)$ - predicate for getting the primary key from the r_i; $f\_k(r_i)$ - a predicate of obtaining a secondary key from the r_i. Then the rules for mapping tables, attributes, and instances into ontology can be design [Santoso et al, 2011]. Only database scheme is used in [Santoso et al, 2011], without considering the actual data and processes that accompany them. While a large amount of data stored in relational databases, represent a valuable resource for building ontologies.

The use of ontologies for data mining and knowledge discovery in databases is proposed by many researchers [Jung, 2009; Savvas and Bassiliades, 2009; Зуева et al, 2008; Ferilli, 2011; Pomares et al, 2011]. In this paper, attention is focused on the process ontologies and its use for information management.

Process ontology

One of the most famous books on the philosophy of the processes is Process and Reality, (1929), written by Alfred North Whitehead. The author argues that all events are connected with each other and with the environment in which they arise. Thus, the world is represented as an interconnected system of large and small events; some of them are relatively stable. The events are always changing. The changes represent the actualization of certain features and disappearance of others. The world is not just exists, it always becomes. As in [Palomäki and Keto, 2006] here the idea is discussed that everything is a process and consists of the processes. These processes are divided into constant processes that are interpreted as *concepts*, and the processes which are interpreted as *events*, represent a finite set of four-dimensional space-time. Thus, the world is built from events, i.e., ontologically, all consists of processes.

The consideration of processes includes [Jussupova-Mariethoz and Probst, 2007]:

- *when* a process should be initiated and finished;
- *who* participates in this process;
- *how* this process should be performed; which results must be examined, analyzed and taken into account.

Spatial and temporal order is constructed from the relation between events $e_1, e_2, ..., e_n$. The relationship is a causal connection between events, where the cause of the event is happening before its effect. The process in its entirety is interpreted as a topological space ***T***. The space ***T*** has starting point ***a*** and the end point ***b*** of the process, which are events. The chain from ***a*** to ***b*** contains a sequence of events. The formal description of the process ontology is proposed in [Palomäki and Keto, 2011].

In context of information management systems different processes can be divided into core processes (associated with the creation of a product or service); providing processes (varying depending on changes in the composition of the basic processes and technology) and external processes of interaction. Additionally, processes can be identified that determine the trends and directions of development of basic processes, depending on the analysis and estimated trends aiming in improving management procedures in the organization [Черний and Тузовский, 2009].

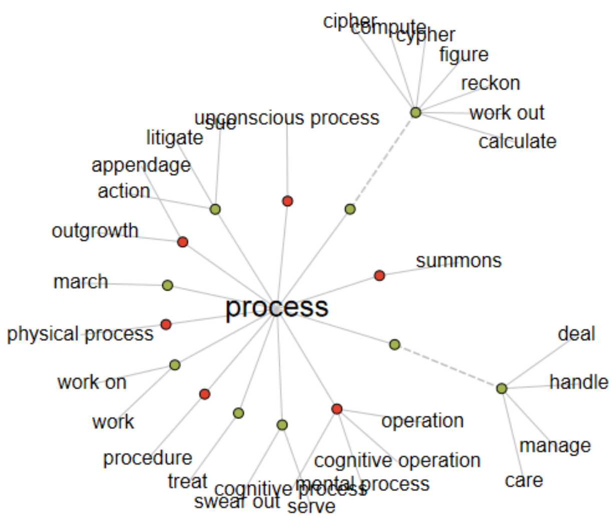

Figure 1. A part of thesaurus for the word “process” (designed using resources from http://www.visualthesaurus.com)

Using process ontology to support the decision-making in information management

Observations show that in the systems of organizational management a mixture of workflow and dataflow technology can be seen. Thus this work focuses on how to identify implicit patterns (as processes) in the streams of data available in the documents held in the systems of organizational management.

All information and data in the organization is contained in a multitude of sources ***S*** (documents, files, databases, external resources), ***S*** = $\{S_1, ..., S_n\}$. Such information is structured and includes numerical data and text fragments. Extracting knowledge from a specific domain can be considered as the construction of ontology. Using a hierarchy of concepts as the main (basic) knowledge allows the expression of the identified knowledge at a higher level of abstraction.

As an ontology a symbolic system $\{C, T, P, F, A\}$ will be considered, where *C* is the set of concepts, *T* - a thesaurus, or partial order on the set *C*, the hierarchy of relationships, "subclass" and "superclass"; *P* - the set of predicates (properties); *F* - a function that assigns to each element of *P* an element from the set of C (considering them in *T*); *A* -is a set of axioms of the ontology.

Thus, the information resources can be distributed among a set of hierarchically organized categories of thesaurus. Each category is described semantically. Software module can be developed that allocates annotation of documents concepts, instances of concepts and relationships between them.

When in a large organization a document is receiving (this is a starting point of the process) there is a problem of its proper handling and direction to the appropriate department. Resolution of the document and its classification is sometimes difficult and can bring to the loss of time and possible non-efficiency in its work. Each document represents a specific event; the relationship between documents defines the process. Each action is associated with the document; it is an event in the chain process of passage of the document. The process, which has been formed during solution of certain problems, is implicitly stored in the database. Then the objective is to identify processes that have brought to the event, as it reflected in the set of documents, and to predict future events based on the past experience.

Description of the incoming document is summarized in terms of problem-oriented thesaurus with text processing technology. Based on this description the graph of the document is constructed. According to the obtained descriptions semantic search can be organized later. Then the concept - synonymous are normalized. The conceptual closeness is derived from existing concepts in the domain.

To determine the relationship of units with one or more specified activities in the information system a method may be used for calculation of the semantic proximity, which also assesses the relationship of these units to the selected areas. Semantic interoperability can be calculated using the various existing methods. For example, an algorithm for computing the conceptual similarity with the use of problem-oriented thesauri can be based on fuzzy logic that is used to ease the difficulties in developing and analyzing complex systems.

Concepts in the ontology have many attributes, operations and associations. The mechanism of fuzzy inference is used to calculate the conceptual closeness as the similarity of attribute x_A, the operation of x_O, by association in this area x_D and the range of the similarity x_R - as the degree of affiliation between the concepts. That is, the concept can probably be qualified to a given node in the ontology if the conceptual closeness is high, and so a group of entities with identical attributes, operations, and associations with other entities is formed.

Discovering process models from information system event logs is definitely non-trivial. Within the analysis of event logs, process can be defined as the automated construction of structured process models from event logs [Goedertiera et al, 2011].

By the classification of records and the use of the process ontology the system evaluates the documents. The results are provided to the experts in the form of a semantic network of documents, which have a conceptual affinity with concepts and relations in the ontology. In addition, the ontology of processes will determine what information to extract and how to accelerate the semantic search. Semantic search is looking for documents in the information resources of the organization, whose semantic descriptions are similar to the semantic query. As a result of the semantic search, a list of found by the inquiry documents is ordered according to the semantic proximity value and further grouped according to the process. This allows extracting and using of the information and knowledge stored during operation of information systems.

Conclusion

The main problem for the information management systems is to manage the information and knowledge. The ontology systems specify semantic information about documents, services, and workflows used in various information systems. Ontology is also used to model the relations between documents and services and to manage process configurations.

The primary aim to use of ontologies is to integrate different applications. The diverse of service models and tools in information systems is constantly increasing, the necessity arises to have uniform base for their using [Daskalova and Kolchakov, 2000]. Exchanging of various data needs to take into consideration not only syntaxes but semantics of the data and processes.

The problem of inclusion of intelligent information systems constitute a scientific problem, ensuring that the theoretical development of decision support (DSS) in real-world application areas is based on their specificity. The knowledge-intensive approaches such as ontology are suitable for modeling complex systems.

To provide support decision making in information systems that is focused on specific goals and objectives of management process the problem-oriented thesauri are used for the formation process ontology.

The use of ontologies allows processes to implement algorithms and decision support functions. The article focuses on the use of problem-oriented thesauri to create an ontology of processes. Rules of generalization and analysis of data and methods for finding solutions based on problem-oriented thesauri and ontologies processes still have to be developed.

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Major Fields of Scientific Research: Knowledge-Based Systems, Learning Structures, Semantic Technologies

RESOURCE APPROACH TO DATA MINING BASED ON NETWORK TRAFFIC

Vochkov D.B., Bakanov A.S., Tashev T.D.

Abstract: *In the presented paper is considered resource approach to intellectual data analyses based on network traffic. A model for calculation of loading on different segments of the network in the distributed systems for organization control is designed. This allows more effective execution of data searching and analysis procedure and also significant reduction of the time for data processing.*

Keywords: *Intellectual data analyses, network traffic, resource approach.*

ACM Classification Keywords: *I.2.1 Applications and Expert Systems*

Introduction

In the presented paper is considered resource approach to intellectual data analyses based on network traffic. The term resource in our context includes information as well as telecommunication component. A data mining and information evaluating approach is proposed based on preliminary quantity evaluation of the resource using combined criteria with followed by multicriterial analyses.

Resource approach to intellectual data analyses

Intellectual data analysis problems in the organization control systems are considered in details in the work of [Баканова Н.Б., 2007], [Bakanova N., Atanasova T., 2008], [Петровский А.Б., 2004], and also other authors. In the presented paper intellectual data analysis is applied to the resource. In term resource we will understand information as well as telecommunication component. One of the most important problem while creating distributed information systems for organization control is information interaction with far apart departments and sub-administration authorities. In accordance with the specifics of the application problems of the organization control operative data exchange between the distributed network nodes is required and stable interactive mode execution for control activity support is demanded. In the organization control components of the information flows are documents that can be estimated using a row of criteria in accordance of a chosen scale. As criteria we will consider the following: date of the creation of the document/date of the document changing, number of readings (editings), number of document authors, document size etc. so it is possible to organize combined resources using a row of criteria in accordance of one or another scale. The existence of a systematic structure capable of analyzing data using multicriteria will allow more effective execution of the procedure of data searching and analyzing and also to significantly reduce the time needed for data processing.

Quantified estimation of the network traffic

For characteristics determination is proposed to use real data which are collected in subsystems for monitoring implemented in the life-supporting complex of application systems for organization control. The size of the data required depends on the object type and the request conditions which means that data size will be calculated individually for every single request. The size of the information exchange will depend on the stage of document processing (data about workers, execution, control, additional images etc.). The data size concerning the results of request searches and communiqués is determined by the quantity of the chosen records and the set of the returned fields according to the criteria chosen. The data size, when a request is directed to an element of a reference book, depends on the request context (the set of meanings available for the user to choose, set of fields dependent on the object from which the reference book is called out etc.) Generally object data are stored in different fields of several tables. Let object data are stored in M-tables. In every j-th table object data are distributed in Kj-attributes. Then object data size (Qj) situated in j-th table and object data size d can be determined using the equations in [Волчков Д.В. и др., 2012]. The so obtained size of the requested data is recorded in monitoring Data Base at the moment when the object is called out.

The rate of channel utilization is determined by the part of the general time during which data transfer is provided through the channel. To determine if the channel's data transfer ability for traffic transmission using the current level of documentation load we have as a first step to calculate the channel loading rate in the time interval (t_0; T), when the number of call outs is maximum. Source data are information about access time to objects of Information system and the size of requested data. This information is available from the monitoring Data Base.

Let for the observation time interval (t_0; T) are fixed call outs to N-objects of Information system.

From the monitoring Data Base are known access time to objects $t_1, t_2, \dots, t_N$ and size of the transmitted data $d_1, d_2, \dots, d_N$. In order to simplify the calculations we will accept that object data will be chosen from queue with length w and transmitted bit by bit. Current loading rate can be determined using the equations in [Волчков Д.В. и др., 2012]. If we accept the required loading rate ρ, using the dichotomy method we can calculate the magnitude of the recommended throughout ability of the channel utilizing data about documentation loading

Based on the so described approach a program packet for calculation of the recommended network characteristics is developed.

Conclusion

As a result of this work a model for calculation of loading on different segments of the network in the distributed systems for organization control is designed. The new element of the proposed approach is that in its foundation lays analysis of monitoring data about the current documentation loading which are collected in a constantly working system. This allows more effective execution of data searching and analysis procedure and also significant reduction of the time for data processing. Based on this approach a prototype of a program packet is designed which collects data about documentation loading, analyses the current loading rate of the network segments and calculates the throughout ability of the channel required for stable functioning of the information system of the organization.

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AN INTEGRATED FRAMEWORK OF DESIGNING A DECISION SUPPORT SYSTEM FOR ENGINEERING PREDICTIVE MAINTENANCE

Daniela Borissova, Ivan Mustakerov

Abstract: *The paper describes a framework of decision support system for engineering predictive maintenance for civil engineering. The proposed framework integrates traditional decision support system with the advances of expert system. While the traditional decision support system constitutes data management, decision methodology and user interface the advances of expert system embrace symbolic reasoning and explanation capabilities. That assists decision maker in making strategic decisions by presenting information and interpretations for various alternatives. The essence of the proposed integrate framework of decision support system is the ability to incorporate actual information from structure health monitoring and structure health modeling modules with knowledge management module in a structure of health management module. The data flow diagrams are used to define how data is processed and stored. They also show the points of data entry and exit and are important tool assisting in building a logical model of the designed system. All of these contributed the predictive maintenance enhancement by using of advantages decision support system together with the capabilities of expert system.*

Keywords: *decision support system, knowledge management, expert system, predictive maintenance.*

ACM Classification Keywords: *H.4.2 [Information systems applications]: Types of systems – Decision support; I.2.5 [Artificial intelligence]: Programming Languages and Software – Expert system tools and techniques.*

Introduction

Nowadays, production assets are under constant pressure for reducing operating costs, enhancing reliability of the equipments, and improving the quality of the product. Intelligent fault diagnosis and failure prognosis is a cutting-edge direction involving interdisciplinary methods. It requires understanding of the physics of failure mechanisms for condition-based maintenance in materials and structures and also presents strategies to detect faults or incipient failures. The goal is to provide a framework of decision support systems (DSS) for engineering predictive maintenance helping to take intelligent decisions. Predictive maintenance is the combining of various measurements or data-sources to establish patterns that allow the state of an engineering system to be predicted. The purpose of predictive maintenance is to establish criteria upon which planned maintenance can be carried out before a failure or unexpected stoppage. Predictive maintenance strategies are very efficient in mechanical-failure modes, when failure probability increases with time, and one or more condition-monitoring techniques can predict the failure before breakage [Gilabert & Arnaiz, 2006]. Actuators and sensors placement require specific knowledge to perform the constraints as it is demonstrated [Flynn & Todd, 2010]. The problem of optimal sensor placement considers not only to find the best sensors location for a given task but also to estimate the required number of sensors for the best sensor performance [Borissova, et al., 2012]. Optimal location defining and optimal numbers of sensors determining are two separate problems. The knowledge and experience of engineers are combined with signal processing for the proper solving of optimal sensors locations problem. Designers and end-users of structures know where are the critical machinery areas which need to be analyzed, controlled or monitored. Then an intelligent signal processing could help for the best sensor locations.

The problem of optimal number of sensors relies very much on advanced signal processing techniques [Staszewski & Worden, 2001]. From the signal processing point of view, optimal sensor location is optimization and/or selection problem.

Condition-based maintenance is a decision-making strategy to enable real-time diagnosis of impending failures and prognosis of future equipment health, where the decision to perform maintenance is reached by observing the "condition" of the system and its components [Peng et al., 2010]. Condition-based maintenance method is used to reduce the uncertainty of maintenance activities, and is carried out according to the need indicated by the equipment condition. The existence of indicative prognostic parameters can be detected and used to quantify possible failure of equipment before it actually occurs. In maintenance, common problems of equipment are aging and deterioration. The trend of the deterioration of critical components can also be identified through a trend analysis of the equipment condition data. Maintenance decisions depend very much on actual measured abnormalities and incipient faults, and the prediction of the trend of equipment deterioration [Yam et al., 2001]. The condition-based maintenance is conceived to detect the onset of a failure, avoiding critical damages of high cost components before they might happen, thus reducing overall maintenance costs. Possible faults are detected by monitoring representative parameters by signal analysis techniques and comparing signals during normal and abnormal conditions [Velarde-Suarez et al., 2006; Charbonnier et al., 2005]. Also, the methods of case-based reasoning can be applied in units of analysis of the problem situation, search for solutions, learning, adaptation and modification, modeling and forecasting [Eremeev & Varshavskiy, 2008].

The main idea of predictive engineering maintenance is to monitor the health of critical machine components during operation and support the maintenance decisions based on the conditions estimation. The aim of current paper is to provide an integrate framework for development of a new generation of decision support systems by providing tools and methods for a better integration of knowledge management in an evolving environment. The main interest lies not only in improved data analysis, but also in better formalization and use of diagnosis for the goal of engineering predictive maintenance.

Problem Description

The most effective predictive maintenance programs trend to looking for signs of early failure, allowing the equipment to be repaired at minimal cost and down time. In order to best utilize trend analysis, data must be available on a regular basis. Obviously, the more frequently the sampling is performed the more accurate the analysis becomes. Diagnostic reports from the DSS on the condition of the machinery assist maintenance personnel in making critical decisions regarding equipment health conditions. DSS as computer-based information system supports business or organizational decision-making activities. DSS aid in problem solving by allowing for manipulation of data and models whereas expert systems allow experts to "teach" computers about their field so that the system may support more of the decision making process for less expert decision makers. From maintenance point of view, a properly designed DSS should integrate not only decision making process where human user is required to weigh all the factors in making a decision but also the capabilities of expert system which acquire knowledge from an expert and apply a large but standard set of probability based rules to make a decision in a specific problem setting. Such predictive maintenance software-based system will help decision makers compile useful information from monitoring, documents, personal knowledge, and models to identify and solve problems and to make the most appropriate decision.

Because decision-making is based on many different considerations, decision support systems belong to a multidisciplinary environment, including among others database research, artificial intelligence, human-computer interaction, simulation methods, and software engineering. Combining the capabilities of DSS (contain equations that the system uses to solve problems or update reports immediately, and the users makes the final decisions on the basis of the information) with advantages of expert system (works from a much larger set of modeling rules, uses concepts from artificial intelligence to process and store the knowledge base and scans base to suggest a final decision through inference) an integrated framework of DSS for metallurgical engineering predictive maintenance is proposed.

General Context of the DSS Conception

Decision support systems represent a class of computer based information systems, including the knowledge based systems that support decision making in respect of various activities. Properly designed DSS are interactive software system designed to facilitate the decision maker to use information from data, documents, personal knowledge and/or models to identify and solve problems and make decisions. A DSS is a way to model data and make quality decisions based on it. DSS support decision maker, when scrolling through large amounts of data and the choice between different alternatives. Systems for decision support have a certain structure, but in fact the data and decisions based on them are constantly changing. The key to decision support systems is data collection; analysis and structuring of data collected and determines the best decision or strategy as a result of this analysis. Usually it does not matter whether computers, databases or people are involved, this is a process of collecting raw or unstructured data, which are used to decision making.

Types of Decision Support Systems

Concerning the relationship between users and applications, DSS can be divided into three categories – passive DSS, active DSS and proactive DSS as shown on Fig. 1 [Kwon et al., 2005].

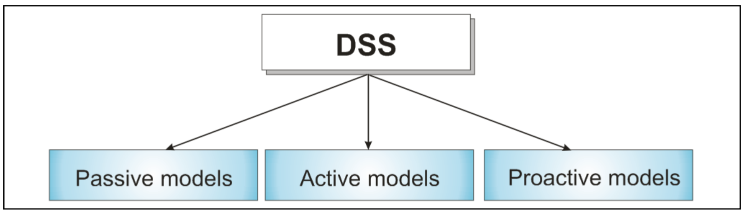

Figure 1. DSS models based on the relationship with decision maker and his preferences

The passive models of DSS only collect data and organize it effectively and do not provide specific solutions, i.e. they only show the collected data. Active decision support systems process data and clearly show solutions based on that data. Although there are many systems that are able to be active, in many organizations will be difficult to believe in a computer model without human intervention. The third category is proactive DSS, which known as ubiquitous computing technology-based DSS which contains decision making and context aware functionalities. They combine the human element and computer components to work together to get the best possible solution.

While the above DSS models take into account the interaction with the user, another popular DSS model consider the way of support (Fig. 2) [Kwon et al., 2005].

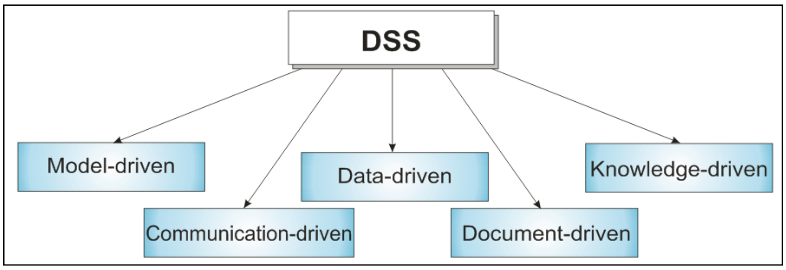

Figure 2. DSS models, based on the way of support

Model-driven DSS is complex systems that help decision maker to analyze or choose between different options. They use algebraic, decision analytic, simulation, and optimization models to provide decision support. Communication-driven DSS enhances decision-making by network and Internet technologies to provide environment for group decision making. Data-driven DSS emphasize on data collection and their manipulation for particular decision maker needs satisfying. They include a database designed to store data in such a way as to allow for its querying and analysis by users. Document-driven DSS uses a variety of documents such as electronics spreadsheet documents and database record for information processing and strategies defining. Knowledge-driven DSS use specific rules coded in computerized expert systems to support the decision maker.

Decision Making Process

According to Baker et al. [Baker et al., 2001], decision making should start with the identification of the decision maker(s) and stakeholder(s) in the decision, reducing the possible disagreement about problem definition, requirements, goals and criteria. Then, a general decision making process can be divided into the following steps:

- Problem definition – the main reasons identification as limiting assumptions, system and all stakeholders. The aim is to convey the essence in a clear sentence that describes both the initial conditions and desired conditions. The formulation of the problem, however, must be short and clearly expressed in writing and agreed by all decision makers;
- Requirements determination – description the requirements that the solution to the problem must meet. In mathematical form, these requirements are constraints describing the set of possible (admissible) solutions. Even if there are subjective evaluations on the next steps it is required specifications in precise quantitative form;
- Definition of objectives – general statements of intent and desired values, i.e. establish the goals that solving the problem should accomplish. In mathematical form, they are functions, as opposed to requirements that are constraints. The objectives can be conflicting, but it is natural to solve practical problems;
- Identification of alternatives – different approaches to change the initial state to desired state of the process. If the number of possible alternatives is finite, they can be checked one by one, if eligible. If the number of possible alternatives is infinite, the set of alternatives is seen as a set of solutions satisfying the requirements expressed mathematically as restrictions;
- Determination of criteria – needed to define the measures of objectives to estimate how each alternative achieves the objectives. The criteria are usually based on objectives but sometimes it is possible to have more than one criterion for some objective;

- Select a tool for decision making – different tools that can support the decision maker. Choosing the appropriate instrument depends on the specifics of the problem and the objectives of the decision maker;
- Assessment of alternatives against the criteria – alternative evaluation by appraising it against the criteria;
- Solution verification – the proposed solutions are compared against the goals and corrective actions are taken if needed.

Identifying and choosing alternatives based on the values and preferences of the decision maker are realize as a result of decision making process. These basics steps will be incorporate in the proposed integrated framework of DSS for engineering predictive maintenance.

Conceptual Model for Decision Support System

In the context of decision support systems, DSS are often an agglomeration of different techniques and methods that aim at fulfilling a function to support the decision maker. DSS structure consists in many modules and sub-modules depending on the flow of collecting and processing data. Different authors identify different components of DSS. Three fundamental components of DSS as database management system, model-base management system and dialog generation and management system are identified in [Sprague & Carlson, 1982]. According to [Power, 2002], DSS is described by four major components: user interface, database, model and analytical tools, and DSS architecture and network. Another generalized architecture [Marakas, 1999] with five distinct parts: data management system, model management system, knowledge engine, user interface, and user(s) is proposed. Taking into account the above considerations a conceptual architecture of typical DSS is shown on Fig. 3.

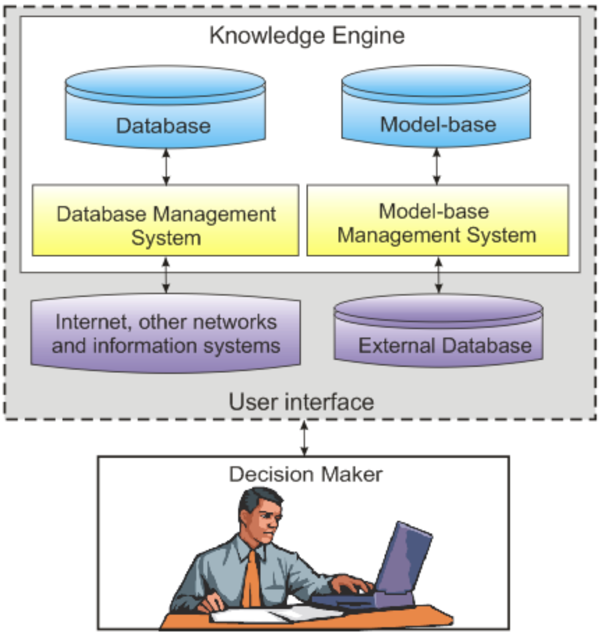

Figure 3. Architecture of conceptual DSS model

The DSS dialogue requires tradeoffs between simplicity and flexibility. Therefore, the user interface of DSS should facilitate decision makers to have easy access, manipulation and usage of common decision domain terms with all aspects of communication between the user and the DSS. Decision maker accesses database and model-base through database management system and model-base management system. They enable the user to build a system to assist in making a particular type of decision. External database access allows the DSS to examine the existing outside information, while connections to other network and information systems provide access to information external to the organization like World Wide Web.

Different decision strategy could be used to transform initial information to a decision maker point of view. In decision-making process there are various kinds of uncertainty, depending on the reasons for its occurrence. Among the many sources of uncertainty the mainly distinguished incompleteness is the lack of information, fortuitousness, which cannot be predicted. In such problems, optimal strategies approaches for decision making under uncertainty conditions could be more appropriate [Borissova et al., 2011]. Although there is no widely accepted definition of DSS, these systems can integrate a number of decision support technologies (tools), including optimization and simulation models, information systems, data-mining tools, expert or knowledge-based systems, statistical and graphing tools, etc. Nevertheless, there are three fundamental components of DSS architecture that always exist – the database, the model-base (the decision context and user criteria) and the user interface.

An Integrated Framework of Decision Support System for Engineering Predictive Maintenance

The design of a DSS for engineering predictive maintenance starts with choosing of the objectives. The end-user input will help determine the exact objectives, outputs and any additional requirements. The specifics of the predictive maintenance require usage of some monitoring system for engineering critical structural sections. This ensures that appropriate sensors for the requirements of monitoring will be selected and optimally located in such a way that sufficient information can be gathered. Typical predictive maintenance includes methods for data acquiring and information fusion combined with signal processing. In the current paper knowledge management subsystem is proposed as a module in the DSS. It stores and manages knowledge from prior data, human expertise, examples (cases) for the goal of machine learning and case-based reasoning. That module benefits from learned experience and will contribute to intelligent behavior and improved performance based on artificial intelligence. The included inference engine will support the intelligent decisions making about the structure health. The advantages of DSS could be combined with capabilities of expert system into an integrated framework of DSS for civil engineering predictive maintenance. A general framework of such DSS could be compound of four main modules for: structure properties defining and sensors placement, structure health monitoring, structure health modeling and structure health management as it is shown on Fig. 4.

The structure properties defining and sensors placement module provides tools for choice of proper sensors type, number and locations. The proper sensor type is based on structure properties and includes measurement range (sensitivity), frequency range, broadband resolution (noise), temperature range, sensitivity tolerance and size. The knowledge of a structure, past experience or analytical tools as finite element analysis can be used to define the sensors locations. In addition, different fitness function can be used to formulate optimization task, which solution will define optimal sensors locations.

The structure health monitoring module derives directly from routinely collected condition monitoring signals from the sensors and from historical records to produce prediction outputs directly in terms of condition monitoring data. The signal processing of sensor data is one of the most important functions of structural health monitoring systems for goal of predictive maintenance. The results from signal processing are collected in an actual sensor database for additional processing and feature extraction and selection, pattern recognition and information fusion. The external data sources as Internet, other networks and information systems are also used. The collected data are assessable through database management system as aid in the decision making process.

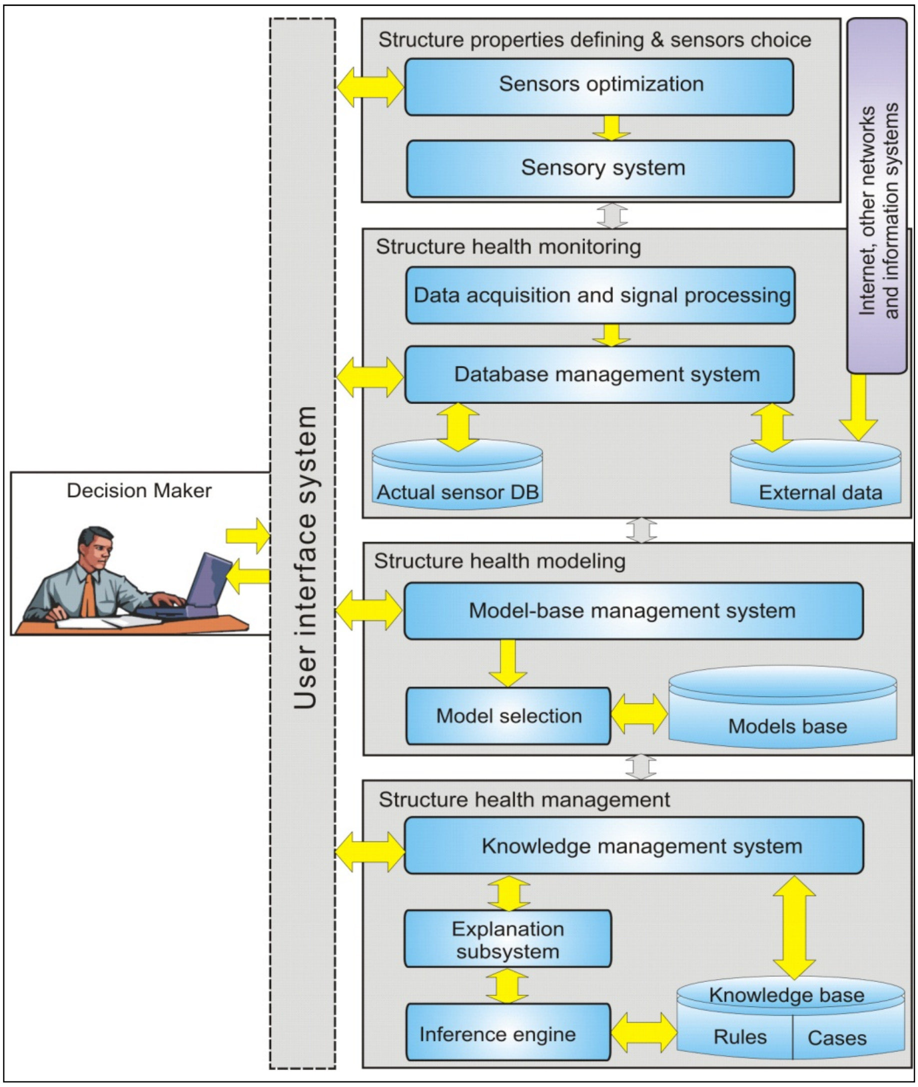

Figure 4. An intergated framework of DSS for engineering predictive maintenance

Other characteristic of proposed DSS is the modeling capability represented by structure health modeling module. Some of models can estimate the time to failure of a machine as well as forecasting the fault condition. The way in which a prognostic model is developed differs therefore from the method for building an explanatory model. The prognostic model is focus on the search for a combination of factors which are as strongly as possible related to the outcome. Accurate prognostic models are based on algorithms that are capable of predicting future component failure rates or performance degradation rates. Development of strategies for assessment prognostic modeling of machinery working life involves various methods including structural system reliability, probabilistic-based life cycle assessment and maintenance, optimization of multiple criteria under uncertainty and integration of monitoring in life cycle management. Combining the advantages of these methods could aid the decision-maker in decision making process for engineering systems diagnostics under uncertainty or incomplete information conditions. A well-designed combination model could combine two or more theories and algorithms to model the system in order to eliminate the disadvantages of each individual theory and utilize the advantages of all combined methods. It should be pointed out, that it is a challenging work to choose appropriate methods and combine them together for modeling.

The engineering predictive maintenance is a specific subject area which is characterized by availability of past information about the possible problems, their diagnosis, assessment of situations and effective solutions. That information can be incorporated in an expert system module used for structure health management to recommend courses of action and decisions. The structure health management module is composed of knowledge management system, knowledge base, inference engine and explanation subsystem. The knowledge management system is responsible for knowledge extraction and storing in a knowledge base in the form of rules. It also interacts with decision maker to show him the results of incorporated inference engine and how these results are obtained through the explanation subsystem. Knowledge extraction conducted primarily during interviews with experts, field visits, service order, manuals, technical documentation and actual operations. During the interview process, conversations were recorded in detail and then transformed into acceptable format for diagnosing rules. Usually, rules are expressed in the form: *IF* condition, *THEN* consequence. The outcomes can be used also to test other conditions/rules, or even add a new fact to the knowledge base. These rules can be specific domain rules or heuristic rules and can be chained together using logical operators. The knowledge consists of concepts, objects, relationships and inference rules.The set of rules constitute the knowledge base. Another part of the knowledge base stores a set of problems and answers needed for case base reasoning. Condition base reasoning solves new problems by retrieving relevant prior cases and adapting them to fit new situations. Condition base reasoning is responsible to find the case that is most closely related to the new problem and present a case's solution as an output, with suitable modifications. Condition base reasoning can be effective even if the knowledge base or domain theory is incomplete. Certain techniques of automated learning, such as explanation-based learning, work well when only a strong domain theory exists, whereas condition base reasoning can use many examples to overcome the gaps in a weak domain theory while still taking advantage of the domain theory. These characteristics of condition base reasoning make it appropriate for diagnosis, prognosis, and predictive maintenance. The inference engine applies the knowledge base to the particular fact of the case under consideration to derive conclusions that can be used by the decision maker. An important feature is the possibility to justify the conclusions by the explanation subsystem. It should answer the questions of type “how the conclusion is reached” or “why the conclusion is reached” or “trace the conclusion” and could be a great help for decision maker to take the solutions about the predictive maintenance activities. The expert system included in the DSS compensates for the user's limitations about some expertise areas. It makes use of all available expert resources to present the most complete picture of the problem possible.

The advantage of proposed integrated framework of DSS contribute to enhance the predictive maintenance taking into account decision maker preference together with the capabilities of expert system by means of collected knowledge to make a decision in a specific problem setting. Therefore, the maintenance decisions rely on not only of decision maker but also on the knowledge of actual sensor data base, model base and rule base knowledge.

Data Flows in the Proposed DSS Framework

An essential step in DSS design process is to describe how the system transforms data. For that goal, the data flow diagrams are used to define how data is processed and stored. They also show the points of data entry and exit and are important tool assisting in building a logical model of the designed system. A generalized data flow diagram of the proposed DSS is shown on Fig. 5.

To describe the logic and the actions on the data through data flow diagram the following basic steps could be distinguished:

- Identifying the main processes and the external data sources and their inputs and outputs;
- Identifying the data flows from the external entities;
- Identifying the processes to perform to generate the input and output data flows;

- Identifying the data stores;
- Connecting the processes and data stores with properly directed data flow;
- Naming each data flow, data store and process.

The interaction between decision maker and DSS start with definition of the structure properties and parameters to be monitored. Type and sensor's locations are defined on the basis of some theoretical investigations as finite element analysis for example, or on the basis of past experience or from external data queries. The theoretical investigations on sensors locations usually lead to large number of sensors. The next step is to minimize sensor's number by optimizing their layout design in term of structural health monitoring. This is realized by optimization tasks solving which are implemented in the first DSS module. The decision maker is responsible to choose optimization criterion and/or acceptable range of data loss from the sensors. The data from the installed sensors is collected and processed. Signal processing of sensors data supplies the actual monitoring data that is stored in actual database and used for structural health monitoring. Statistical process control is another tool aimed at continuously monitoring the common cause system and detecting significant deviations, possibly pointing to special assignable causes.

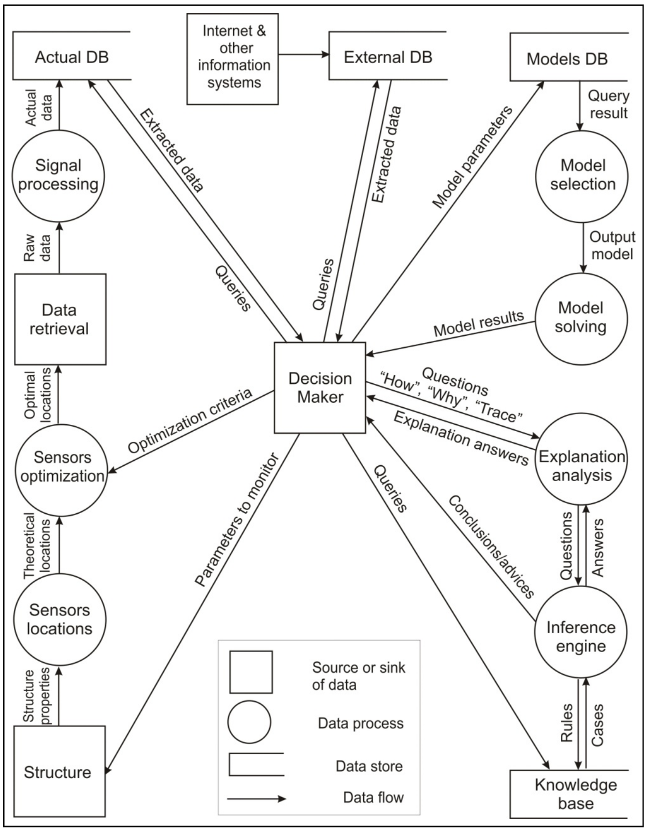

Figure 5. Generalized data flow diagram of the proposed DSS for engineering predictive maintenance

The external data sources as Internet, other networks and information systems are assessable through database external database. This component allows the DSS to examine and use outside experience. Model base is a set of computer decision models similar to database, the only difference is that its stored objects are models. The models in the model base can be strategic, tactical, operational and analytical, etc. The data and parameters provided by decision maker are used to select a model, which is suitable for analyzing a situation. The selected model represents knowledge about a system by means of algebraic, logical, or statistical variables that interact by mathematical functions or logical rules. The mathematical methods analyze and solve the selected model to support decision making. Decision making under uncertainty enhances the above methods with statistical approaches, such as reliability analysis, simulation.

The knowledge in structure health management module is based on "expertise" about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems. It can suggest or recommend actions to decision maker that will improve fault detection and recovery. A knowledge base consists of descriptions of the elements in the process along with their characteristics, functions, and relationships expressed as a collection of organized facts, rules, and procedures. When certain events occur the decision maker makes queries to knowledge base and inference engine advices what actions to implement. Decision maker can also judge the reasoning behind a conclusion by another query to explanation subsystem.

Summary and Conclusion

In the current paper a framework of decision support system for engineering predictive maintenance is proposed. It integrates traditional decision support system with the advances of expert system. While the traditional decision support system constitutes data management, decision methodology and user interface the advances of expert system embrace symbolic reasoning and explanation capabilities. That assists decision maker in making strategic decisions by presenting information and interpretations for various alternatives. The essence of the proposed decision support system framework is the ability to integrate actual information from structure health monitoring and structure health modeling modules with knowledge management in structure health management module. Therefore, knowledge and decision maker are key factors in maintenance. The maintenance decisions rely on not only of decision maker preferences but also on the knowledge of actual sensor data base, model base and rule base knowledge. So, to enhance the predictive maintenance a decision maker is required to exploit the capabilities of expert system in a defining a maintenance decision.

The proposed framework is tested on a case study at metallurgical company. The sensors optimization module has been developed and numerically tested by using actual data of a sample structure. A number of mixed integer linear programming tasks are formulated and solved with different criteria and restrictions for sensors accuracy deviation. Model database is in the process of completing for high temperature metallurgical objects (fluidized beds, anode refining, etc.). In parallel, expert's knowledge is in process acquisition for the goal of knowledge base creation.

The benefits of the proposed framework of decision support system for engineering predictive maintenance is in efficiency savings, only carrying out maintenance when necessary but in-time to prevent failures. This can often lead to substantial increases in productivity and decreasing of the maintenance costs.

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Major Fields of Scientific Research: Decision support systems, Software systems for information processing, Modeling and optimization for renewable energy sources and for night vision devices, Web-based applications and Web design.

MULTI-OBJECTIVE DECISION MAKING UNDER CONDITIONS OF UNCERTAINTY AND RISK OF KNOWLEDGE QUANTUM ENGINEERING MEANS

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***Abstract**: Methodology of a complex solution for a problem of decision making under conditions of multi-objective optimization, uncertainties and risk based on the use of mathematical models and knowledge quantum engineering (EKQ) methods is developed.*

***Key words:** multi-objective optimization, utility function, interval scholastic uncertainty, decision making, knowledge quantum engineering.*

Introduction & Setting up the problem

The *decision-making* is an obligatory and an integral problematic stage in the human activity. Independent of the universe of discourse (enterprise, knowledge domain) the general problem of decision-making reduces to solution of the main four problems: 1) *the objective setting up* and *analysis;* 2) *the feasible solutions set generation;* 3) *choice and substantiation of the feasible solutions estimation system (estimation problem);* 4) *definition of the best solution (optimization problem).* The subject making decision (SMD) is always interested in making effective decisions, as ineffective decisions in the vital and productive situations result in considerable losses in possibilities and resources. It is a common knowledge that necessary requirements on *effectiveness* of decisions are their *completeness, timeliness and optimality,* which are conceptually conflicting. The quest for meeting the indicated requirements results in serious methodological and computational difficulties. In particular, the provision of the decision *complexity (completeness)* results in the need for more complete accounting of the internal and external factors, this increases the decision making problem dimensionality and involves its *multi-objectiveness* acknowledgement. In this case the *indeterminacy* rises caused by incompleteness of the knowledge of reciprocal action of factors, inaccuracy of their measurement, random external and internal actions. Attempts to eliminate the initial *indeterminacy* by means of research require a high qualification of a SMD, considerable time and, as a result, involve the decision making *inopportuneness.*

Today the traditional approach does not meet requirements of practice both as to *precision,* and as to *effectiveness* by virtue of the unjustified problem decomposition into two conventionally independent problems. The first problem is the determinate problem of multi-objective optimization is solved without regard for *indeterminacy*, the second problem is the problem of decision making under conditions of *indeterminacy* without regard for *multi-objectiveness.* This is stipulated according to Adamar by the crucial *incorrectness* of the multi-objective optimization problem by virtue of its solution *non-uniqueness.* It is possible to solve the problem correct only to the *compromise* solutions domain or through *regularization* [1, 2]. On the one hand the *regularization* of the problem for defining the *unique* solution through calculation of the generalized *multi factorial* scalar estimate of efficiency is based on the subjective expert estimates, their determination results in considerable errors. On the other hand the models and methods for decision making under conditions of *indeterminacy* of the scalar estimate proved to be inadequate without regard for its *multi-objectiveness.* Consequently, the quest for rising *efficiency* of the decisions being made calls for development of the methodology of the *complex* solution of the decision making problem with continuous regard for *multi-objectiveness* and *indeterminacy* of the initial data.

The state of the problem. The survey and analysis of publications [1-20] point to the urgency of the problem of development of the *formal* models and methods for decision making under conditions of *multi-objectiveness, indeterminacy* and *risk.* The prospects for formalization of the *complex* procedures of decision making with *simultaneous regard for* the indicated conditions are opened when using the *utility theory* [7, 8], *interval analysis* [2, 17] and *fuzzy sets theory* [13, 14, 20]. But the obtained results are still far from exhausting the problem at present. From [2] it is known that *the admissible* set of decisions $Z = Z^S \cup Z^C$ contains in the general case the subsets of *consistent* Z^S and *inconsistent* (*compromise*) Z^C decisions. Not a single local (partial) criterion of efficiency $k_j(z) \in \langle k_j(z) \rangle \subseteq Z^C$ from the *compromises* domain Z^C can be improved without deterioration of the quality if only one local criterion of the specified criteria finite sequence $\langle k_j(z) \rangle$, $j = \overline{1,n}$. According to the definition the sought *optimal* decision $z^* \in Z^C$. That is why the *multi-objective decision making problem* **(MDMP)** can be *formally* presented by the relation

$$z^* = \arg \underset{z \in Z^c}{extr}\, \Theta [\, \langle k_j(z) \rangle],\ \forall j = \overline{1,n}, \tag{1}$$

where Θ is some ***regularizing*** procedure making it possible to choose the ***unique*** decision from the domain of *compromises* Z^C according to a definite *optimality principle.*

Formal approaches to the *regularization* based on some compromise schemes (sub optimization, lexicographic optimization etc.) are known [1, 2]. *Heuristic* principles of the ***regularization*** are often used when the choice of decision in the **MDMP** (1) is realized by a *decision maker* **(DM)** using own experience as a basis [2, 3]. Each of the offered ***optimality principles*** has its own domain of correct practical application and significant shortages [1-3].

The ***principle of optimality*** involving formation of the ***generalized scalar criterion*** on the set of the individual criteria $\{k_i(z)\}$, $i = \overline{1,n}$. It is termed the ***utility function*** $\Pi(z)$ [7 - 9]:

$$\Pi(z) = Q\,[\lambda_i, k_i(z)];\ i = \overline{1,n}, \tag{2}$$

where λ_i are the *isomorphism* coefficients bringing the dissimilar individual criteria $k_i(z)$ to the isomorph form; *Q* is the operator realizing the procedure of the *utility function* $\Pi(z)$ calculation for all $z \in Z^C$. The *utility theory* [8], which assumes existence of the *quantitative* estimate of decisions *preference* « $\succ$ », serves the theoretical basis for the *multi-objective scalar estimates* formation (2).This means that if the solutions

$$z_1, z_2 \in Z^C \text{ и } z_1 \succ z_2 \text{, то } \Pi(z_1) > \Pi(z_2) \tag{3}$$

Consequently, the solutions ***"utility"*** is the *quantitative* measure of their *"effectiveness",* and **MDMP** (1) consists in choosing the *best* decision z^* **:**

$$z^* = \arg \max_{z \in Z^C} \Pi(z). \tag{4}$$

According to (4) *justification for the method* is required for formation of the ***utility function*** as a *metric* in the space of the individual criteria $k_i(z)$. It is characteristic that no ***objective*** metrics exists, and the principle of decisions *ranking* represents ***subjective*** preferences of a **DM.**

Hence, the *utility theory* and the selection of the concrete ***utility function*** in the form of the operator *Q* in (2) bear the *axiomatic nature,* where the *axiomatics* represents *preferences of the concrete* **SDM** or **DM.** That is why the main *hypothesis* for existence of the ***"rational"*** *behavior,* which admits ***reproducibility*** and ***similarity*** of different **DM's** decisions under *identical conditions,* lies at the basis for *the utility theory*. In the frameworks of this *hypothesis* the decisions ranging process formalization helps a **DM** to identify his preferences and estimate *quantitatively* all decisions $z \in Z^C$ through *metrics*. Hereinafter the *estimation procedure* can be realized precisely on this basis using a computer without the **DM** participation. By this means the possibility is achieved to create the *decision making support system* (**DMSS**) of different purpose [1; 2; 10-12; 14 - 16; 18 - 22]. The analysis of these publications attests that the *effective formalization* of finding ***the best,*** in a certain sense, ***multi-objective*** decision is possible only for the *well-structured* problems [1, 2]. Analysis of these publications testify to the fact that *effective formalization* of finding **the best** from the certain viewpoint *multi-objective* decision is possible only for well-structured problems [1, 2]. But in actual practice, *weakly structured* problems are more abundant, the formalized methods are not developed completely for their decision. Thus, the modern tendency of the **DMSS** creation is based on a compromise between a human ability to decide complicated problems and possibilities of formal methods and computer simulation of the *intelligent* activity. Neural networks [14], knowledge engineering expert systems [15] and other systems of the artificial intelligence [10 – 16; 18 - 21] belong to such systems. *Formalization* of the human ***intelligent*** activity in the decision making processes is the general requirement for all these systems. Investigations into this direction are always urgent both for the scientific and practical purposes of automation of the ***imaginative*** work of people.

The objective of this work consists in development of the methodology for solving the problem of the ***knowledge-oriented*** decision-making taking into *complex* account of *multi-objectiveness, uncertainty* and *risk* based on creation of *intelligent* information technologies using the knowledge bit engineering (**KBE)** [10 – 12; 22].

Methodology of decision-making using KBE means. The object in view is reached by solving **MDMP** (1) through the application of the *utility function* of the kind (2) with the operator Q, realized using the **KBE.** Let us use the *systems* approach to the problem of the purposeful decision making based on *knowledge*, the essence of this approach will be set forth in the theoretical-multiple representation. Let us term the set *E* of homogeneous or heterogeneous elements, on which the set of cause-and-effect relations *R* ordering the elements $e \in E$ into the *structure* *C* is specified, as the *purposeful decision making system S* ,:

$$C = \{ E \times R \} \tag{5}$$

To attain the specified ***aim*** the system *S* should offer a set of properties $X = \{x_1, x_2, ..., x_n\}$. Let us map the ***aim*** onto the set ***X*** and single out some subset $G \subset X$ of the system properties, which make it possible to attain the aim through selection and synthesis of its *structure C* (5) with the required properties *G.* Then the *purposeful decision making system S* is defined by the ordered set in the form of the Cartesian product:

$$S = \{\{E \times R\} \times G\} \tag{6}$$

It is evident that the *domain of* $Z(S)$ *existence* of the system *S* with the properties *G* is defined by the set of *structures* *C* (5) which can be find *inductively* under conditions of *uncertainty* and *risk* through the system learning using knowledge-precedents. From *economical, ecological, social and technical considerations* limitations are imposed on the domain $Z(S)$ in the form of prohibitions on the use of some elements $e \in E$ and relations $r \in R$. As a result a set of *acceptable* structures, i.e. *acceptable* decisions of $Z^C \subset Z(S)$, is singled out.

Then the *decision* of **MDMP** of (1) type using **EQK** means is realizable in **4** *stages.* **1**) Definition of the ***aim*** with singling out the properties *X* of the system *S* to attain it. **2**) Inductive synthesis in learning precedents of the acceptable set of structures *C* (5) as ***knowledge bases*** providing the mechanism of decisions logical deduction. **3**) Determination of metric for comparison of the admissible decisions (the *estimation* problem). **4**) Selection of the ***best*** decision version of $z^* \in Z \subset Z(S)$ (*optimization* problem).

Singularity** of* **KBE** *methodology for* **MDMP** (1) decision consists in the synthesis of *S* (6) system by means of the δ **- knowledge quantum base** (**B** δ **KQ**) as a system of the *implicative* and *functional* regularities in the space of X^n *properties* [22], ***inductively created at *learning* from the precedents. **B** δ **KQ** has a network structure C (5) of the cause-effect relations between the ***initial*** δ quanta (*message* events), ***intermediate*** and ***output*** δ - quanta (i.e. *goal consequences*- decisions) with the δ - quanta based built-in mechanisms of the ***deductive*** output of the decisions being made. The parameter $\delta \in \{t, \pi, v, \varphi, ...\}$ characterizes the concrete conditions of δ *-uncertainty* and corresponding ***type*** of the used δ -quanta of *knowledge*: ***faithful*** (δ = ***t*,** **tk**-*knowledge*), ***approximate*** (δ = π **,** π **k**-*knowledge*), ***probabilistic*** (δ =**v,** **vk**-*knowledge*), ***fuzzy*** (δ = φ , φ ***k****-knowledge*). For example, **vk**-*knowledge* is used under conditions of **v**-*uncertainty* and ***risk*** as the selection of the alternative decisions is realized on the basis of estimates of the ***probability*** of these or those selection ***consequences*** occurrence**.** It is precisely this **v**-quantum of knowledge contains in its procedure component the built-in algorithms for calculating the *quantum events,* taking into account their cause-effect relations logics. φ ***k-****knowledge* with the built-in algorithms of *fuzzy sets phasefication* and *dephasefication* according to the specified *membership* functions are used by analogy with **vk**-*knowledge* under conditions of φ *-uncertainty* (with ***fuzzy*** data).

Precedents for (**B** δ **KQ**) ***learning*** are described by the *tables of empirical data* **(TED)** and *scenario examples of learning knowledge* **(SELK)** with indication of the names of e_i *–premise,* c_j – intermediate, C_k **–** *purposeful* δ - ***quantum events*** with logical connectives "AND", "OR", "NOT" between events. The process of ***learning*** initially consists in the algorithmic transformation of **TED** and **SELK** ***into the logical net of possible reasoning*** (**LNPR**). Then LNPR is transformed into δ - quantum net for decision output (δ QNDO) through automatic quantification. At the output of δ QNDO there are s δ -quantum vertexes {Ck}={zk}= $\hat{z}$, (k=1, 2,…,s), which correspond to the unique complex $\hat{z} \in Z^C$ of purposeful decisions-effects in MDMP, which depend on the specified premise ei and intermediate cj δ - выходе δ - quantum vertexes-events. Consequently, in MDMP (1) the process of the output of the multi-objective decisions complex {zk}= $\hat{z}$ is realized automatically through B δ KQ $\equiv$ δ QNDO after sending to the input the premises e.i. (i = 1, 2,…,n) describing the observed situations relative to the system object of decision making (ODM). Intensification of the complex $\hat{z} \in Z^C$ of δ -quantum vertexes Ck, (k=1, 2,…,s) at the output of δ QNDO defines the result of purposeful decisions output for the given system ODM.

Efficiency of the ***knowledge-oriented*** *multi-object decisions in the* **EQK** is estimated by the exterior criterion $K_э$($\hat{z}$), which characterizes ***utility*** from the viewpoint of the *minimal* ***risk*** *of negative consequences* of the whole complex $\hat{z} \in Z^C$ of the made ***purposeful*** decisions, generated by δ **QNDO** for the system **ODM.** Estimation of $K_э$($\hat{z}$) can be defined by the value of the ***probability (risk)*** of ***erroneous*** decision making after testing of the given δ **QNDO** on the ***control situations.*** This makes it possible to rank the *alternative* δ **QNDO** by the quality in the indicated sense from the general region of $Z(S)$ existence. The ***rational*** *complex* of solutions $\hat{z}_{рац} \in Z^C$

generated by δ **QNDO** with the *least* value of the estimate ***K*э**($\hat{\boldsymbol{z}}$) is considered to be ***the best*** ones. The essence of the **MDMP** (1) solution by steps consists in the following.

In the **1st** ***stage*** the ***aim*** of *S* (6) system is defined as some ***desirable*** state of the systems **ODM,** its accomplishment requires purposeful actions. In our case the ***aim*** consists in the ***inductive*** *synthesis with irradiation of* **B** δ **KQ** $\equiv \delta$ **QNDO** which ensures derivation of the *complex* {z_k}**=** $\hat{z} \in Z^C$ of the ***purposeful decisions*** ***C*k** for the whole systems **ODM** . Experts single out the *particular* functional *properties* $X = \{x_1, x_2, ..., x_n\}$, required to attain this aim, which are measured in scales of *different types* and define potential *efficiency* of the system *S*. Hence, the *properties X* are the *local criteria* for estimating *efficiency* of the decisions being made, and the ***problem*** (1) being considered is the ***multi-objective*** one, as the ***aim*** is characterized by a set of *particular* criteria *X.*

In the ***2nd stage*** the experts together with DM substantively form **TED** and **SELK** needed for the synthesis of the *purposeful* **LNPR** in the learning mode. **LNPR** transforms through *automatic* ***quantification*** into δ **QNDO,** the sets of *acceptable* decisions $\hat{z} \in Z^C$ of the **MDMP** (1) problem are defined with its help. It is possible to form several versions of TED and SELK for synthesis and learning of the *totality* of different δ **QNDO** on the *precedents* of different types with the aim of the further *rational* version of δ **QNDO** choice**.**

In the ***3rd*** ***stage*** the problem of ***estimating*** is solved, i.e. some ***measure*** is defined making it possible to compare objectively the efficiency of *complexes* of solutions $\hat{z} \in Z^C$ between themselves and, hence, estimate ***quality of*** δ **QNDO** generating $\hat{\boldsymbol{z}}$ under conditions of *multi-objectiveness,* ***risk*** and δ ***-uncertainty*** ($\delta \in \{t, \pi, \nu, \varphi, ...\}$). Such a ***measure*** should take into account both a *positive* ***effect,*** i.e. the stage of the ***aim*** attainment, and ***expenditures*** for attainment of this effect. The concrete expenditures for creation of the system *S* (6) also requires a synthesis of any version of the structure *C* (5) which is realized by the net δ *-quantum* graph $G_{\delta k} \equiv \delta$ **QNDO.** On the ***output*** $G_{\delta k}$ the *complex* of the required solutions {***C*k**}= $\hat{z} \in Z^C$ is obtained after activation of the *message* δk -knowledge ***e*i** on the graph ***input***. This makes it possible to apply the ***model*** $\Phi(\hat{z})$ of the ***informal*** *multi-objective* estimation of *decisions* ***efficiency,*** available in **KBE,** by the value of the ***probability*** of *unfavorable* ***consequences*** of the *decisions made* with the use of the outer criterion ***K*э**($\hat{\boldsymbol{z}}$):

$$\Phi(\hat{z}) = Q[K_э(\hat{z});\ \delta KCBP;\ B_j], \quad (j = 1, 2, ..., s) \qquad (7)$$

Model (7) is presented by the *operator mapping* $\Phi(\hat{z})$ for definition of the ***utility*** of the *complex* of ***purposeful*** decisions $\hat{\boldsymbol{z}}$ = {*C1,…,Cs*}$\in Z^C$ by the specified methods of the algorithmic calculation of the ***K*э**($\hat{\boldsymbol{z}}$) *efficiency* estimation. This *mapping* is realized by the *operator* Q, which characterizes the structure of the model $\Phi(\hat{z})$ taking into account the *procession* of *parameters* B_j , kind of dependence between *input* and *output* **B** δ **KQ** $\equiv \delta$ **QNDO** and provides generation of $\hat{\boldsymbol{z}} \in Z^C$ with calculation of the value of ***K*э**($\hat{\boldsymbol{z}}$) ***risk*** to make ***erroneous*** decision in *control* situations.

The concept of informal multi-objective estimation of the decisions being made in EQK is based on the universally adopted verified in practice confidence in professional knowledge and experience of specialists in the problematic domain, when choosing the alternatives without evident multi-objective formalization of the choice. As professional knowledge and experience of experts admit the δk -knowledge formalization in the form of a special B δ KQ $\equiv \delta$ QNDO [10, 22] it is possible avoid the known difficulties of the explicit formalized synthesis of the generalized criterion for aggregating of the local criteria when estimating the decisions efficiency. With this aim in view it is sufficient to estimate utility of the found final totality Bδ KQ$\equiv\delta$ QNDO under concrete conditions of δ-uncertainty and risk with the help of the Kэ($\hat{z}$) external criterion reaching the *minimal* ***risk*** of the ***erroneous*** decision making in the control situations. In this case the model $\Phi(\hat{z})$ (7) fits the axioms of the selection theory under conditions of ***risk*** of von Neuman and Morgenstern [7, 8] and is proper for estimating efficiency of the *knowledge-oriented* decisions simultaneously under ***complex*** conditions of *multi-objectiveness,* δ ***-uncertainty and risk.*** Contrary to the *polynomial approximation* of dependence (7) known from [1, 2] in EQK it is used δ ***-quantum*** graph $G_{\delta k} \equiv \delta$ **QNDO** described by the *generalized* s*-value* predicate P ($G_{\delta k}$) in the form of *disjunction* s *of Boolean* functions $F_i(\varphi_i(\tilde{x}_j), \tilde{B}_i)$, ($i$=1,2,..., s). The number *s* of purposeful decisions (***C1,...,Cs***)$\in \hat{z}$ defines *s-digit* of the generalized predicate P($G_{\delta k}$). The functions $F_i(\varphi_i(\tilde{x}_j), \tilde{B}_i)$ fit δ-*quantum path* of the graph $G_{\delta k}$ and describe logical *cause-effect reasoning* in δ **QNDO** relative to *s* ***purposeful*** decisions-***effects C1,...,Cs*** in the complex $\hat{z}$. In this case the parameters $b_i \in B_j$ of the model $\Phi(\hat{z})$ are defined with an accuracy of the *interval uncertainty*, this is stipulated by the diversity of the *experts'* judgments when forming **SELK.** The *interval uncertainty* means that only boundaries of the interval $[b_i^{\min}, b_i^{\max}]$ of the possible values of parameters b_i are known. The values α_k^j of indications $x_j = (\alpha_1^j, \alpha_2^j, ..., \alpha_{\rho_j}^j)$, $(j = 1, 2, ..., n)$ of **ODM** also can be specified by the boundaries of the intervals because of so-called **NOT-***factors* (*incompleteness* of knowledge, *inaccuracy* of measurements etc.). In this connection all ***interval*** values used in δ *-uncertainty* are symbolized by «~».

Thus, separate ***complex*** of solutions $\hat{z} \in Z^C$ in **MDMP** (1) represent the ***net system*** of the logical derivation *s* of ***purposeful consequences*** in the form of δ **ODM** which is described by ***disjunction*** of Boolean functions $F_i(\varphi_i(\tilde{x}_j), \tilde{B}_i)$, ($i$=1,2,..., s), depending on two-valued predicates $\varphi_i(\tilde{x}_j)$ and procession of parameters $\tilde{B}_i$, characterizing, respectively, ***meaning*** and ***quantity*** of δ *-quantum* vortex- ***events*** with logical connections between them. The predicates $\varphi_i(\tilde{x}_j)$ describe the ***logic of cause-effect*** connections between *local criteria-****properties*** $k_j \equiv \tilde{x}_j$, $(j = 1, 2, ..., n)$ of **ODM**. Hence, the ***model*** $\Phi(\hat{z})$ (7) for estimation of the *knowledge-oriented* solutions under conditions of ***multi-objectiveness, risk*** and δ ***-uncertainty*** can be written as:

$$\Phi(\hat{z}) = Q[K_э(\hat{z}); \quad \bigvee_{i=1}^{S} F_i((\varphi_i(\tilde{x}_j), \tilde{B}_i)] \qquad (8)$$

In the ***4th stage*** the choice of the unique *rational* decision $\hat{z}_{рац} \in Z^C$ the from the admissible set Z^C is realized on the use of the ***2nd stage*** and the model (8) results. Then, according to the formulas (4) and (8), the problem (1) is specified, i.e. **MDMP**, obtains the following formal form in terms of the knowledge quanta engineering:

$$z^* = \hat{z}_{рац} = \arg\min_{\hat{z}\in Z^C} \Phi(\hat{z}) = \arg\min_{\hat{z}\in Z^C} [Q(K_э(\hat{z}); \quad \bigvee_{i=1}^{S} F_i((\varphi_i(\tilde{x}_j), \tilde{B}_i))] \qquad (9)$$

The concept "*rational*" decision is more reliable here than the "*optimal*" one by virtue of the *informal-multi-objective* motivation of the offered metrics (8) for estimation of the decisions being made under ***complex*** conditions of *multi-objectiveness,* δ *- uncertainty* and *risk.*

Results of the **EQK** presented methods computer realization [10 – 12; 22] confirm its efficiency and advantages over the available approaches when solving many practical decision-making problems in different conjectural domains.

Conclusions.

1) The methods are developed on the basis of **EQK** means application and *intelligent* information technologies for solving the problem of *knowledge-oriented* decision making with a *complex* consideration of *multi-objectiveness,* various types of δ - *uncertainty* ($\delta \in \{t, \pi, v, \varphi, ...\}$) and *risk*.

2) Contrary to the available approaches the offered **EQK** methodology ensures the *cause-effect inference* of efficient *multi-objective* decisions under different conditions of δ ***- uncertainty*** and ***risk*** at the expense of δ ***к****-knowledge* in the model of *informal-multi-objective* estimation of alternatives through *external* criterion according to their ***utility*** in terms of any preferences of **DM** without resorting to the synthesis of the *generalized* criterion with weighting the *local* criteria.

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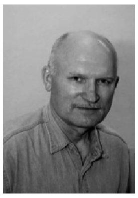

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ИСТОЧНИКИ НЕОПРЕДЕЛЕННОСТИ ЧЕЛОВЕЧЕСКОГО ФАКТОРА В ДИДАКТИКЕ

Владимир Камышин

Аннотация: *Поскольку принятие решений – это наиболее признанный вид интеллектуальной деятельности человека, то этот тезис был распространен и на деятельность участников учебно-воспитательного процесса (педагогов и обучаемых), которая представляется как непрерывная цепь решений, вырабатываемых и реализуемых в условиях воздействия многочисленных факторов разнообразной природы. Классификационные признаки решений в учебно-воспитательном процессе совпадают с характерными признаками окружающей среды, предложенными Р. Говардом (R. Howard). А именно, они, во-первых, являются динамичными, поскольку уровень обученности и воспитанности обучаемых действительно является функцией времени и зависит от предыдущего их состояния. Во-вторых, процесс обучения и воспитания является многоцелевым и многокритериальным, что соответствует определению векторных (сложных) задач принятия решений. В третьих, в учебно-воспитательном процессе присутствуют все признаки детерминированности (в меньшей степени) и рисков, имеющих стохастическую и нестохастическую природу. Если первые из них учитываются по результатам многократной практики реализаций методов, технологий, процедур обучения и воспитания, то источниками последних является природная, целевая и поведенческая неопределенность, объясняемая как минимум проявлением типологических особенностей участников учебно-воспитательного процесса, их конфликтным взаимодействием, что исследуется и моделируется методами теории игр, а также проявлением опасных качеств поведения, оперативного мышления и принятия решений.*

Особое внимание уделено системному анализу неопределенностей человеческого фактора в учебно-воспитательном процессе, который рассматривается как гуманистическая образовательная система (в соответствии с пониманием Л. Заде и критериями А. И. Губинского). Имеется в виду: отсутствие знаний о явлениях и закономерностях функционирования объектов управления (в том числе, невозможность выявления, учета и точного описания альтернатив, особенно с помощью одной функции полезности); взаимодействие участника учебно-воспитательного процесса с объектом и/или явлением окружающей среды (природной, социальной, учебной); постановка цели; построение стратегий решения теоретических и практических задач, а также информационно-лингвистической неопределенности описания проблемных ситуаций в дидактике.

Ключевые слова: *классификационные признаки проблемных ситуаций в дидактике; неопределенность, связанная с человеческим фактором (участниками учебно-воспитательного процесса) и лингво-информационными процессами; источники риска нестохастического характера.*

ACM Classification Keywords: *J.1 Administrative Data Processing,* Education. *J.4 Social And Behavioral Sciences.*

Актуальность

Совершенствование *учебно-воспитательного процесса* (УВП) любого учебного заведения невозможно без учета опыта удачных/неудачных решений, а также риска таких решений. При этом под *принятием решений* (ПР) согласно [Козелецкий, 1979; Надежность и эффективность в технике, 1988; Рева, 2001; Рева, 2007; Камишин, 2012], будем понимать целеустремленный акт эмоционально-волевого выбора одной стратегии, альтернативы, следствия, результата и т.п. из нескольких, путем преобразования исходной информации, когда ситуация не определена. Действительно, преподаватель выбирает методы, средства, педагогические приемы обучения, принимает решение при оценке знаний, проявляет эмоции и волю, отчитывая нерадивого обучаемого или выставляя ему негативную оценку, в результате чего учащийся может быть не только лишен стипендии, но и отчислен из высшего учебного заведения (ВУЗа), а в обычной школе, скажем, не получит золотую медаль и т.п. Тот же школьник, студент принимает решение о посещении занятий, выполнении домашних заданий, участии в работе на занятиях, в общефакультетских или вузовских (школьных) мероприятиях и т.п. В то же время, учитывая [Козелецкий, 1979; Надежность и эффективность в технике, 1988; Рева, 2007; Камишин, 2012; Мушик, 1990; Психология: словарь, 1990], под риском будем понимать возможность наступления нежелательного события в УВП.

Внимание автора именно к процессам ПР в УВП не является случайным и объясняется следующим:

во-первых, ПР – это вид интеллектуальной деятельности человека, который повторяется наиболее часто (до 10000 (!) выборов/день) [Шеридан, 1980; Эдвардс, 1991; Ходаков, 2005];

во-вторых, речь идет о ПР в так называемой *гуманистической системе* [Рева, 2001]. Л. Заде, один из основателей теории *лингвистических переменных* (ЛП) и *нечетких множеств* (НМ), определяет, что «гуманистические – это такие системы, на поведение которых большое влияние оказывают суждения, восприятия или эмоции человека: экономические системы, правовые системы, общеобразовательные системы и т.п. Сам человек (индивид) и процессы его мышления также могут рассматриваться как гуманистические системы» [Заде, 1976]. Согласно с критериями, которые разработаны А. И. Губинским для определения разнообразных классов гуманистических систем, под *образовательной гуманистической системой*, будем понимать такую, где «целью деятельности специалиста-педагога (преподавателя), или педагогического (преподавательского) коллектива является передача (ученикам, студентам, слушателям и т. п., необходимых знаний, навыков и умений, в том числе умений учиться» [Губинский, 1982];

в-третьих, участникам УВП присуща так называемая *поведенческая неопределенность* [Надежность и эффективность в технике, 1988; Рева, 2001; Рева, 2007; Камишин, 2012], объясняемая, по меньшей мере, тремя составляющими: проявлением типологических особенностей личности (темпераментом) [Шпаченко, 1976; Русалов, 1979; Вопросы морально-политической и психологической подготовки летного состава, 1982; Стреляу, 1982; Рева, 2003], неопределенностью поведения противника [Камишин, 2012; Мушик, 1990; Льюис, 1961; Фон Нейман, 1970; Рева, 2005; Рева, 2005; Рева, 2007] и проявлением опасных свойств (стратегий, отношений, качеств) поведения, оперативного мышления и принятием решений [Камишин, 2012; Jensen].

Обобщая вышеизложенное, следует указать на важность учета в УВП проявления *человеческого фактора* (ЧФ). С другой стороны, на этот самый процесс, особенно на ПР, влияет большое количество факторов самой разнообразной природы. Таким образом, проблему проявления, описания и систематизации факторов неопределенности УВП следует считать актуальной.

Анализ исследований и публикаций

Большая сложность гуманистических образовательных систем требует применения в их исследовании и совершенствовании подхода, в корне отличающегося от общепринятых количественно-стохастических методов анализа систем. Таким образом, вышеупомянутая проблема проявления, описания и систематизации факторов неопределенности УВП должна решаться с помощью методологии теории ЛП и НМ [Надежность и эффективность в технике, 1988; Камишин, 2012; Заде, 1976; Орловский, 1981; Кофман, 1982; Шапиро, 1983; Нечеткие множества и теория возможностей, 1986; Борисов, 1989; Иваненко, 1990; Дюбуа, 1990 и др.]. Ведь действительно, исходя из того, что «... элементами мышления человека являются не числа, а элементы некоторых нечетких множеств, или классов объектов, для которых переход от “принадлежности” к “непринадлежности” не скачкообразный, а непрерывный», становится понятным дефиниции самой ЛП, под которой понимают элементы (слова или предложения) природного или любого искусственного языка [Надежность и эффективность в технике, 1988; Заде, 1976]. Такие переменные составляют основу нечеткой логики и приближенных способов рассуждений, которые могут оказаться больше созвучными сложности и неточности гуманистических систем, чем обычные численные методы анализа. С помощью ЛП можно приблизительно описывать явления, которые настолько сложны или плохо определены, что не поддаются описанию общепринятыми методами.

Из анализа научных источников следует, что применение методологии теории ЛП и НМ в дидактике осуществляется в СНГ, главным образом, учеными и специалистами Азербайджана, России и Украины. При этом считаем целесообразным выделить работы [Рева, 2007; Камишин, 2012], поскольку в них с позиций системного анализа заложены основы классификации *проблемных ситуаций* (ПС), в том числе и неопределенных, которые могут возникнуть в УВП *(рис. 1).*

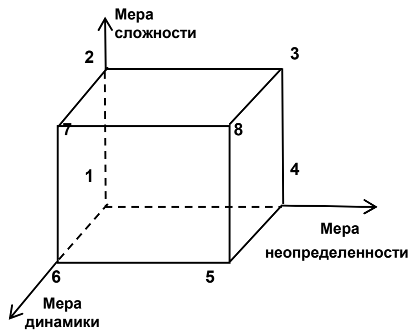

Рис. 1. Пространство учебной среды с расположенными в нем видами задач принятия решений

С другой стороны, считаем целесообразным применить опыт исследований проблем неопределенности в авиационных эргатических гуманистических системах [Недбай, 2010; Рева, 2010], адаптация и развитие которого для нужд дидактики будет способствовать более полному и всестороннему анализу процессов функционирования уже образовательных гуманистических систем. Такое обращение к авиации является неслучайным и объясняется тем, что эта отрасль человеческой деятельности всегда аккумулировала результаты самых современных научных достижений. Вот почему на мировом рынке 1 кг современного самолета имеет стоимость $ 2000, 1 кг автомобиля – $ 15, а 1 кг сковородок – $ 1 [Плотников, 1991].

Цель статьи заключается в формировании системообразующих признаков ПС в УВП, выявлении, а также системном описании источников неопределенности в них и во время ПР его участниками.

Классификационные признаки и источники неопределенности ПС в дидактике

Итак, опираясь на уже упоминавшиеся научные источники [Недбай, 2010; Рева, 2010] и рис. 1, представим общую классификационную схему неопределенности, которая возникает или даже может возникнуть в образовательной гуманистической системе «участники УВП (диада “педагог – обучаемый”) – технические средства учебы (лабораторное оборудование, ПЭОМ и т. п.) – учебная среда» (рис. 2).

Рис. 2. Классификация видов неопределенности в функционировании образовательной гуманистической системы «участники дидактического процесса – технические средства обучения – учебная среда»

Стремясь достичь сформулированной цели, будем рассматривать деятельность участника УВП как непрерывную цепь решений, которые вырабатываются и реализуются в явной и неявной формах. Понятно, что в целом, эти решения характеризуются неопределенностью получаемой информации и вариативностью управляющих влияний. В такой интерпретации обучение и воспитание учеников, студентов удобно рассматривать как одно- и многошаговый процесс ПР, основанный на приближенной стратегии и нечетких наблюдениях фазовых состояний (уровней обученности и воспитанности) объекта управления, при которых выбор нечетких управляющих влияний направлен на достижение «размытой» конечной цели, начиная с любого начального состояния и с учетом нечетких ограничений, которые налагаются на наблюдаемые состояния и управления объекта дидактичного воздействия [Камишин, 2011].

Таким образом, предлагаемое описание процесса ПР в большей степени отвечает природе формирования и реализации управляющей деятельности в УВП, характеризуемое, скажем, накоплением в памяти педагога опыта формирования дидактичных навыков в виде пары нечетких образов «замеченное состояние обучаемого – управляющее воздействие». На этапе применения этого опыта речь идет об ассоциации образа текущего состояния объекта-ученика в пространстве среды результатов обучения и воспитания с предварительно накопленным опытом (концептуальной моделью) и выработкой в процессе ассоциативной обработки информации образа управляющего влияния для его последующей реализации.

Как следует из рис. 2, проблема неопределенности имеет смысл преимущественно на том этапе, когда УВП нуждается во вмешательстве педагога, поскольку именно в этом случае возникает необходимость

ПР о последующих действиях, которое, в свою очередь, будет влиять на состояние всей системы в следующий момент времени.

Касательно процесса ПР неопределенность условно распределяют на три класса. Первый класс - это так называемая «неопределенность природы», то есть факторы просто неизвестные участнику УВП; второй класс - это «поведенческая неопределенность», некоторые элементы которой были рассмотрены выше при обосновании актуальности исследования. Это связано с тем, что человек всегда существует в условиях, когда результаты его решений не строго однозначны, а зависят от других лиц (партнеров, противников и т. п.), действия которых он не может учесть или предусмотреть в полной мере. Третий класс - это «неопределенность желаний и целей», поскольку в действительности всегда существует несколько целей, которые невозможно описать с помощью одного показателя (критерия) [Орловский, 1981].

В ситуации неизвестности *(рис. 3)* информация о задании, явлениях или законах функционирования дидактических объектов управления практически отсутствует (начальная стадия изучения задания). В процессе сбора информации на определенном этапе может оказаться, что собрана еще не вся возможная информация (неполнота). Также может сложиться ситуация, когда собрана не вся необходимая информация (недостаточность).

Рис. 3. Источники неопределенности, связанные с отсутствием знаний о явлениях и законах функционирования дидактического объекта управления

Некоторые элементы УВП, временно описываются по аналогии с ранее исследуемыми, поэтому имеем лишь описание, «которое замещает» (неадекватность). Также возможно использование опыта и приемов решения учебных заданий, что может быть малоэффективным в конкретном случае. Наличие таких видов неопределенности (недостоверности) связано или с тем, что процесс сбора информации временно прекращен, например, в результате необходимости немедленно решать другое, внезапно возникшее задание, или в связи с недостатком ресурсов (времени), выделенных для сбора информации. Однако возможность результативного продолжения изучения и выполнения задания все же существует.

Ситуация неопределенности, связанная с отсутствием знаний о явлениях и закономерностях функционирования объектов управления, также возникает в случаях, когда для принятие индивидуального или группового решения устанавливаются условные ограничения с целью упрощения

ПС, или когда участник УВП не имеет возможности учесть все связи между элементами поля ПР и т.п. Согласно рис. 3, первый уровень декомпозиции блока отражает ситуацию, когда с целью упрощения процесса ПР вводятся ограничения, которые на самом деле могут и не существовать.

Анализ каждой системы, в том числе и образовательной гуманистической, по большей части нуждается в рассмотрении не всей системы, а выделения некоторой ее части. Это определяется тем, что в действительности невозможно, как правило, выполнить полное формализованное описание сложной системы. При этом выделение определенной части из всей системы выполняется в соответствии с целями исследований и представлением исследователя о системе в целом. В этом случае, выделяя субсистему из всей системы, исследователь вводит определенные границы, которые фактически отсутствуют, поскольку полная система не является дискретной совокупностью субсистем, а скорее должна рассматриваться как определенное поле, где субсистемы имеют те или другие взаимосвязи и, некоторым образом, «пересекаются» и проникают одна в другую. Таким образом, переход от одной субсистемы к другой не может осуществляться скачкообразно через четко установленную границу, а происходит постепенно и непрерывно. Такого рода переход иллюстрирует, скажем, дидактическую цепочку «детский садик – школа – университет».

Анализируя определенную субсистему, педагог-исследователь не имеет возможности учесть все взаимосвязи между субсистемами и их элементами (внешние и внутренние), потому он использует свои представления об этих связях, а также мнения специалистов-экспертов. По большей части, эти представления представляются в понятиях, имеющих нечеткое описание и которые не могут быть описаны средствами классической математики. Эту проблему отражает соответствующий уровень субструктуры *(рис. 3, блок «Связи, которые невозможно обнаружить и учесть»)*.

Последующее изучение ПС может привести или к случаю определенности, когда все элементы описаны однозначно, или к неоднозначности. Тогда допускается, что вся возможная информация о задании собрана, но полностью определенное описание не получено и не может быть таковым.

Задача минимизации (максимизации) заданной функции на заданном множестве допустимых альтернатив обычно рассматривается как стандартная задача математического программирования [Орловский, 1981]. Однако при моделировании в реальных условиях лицо, принимающее решение (ЛПР), может иметь в своем распоряжении лишь нечеткие описания параметров функции и (или) самого множества. Бинарное отношение предпочтения на множестве альтернатив может быть описано несколькими способами, в частности, так называемой функцией полезности (ФП) [Козелецкий, 1979; Надежность и эффективность в технике, 1988; Камишин, 2012; Кини, 1981; Рева, 2010]. Таким образом, неопределенность при решении задач математического программирования может содержаться как в описании множества альтернатив, так и в описании ФП. Такие задачи называются задачами нечеткого математического программирования и именно это отображают два следующих субуровня – «Невозможность провести описание с помощью одной функции полезности» та «Невозможность проведения точного описания альтернатив» *(рис. 3)*.

Проводя дальнейший анализ рис. 3, рассмотрим блок «Неопределенность, связанная с взаимодействием человека с объектом и/или явлением окружающей среды» *(рис. 4)*.

В разных отраслях человеческой деятельности и, в частности, в образовательных гуманистических системах, часто встречаются ситуации, в которых достижение цели в результате ПР отдельным участником УВП (или их группы) зависят не только от отдельного ЛПР (или группы таких лиц), но и от решений (действий) другого лица (группы лиц), которые преследуют свои собственные цели. В этом случае необходимо учитывать наличие влияния этих лиц, которые могут быть как партнерами, так и противниками. Одним из наиболее удобных подходов к решению задач, которые порождаются такими ситуациями, является теория игр. Наибольшее внимание в ней уделяется двум теоретико-игровым принципам рациональности: принципу наилучшего гарантированного результата и принципа, который опирается на понятие равновесия. Собственно игра отображает процесс взаимодействия двух лиц (или групп лиц). Построение стратегии поведения каждого из игроков связано также с проблемой наличия других типов неопределенности *(рис. 4)*.

Рис. 4. Источники неопределенности в процессе взаимодействия человека с другим человеком (между группами людей), или человека с объектом и/или явлением окружающей среды

Следующим блоком классификационной структуры типов и источников неопределенности, приведенной на рис. 2, является блок «Неопределенность постановки целей» *(рис. 5)*.

Подход к решению *задачи ПР* (ЗПР) в условиях неопределенности постановки целей был разработан Л. Заде и Р. Беллманом и получил название «подход Беллмана–Заде». Основой этого подхода является то, что цели ПР и множество допустимых альтернатив рассматриваются как равноправные нечеткие субмножества некоторого универсального множества альтернатив. В пределах этого направления, как правило, рассматриваются соответствующие субзадачи, которые и представлены на рис. 5 [Кузьмин, 1982].

В процессе исследования законов функционирования образовательной гуманистической системы возникает необходимость решения разнообразных задач, связанных с синтезом стратегий управления системой, разработкой мероприятий по обеспечению безопасности функционирования системы, построением моделей работы собственно системы и ее составных элементов и т.п. В этом случае возникает необходимость учитывать неопределенность, связанную с такими видами деятельности участников УВП и его исследователей, как изучение проблемы, постановка задачи, выбор методов ее решения, обеспечение необходимой информацией и т.д. Точнее говоря, при формулировке задачи происходит отображение реальной задачи на некоторый формализированный язык – профессиональный язык специалиста. В результате возникает ряд таких ПС:

- ситуация неизвестности, когда информация о ЗПР практически отсутствует;
- в распоряжении, в первую очередь, педагога как ЛПР, имеется не вся необходимая информация;
- собрана не вся возможная информация;

– не существует точного описания всех элементов, которые подлежат исследованию;
– некоторые элементы описаны не по фактическим данным, а по аналогии и т. д.

Рис. 5. Неопределенность, связанная с нечетко поставленными целями

Как видим, проблемы решения ЗПР определяются соответствующим процессом. Структуру этого блока будут составлять все элементы структур вышерассмотренных блоков. Кроме того, сюда следует отнести еще один элемент, который является важнейшим при всяких условиях ПР – неопределенность, связанную с информационным обеспечением.

Любая информационная единица может характеризоваться такими признаками как «Значение» и «Определенность». Получая любую информацию, мы обращаем внимание, во-первых, на ее содержание, а, во-вторых, на то, насколько она соответствует действительности. При таком подходе может иметь место ситуация, когда информация была передана неточно, другими словами, педагог не может быть уверенным в ее истинности. В этом случае выделяют, собственно, неточность, которую связывают с характеристикой «Значение», и достоверность информации, связываемую с характеристикой «Определенность». Изложенное предствлено схематично на рис. 6.

Неточность информации порождается ее неоднозначностью, которая, в свою очередь, может быть физической и лингвистической.

Физическая неопределенность может быть связана как с наличием во внешней среде нескольких возможностей, каждая из которых случайным образом становится действительностью (ситуация случайности, или стохастической неопределенности), так и с неточностью измерений полностью определенной величины, которые выполняются, скажем, лабораторными приборами (ситуация неточности).

В условиях риска (стохастическая неопределенность) любое ПР может стать причиной одного из многих возможных последствий, причем, каждое следствие имеет известную вероятность появления. Именно величина этой вероятности формирует степень уверенности участника УВП в своих действиях. В условиях нестохастической неопределенности (неопределенность) любое ПР может привести к одному из многих последствий, вероятность появления которого участникам УВП неизвестна.

Лингвистическая неопределенность связана с особенностью интерфейса приема и передачи информации с помощью естественного или профессионального языка для описания ЗПР. Особенно актуальна проблема лингвистической неопределенности связана с использованием неродного языка.

Такого рода неопределенность обусловливается необходимостью оперировать конечным числом слов и ограниченным числом структур фраз (предложений, абзацев, текстов) для описания за некоторое время почти бесконечного множества разнообразных ситуаций, которые возникают в процессе решения учебного задания. Лингвистическая неопределенность порождается множественностью значений слов, которые называют полисемией, а с другой стороны, неоднозначностью содержания фраз.

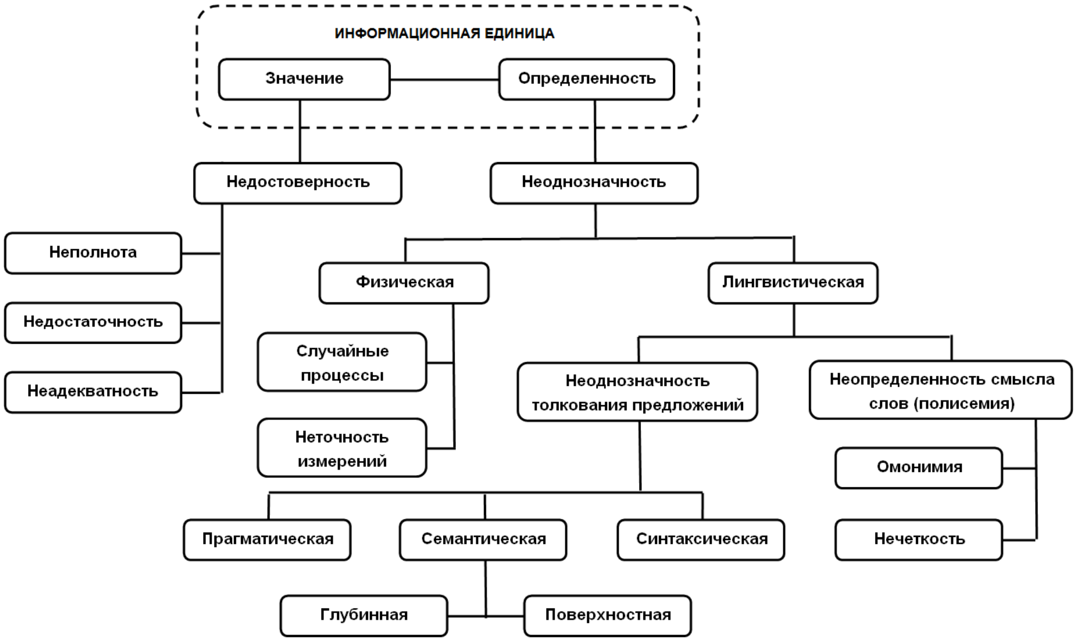

Рис. 6. Источники и типы информационной неопределенности

Следует отметить, что все типы неопределенности согласно рассмотренной на рис. 6 классификационной структуры являются значимыми факторами, которые снижают вероятность получения достоверных результатов исследований образовательной гуманистической системы и вызывают необходимость применения специальных мероприятий и методов, которые бы позволяли уменьшить как общее влияние, так и влияние отдельных типов неопределенности на процесс функционирования системы.

При исследовании проблемы повышения отказобезопасности образовательной гуманистической системы следует остановиться на тех типах неопределенности и ее источниках, которые имеют значительное влияние на процесс построения новых средств и методов исследований и должны быть учтены, в частности, в процессе построения модели этой системы. При этом одним из наиболее значительных является фактор информационной неопределенности, а именно, недостоверность информации (рис. 6).

Недостоверность информации является понятием, которое охватывает такие характеристики как неполнота, недостаточность и неадекватность. Наибольшее влияние этот фактор осуществляет, скажем в случаях, когда для оценивания академической успеваемости учеников, студентов применяется недостаточно валидный и надежный тест.

Следует остановиться на формировании экспертных оценок состояния системы, поскольку эти оценки по большей части имеют характер вербального описания или интервальной числовой оценки, то есть не могут объясняться как конкретное четкое число. В этом случае целесообразным является применение методов ЛП и НМ, в частности, в процессе нахождения группового решения.

Следовательно, еще одним типом неопределенности, имеющим значительное влияние на уровень отказобезопасности исследуемой системы, является неопределенность, непосредственно связанная с деятельностью людей, в частности, с взаимодействием педагога с объектом управления (рис. 4). В свою очередь этот тип неопределенности имеет три составных части:

- – нечеткие условия решения задачи управления (случай, когда множество действий, нормируемых регламентирующими документами в определенной учебной ситуации, не соответствует реальным возможностям как объекта управления, так и управляющего звена);
- – нечеткое задание параметров функций (в результате изменений, которые состоялись в показателях обученности и воспитанности ученика или студента, изменились и характеристики его управляемости, а, значит, функции, их описывающие, не являются адекватными фактическим);
- – нечеткое задание (фактическое состояние системы не является совместимым с теми ограничениями, которые отвечают «идеальной» системе).

Еще одним типом неопределенности, которая имеет место в процессе исследования образовательной гуманистической системы является невозможность выявления и/или учета всех связей между элементами системы. Остановимся детальнее на этом факторе. При определенных условиях исследуемую систему можно рассматривать как эргатическую (рис. 7), потому описание этой системы должно охватывать не только основные, но и дополнительные процессы (субпроцессы), которые также связаны (посредственно или непосредственно) с деятельностью людей. В этом случае имеется в виду то, что описание процесса функционирования эргатической системы, представленной на рис. 7, должно также включать и описание деятельности второстепенных эргатических элементов, к которым относятся деятельность, скажем, представителей служб технического обеспечения.

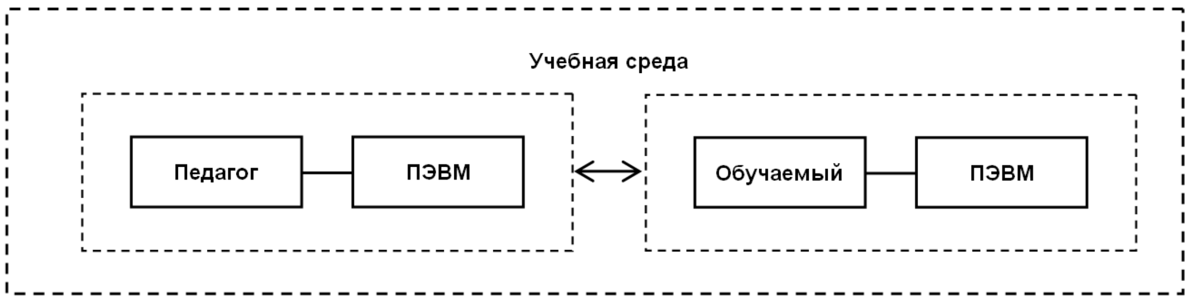

Рис. 7. Представление образовательной гуманистической системы в виде эргатической системы

Связи управляющего элемента и объекта управления с этими элементами могут быть описаны только условно, таким образом, это описание не будет иметь четкой числовой формализации и может рассматриваться как информационное пространство сложной структуры, которое содержит такие виды информации как числовая, лингвистическая, графическая, смешанная и т. п. Учет этих связей может быть осуществлен по результатам возникновения или отсутствия определенного события, которое может быть идентифицировано лишь по перечню определенных признаков.

Именно множество этих признаков в совокупности с множеством признаков состояния обученности школьника позволит избежать полной потери сведений об этих связках. Под признаками в этом случае будем понимать как числовые, так и графические или лингвистические характеристики события, которое опосредственно или непосредственно служит причиной перехода системы из одного состояния в друге.

Все приведенные рассуждения указывают на необходимость решения задачи формирования пространства признаков исследуемой системы с последующей разработкой технологии оценивания уровня ее состояния.

Рассматривая лингвистическую неопределенность также следует отметить, что обычно выделяют два вида полисемии: омонимию и нечеткость. Если отображенные тем самым словом объекты ЗПР существенно разные, то соответствующую ситуацию относят к омонимии. Например, курс (магнитный, истинный, ортодромический). Если же эти объекты подобны, то ситуацию относят к нечеткости. Например, горная местность – любая подстилающая поверхность с высотой возвышенности более 2000 м.

Рассматривая источники неоднозначности содержания фраз, можно выделить синтаксическую, семантическую и прагматичную неоднозначность.

Семантическая неопределенность возникает тогда, когда непонятно содержание фразы (команды). В практике обучения семантическая неопределенность, в частности, у педагогов практически не встречается, хотя ученики могут грешить использованием жаргонных выражений, которые заменяют понятия профессионального языка конкретной учебной дисциплины. Однако, в результате незнания некоторых профессиональных терминов, выражения, в которых они встречаются, будут иметь непонятный смысл.

Прагматичная неопределенность связана с неоднозначностью использования синтаксически и семантически понятной информации для достижения целей деятельности (обучения).

В общем виде проблема ПР в образовательной гуманистической системе может быть охарактеризована совокупностью элементов, которые образуют кортеж [Надежность и эффективность в технике, 1988; Камишин, 2012; Шапиро, 1983; Борисов, 1989]:

$$\langle S, P, Q, \Phi, D, I, F_0 \rangle$$

где S – среда ПС и ЗПР; P – цель педагога как ЛПР; Q – критерии, характеризующие требования к требуемому состоянию обученности и воспитанности объекта управления, т. е. обучаемого; Φ – альтернативные решения, которые могут быть приняты; D – правила выбора решения, которые могут быть применены; I – информация, необходимая для данного класса заданий; F_0 – специфические особенности (оценочная ФП или доминанта) деятельности участников УВП.

В случае, когда S как среда ПС в УВП характеризуется наличием неопределенности, то принимается решение, не зная, в какой ситуации оно будет реализовано. Тогда для педагога, как субъекта управления, будут характерны нечеткость и приблизительность умственных выводов при описании и оценке ситуаций, формулировке целей и ограничений, а также при оперировании исходными данными [Новиков, 1980]. Поэтому при формализации учебного задания возникает необходимость использовать нечеткие понятия и нечеткие процедуры.

Выводы

1. Влияние человеческого фактора на эффективность функционирования образовательной гуманистической системы «участники УВП (диада “педагог – обучаемый”) – технические средства обучения – учебная среда» требует реализации разнообразных подходов для его разностороннего изучения и описания, одним из которых является представление профессиональной деятельности педагогов как субъектов управления, а также учебную деятельность самих обучаемых в виде

непрерывной цепи решений, которые вырабатываются в условиях действия многих факторов разнообразной природы.

2. Детально рассмотрены неопределенности, связанные с деятельностью человека в дидактическом процессе (отсутствие знаний о явлениях и закономерностях функционирования обучаемых как объектов управления; взаимодействие педагога с объектом и (или) явлением окружающей среды; определение цели; получение и обработка информации; построение стратегий решения теоретических и практических задач), а также информационно-лингвистическая неопределенность описания проблемных ситуаций.

3. Полученные результаты являются основанием для последующих исследований и моделирования процессов функционирования образовательной гуманистической системы с использованием методов теории лингвистических переменных и нечетких множеств.

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