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A Survey of the Interactive Multicriteria Decision Support Systems, Developed at IIT-BAS

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Abstract: *A survey of the systems, supporting decision making in multicriteria problems, which are developed at the Institute of Information Technologies at Bulgarian Academy of Sciences (IIT-BAS), is presented. It discusses the structure, the possibilities to process the input data, the participation of the Decision Maker (DM) in the control of the process of search and selection of (weak) Pareto optimal solutions, the visualization and documentation of the current and final results obtained. These systems include the interactive methods, developed at IIT-BAS for multicriteria decision making, which provide much wider possibilities to the DM to express his/her preferences with respect to the solution sought, and apply different strategies to decrease the waiting time for obtain new solutions in hard solved integer multicriteria problems.*

Keywords: *Decision support system, multicriteria optimization, multicriteria analysis.*

1. Introduction

The Decision Support Systems (DSS) may be defined as interactive computer-based systems, designed to support and assist the Decision Maker (DM) in solving non-formalized or weakly formalized problems. The Multicriteria Decision Support Systems (MDSS) are a part of DSS, intended to solve Multicriteria Decision Making Problems (MDMP). These problems can be divided into two groups: problems of Multicriteria Optimization (MO) and problems of Multicriteria Analysis (MA). In multicriteria optimization problems a finite number of explicitly given constraints defines an infinite number of feasible alternatives. They are also

called multicriteria decision making problems with continuous alternatives. In multicriteria analysis problems, a finite number of alternatives is set explicitly, usually in a tabular form. They are also called multicriteria decision making problems with discrete alternatives. The quality of one MDSS depends on the possibilities it offers to the DM in the following aspects:

- entry and edition of the input data;
- description of his/her local and global preferences;
- generation of new solutions for evaluation;
- visualization of the different types of information, necessary for his/her learning in relation to the multicriteria problem being solved;
- management of the process of muticriteria solving, including alteration of some parameters, current results storing, interruption of the computing process, multiple restart of the computing process from different current solutions, etc.

The description of DM's preferences and the generation of new solutions for evaluation depend to a high extent on the type of the multicriteria and single-criterion optimization methods, included in the system. In most of the well-known systems, supporting multicriteria optimization decision making, some interactive multicriteria methods of the reference direction are included and they are designed to solve continuous optimization problems. In the major part of the systems developed to support the solution of multicriteria analysis problems, only non-interactive methods are usually applied.

The development of MDSS at IIT-BAS has launched parallel to the work on creating new scalarizing problems and on their basis – new interactive methods for MDMP solution. The first two systems MOIP and MONIP are designed to function under DOS operating system and intended to solve linear and linear integer, and convex nonlinear and nonlinear integer optimization problems, respectively. The development of the programming languages and operating systems has enabled the considerable improvement of the control programs and interface modules of these systems, so that the possibilities above described are met. The next generation of MDSS – MKO-1, MKO-2, MKA-1 and MKA-2, developed at IIT-BAS, work under MS Windows operating system and are supplied with improved user-friendly interface. The systems apply the interactive methods for multicriteria decision making, developed at Decision Support Systems Department of IIT-BAS, which has been established, developed and headed by Prof. Vassil Vassilev for more than 15 years. The developed interactive methods give wider possibilities to the DM to express his/her preferences in relation to the solution sought and different strategies for reducing the waiting time for new solutions in hardly solved integer multicriteria problems.

The next sections of the publication present the software systems for optimization and multicriteria decision making, developed at IIT-BAS. The structure, the possibilities for input data processing, DM's preferences and visualization of the current and final solutions are described in detail.

2. MOIP and MONIP multicriteria decision support systems

MOIP and MONIP software systems [15, 16] are intended to enable the solution of linear and nonlinear continuous and integer problems of multicriteria optimization and are oriented to function under the control of DOS operating system.

2.1. MOIP decision support system

MOIP software system is developed on the basis of the interactive methods of Reference Directions RD-LIM and RD-IIM [6, 12, 13], developed at the DSS department of IIT-BAS.

It consists of three types of modules: a control program, an editing program and optimization modules. The control program ensures the software environment for execution of the following main functions of the system:

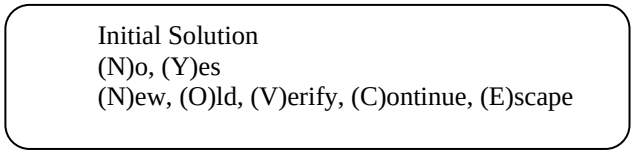
- creating, updating and storing of files, containing descriptions of linear and non-linear integer problems of multicriteria optimization;
- solving of the entered linear and linear integer problems of multicriteria optimization;
- analysis and printing of the obtained Pareto optimal or weak Pareto optimal solutions;
- execution of system commands and DM's training for operation with the system.

The control program is menu-oriented. The interface with the DM is realized with the help of three menus. The software modules, executing the functions above listed, are shown in the main menu. The editing program and the optimization procedures are selected from the other two menus. The optimization procedures realize the interactive methods RD-LIM and RD-IIM, two simplex methods for solving continuous linear single-criterion problems, a method of "branches and bounds" type for solving linear integer single-criterion problems and an approximate method for solving linear integer single-criterion problems [11].

The linear and linear integer problems of MO are entered, corrected and stored with the help of MOIP-E editing program. The main window of MOIP-E is shown on Fig. 1. It is divided in two parts. The upper part of the screen displays a table with multicriteria problem data. The example presented is for a problem with two objective functions, two variables and four constraints.

The lower part of the window contains a command bar. The problem data are entered, corrected and saved, pressing on a command from this line. MOIP-E editing program works with operating memory only. The size of the problems, that can be entered, depends on the available operating memory.

The DM can either enter him/herself an *Initial solution* or the system would find one:



Name	Type	RHS	X_1	X_2		
LB			0	0		
UB			6	100		
Type			I	I		
F	max		1.4	2.1		
F	max		–2	5.3		
A:	<	12.6	1	2		
B:	<	54	8	3		
C:	<	30	–2	6		
D:	<	6.8	2	–3		

M = 4 K = 2 N = 2

MOIP-E F_1 – Help

Fig.1. Main window of MOIP-E editing program

In case the DM selects (N)o command, MOIP system itself sets the initial solution. If the DM presses (Y)es, he/she will have to choose one of the two commands – (N)ew or (O)ld. After choosing (N)ew command, the DM must enter the new desired or acceptable levels of the criteria (this command is used, when no current solution exists). In case the DM is solving an old problem, with an interrupt of the solution process, he/she must use (O)ld command. The criteria values in the last solution found appear on the screen and the DM must enter the new desired and acceptable levels of the criteria. Using (C)ontinue command he/she determines what solution he/she wants to find – continuous or integer.

After finding a new (weak) Pareto optimal solution, a second window appears. It displays the elements of the new solution – the type of the solution, the criteria values and the deviations of these values from the criteria values found at the previous solution. This window shows also a set of commands, questions and prompts for continuing or interrupting the solution process. Here the DM can enter his/her desired and acceptable levels or alterations in the criteria levels.

With the help of (A)sp. Lev. or (D)elta commands the DM inputs the desired and acceptable levels or the desired and acceptable alterations of the criteria values. This is done as the DM successively enters the criterion number and the desired and acceptable level (alteration) of the criterion value in the two windows that have appeared. (V)erify command enables the DM to check the values typed. By (C)ontinue command the process of search for a new solution is started, but before that the DM must define the type of this solution (continuous or integer). If the criteria number is greater than eight, the DM might enter the aspiration levels of all the criteria, using (M)ore command. The (E)scape command turns back the operations to the main menu.

Fig. 3 shows the screen, which appears after finding new Pareto optimal solutions, corresponding to the aspiration levels, shown on Fig. 2.

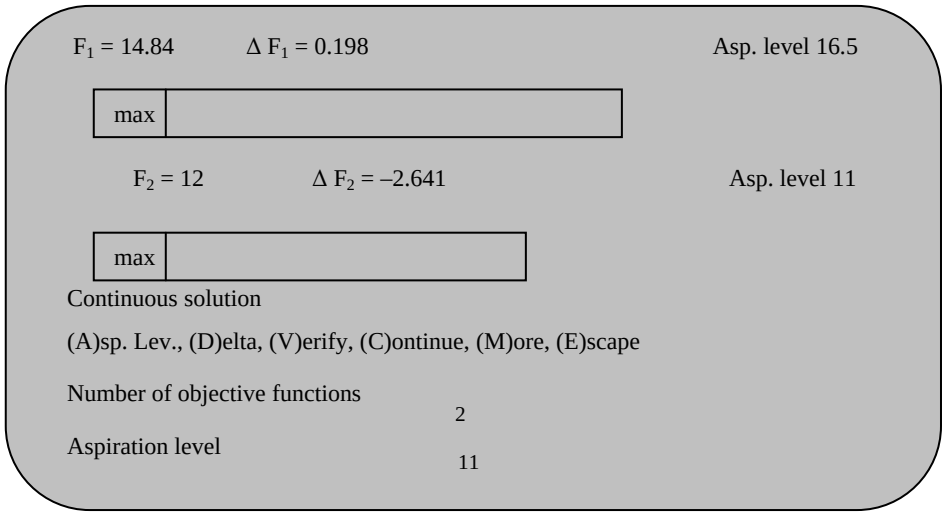


Fig. 2. Setting of DM's preferences

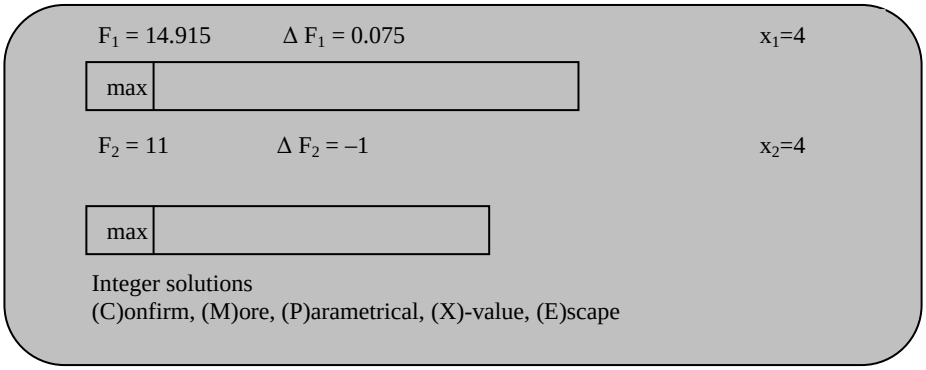


Fig. 3.View and approval of the integer solution

All the current Pareto optimal solutions found in the variables space or in the criteria space, are stored in a protocol file. The DM accesses this file through the main menu and he/she can analyze these solutions and print some of them. Each solution from the protocol file may be used by the DM as an initial solution, when staring a new search for the most preferred Pareto optimal solution of the multicriteria problem.

2.2. MONIP decision support system

MONIP software system is designed to solve convex nonlinear continuous and integer problems of multicriteria optimization. It is developed on the basis of the interactive method of the modified reference point .MRP-NIM [17, 18], developed at the DSS department of IIT-BAS. It also consists of three types of modules: a control program, an editing program and optimization modules. The system

includes some auxiliary modules as well, but each one of them is connected with the main program modules.

The control program is an integrated software environment for creating, processing, storing, linking and executing of different types of files. The basic functional possibilities of the control program may be classified in three groups. The first group covers the possibilities for application of the DOS resources in system own environment. The second group of the functional possibilities includes the options enabling the use in this environment of some software modules, realizing the operations of creating, updating and storing of files, holding the description of MO problems; the interactive solution of the problems entered; and also the localization of errors, connected with direct starting of the editing program and visualization of these errors.

The third group of functional possibilities of the control program contains the possibilities to visualize specific information, connected with the execution of the system and applied operations.

The interface between the DM and the control program is presented in a main menu, shown on Fig. 4.

20:22:17		MONIP		Managing			Program
Scale		Directory of B:\					
Name	Ext	RHSA	Date	Time	Size		Actions
						[D]	Change directory
MONIP	EXE	nnny	9-08-1993	9:03	62899	[F]	Change filter
						[G]	Global select
SED	EXE	nnny	9-07-1993	10:15	32956	[A]	Arrange directory
						[E]	Erase files
NMIP	EXE	nnny	7-09-1993	15:10	140480	[M]	Move files
						[C]	Copy files
TEST1		nnny	15-09-1993	20:05	284	[V]	View
TEST2		nnny	10-08-1993	11:02	264	[N:O]	Edit
						[S]	Solve
PP1		nnny	20-08-1993	15:30	180	[X]	Exit
					DIRECTORY		
					Files found		6
					Total space		240027 bytes
					Selection		0 bytes
					DISK B		
					Volume label		1216220 bytes
					Disk space		1456247 bytes

Fig. 4. Main menu of the control program of MONIP

The separate files and types of operations that will be run, are selected with the help of this menu. The DM has the possibility to control each one of these operations (system and applied) by different windows.

MONIP editing program of the system is used to enter, correct and save MO nonlinear integer problems. The DM accomplishes these operations with the help of an editing program and the Help option in real time. The description of the nonlinear integer problems of MO is in textual form, using a specialized formal

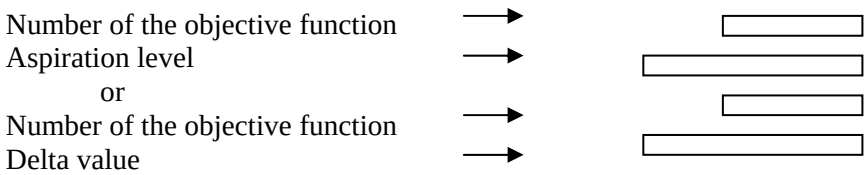
language of a non-procedure type. The multicriteria problems, containing criteria and constraints in the form of arithmetic expressions, are described by this language. The expressions may include arithmetic operations and basic arithmetic and trigonometric functions. Two programming modules are used to process the data entered. The first module is a syntactic analyzer. It realizes the functions of syntactic errors discovery, with indication of their type, with creating tables of constants and variables, with setting their initial values, transformation of the arithmetic expressions in encoded postfix record, ready for interpretation. The second module is an interpreter of the arithmetic expressions. It computes the values of the arithmetic expressions, using their postfix record, generated by the syntactic analyzer. In case a syntactic error is found, the editing program is automatically started.

The optimization modules realize the interactive method of the Modified Reference Point MRP-NIM [17, 18]; a modified method of Lagrange multipliers [1] for solving continuous nonlinear single-criterion problems; and a method of the feasible internal directions [14] for approximate solution of nonlinear integer single-criterion problems. That is why in the general case continuous Pareto optimal solutions and approximate (near) integer Pareto optimal solutions are found with the help of MONIP system..

The control program allows the DM to control the process of solving MO nonlinear problems with the help of two types of screens. The first type is connected with the initial phase of the computing process. The DM enters the name of the protocol file, in which all the current solutions are stored, and selects whether the initial solution will be automatically defined or entered by him/her. The last fact is important, because it enables the DM to continue the solution of a given problem from the moment of interrupt, if the latter has occurred. The second type of screens are main windows, with the help of which the DM can solve nonlinear and nonlinear integer MO problems. These windows display the values of the criteria, the type of optimization, and the deviations of the criteria values from the values in the solution, found at the previous iteration. The variables values and the type of Pareto optimal solutions found (continuous or integer), are also visualized. The lower left part of the window displays a command bar, which contains seven commands:

(A)sp (D)elta (C)ont (M)ore (V)erify (X)-value

The first two commands are connected with the entry of the aspiration levels or with the entry of the desired and acceptable alteration of the criteria values. Two windows appear below the command bar after selection of (A)sp or (D)elta.



The DM may check whether the input information is correct by (V)erify command. The command (X)-value checks the variables values in the solution obtained. With the help of (M)ore command the DM can visualize the objective functions or variables in groups, when their number is greater than eight.

(C)ont command allows the continuation of the computing process at a given iteration. Three variants are possible: In the first variant an integer solution is sought, close to the last continuous solution found. In this case no information is entered by the DM. In the other two variants, after entering the aspiration levels or the desired and acceptable alterations in the criteria values, the solution passes to the search for a new continuous or integer solution.

Since the solution of the nonlinear single-criterion problem requires considerable time, there exists a possibility for the computing process interruption, and later the use of the approximate solution, found until that moment. All the solutions found are stored in a protocol file and the DM accesses these solutions for analysis and evaluation by the control program.

MOIP and MONIP systems are written in C and FORTRAN 77 programming languages. They are realized on a modular principle and have a simple overlay structure. The control program is resident in the operating memory, while the other modules are activated only if needed. MOIP and MONIP systems are research systems. They attain very high level of DM's interface. It is a pity that DOS operating system is already quite seldom used. Due to this reason the application of these systems is quite small. But they have served as the basis for the development of the new professional systems MKO-1, MKO-2.

3. Multicriteria decision support systems of MKO family

The software systems MKO-1 and MKO-2 are intended to support the solution of linear and linear integer MO problems and are oriented to work under MS Windows operating system.

3.1. MKO-1 decision support system

MKO-1 software system is designed [22, 23] on the basis of the Classification-Oriented Interactive Methods COSP-LIM and COSP-IIM, developed at the DSS department of IIT-BAS. MKO-1 system consists of three main modules – a control program, optimization modules and interface modules.

The control program is an integrated software environment for creating, processing and storing of files, associated with MKO-1 files, and also for linking and execution of different types of software modules. The basic functional possibilities of the control program may be divided in three groups. The first group includes the possibilities to use standard MS Windows applications, menus and system functions – *File, Edit, View, Window, Help,* in the environment of MKO-1 system. The second group of functional possibilities includes the control of the interaction between the modules, realizing:

- creation, modification and storing of the files, associated with MKO-1 system, containing input data and data, connected with the process of MO linear and nonlinear integer problems solving;
- interactive solution of the entered MO linear and nonlinear integer problems;
- localization and identification of the errors, occurring in the process of operation with MKO-1 system.

The third group of functional possibilities of the control program includes the possibilities to visualize the information of the problem solved and the solutions found, as well as of the system operation as a whole.

The control program is constructed in MS Visual Basic software environment. There is a menu in the main form with the standard for MS Windows applications, drop down menus for files management, for editing, for windows management and Help. The system basic functions are realized with the help of several child forms and contextual menus. In order to communicate with the optimization modules, an independent class "CSolver" is designed, which is of type processor for data processing. The class contains methods for setting the input data, obtaining the output data and doing the corresponding setups for the type of the variables and the type of the solution obtained. The other main class, which is used in the system, is "CHistory" class. Its purpose is to create a structure, in which the results obtained at each step are stored – the criteria values, the variables values, the DM's preferences and the scalarizing problem generated by the method.

The optimization modules realize two classification-oriented interactive methods COSP-LIM and COSP–IIM [20, 27]; two simplex methods for solving continuous linear single-criterion problems [4, 10]; a method of "branches and bounds" type for exact solution of linear integer single-criterion problems [29]; and a method for approximate solution of linear integer single-criterion problems [11].

The interface modules ensure the dialogue with the DM in the entry and correction of the input data of the multicriteria problems being solved, and during the time of the interactive process of problem solving and the dynamic numerical and graphical visualization of the main parameters of this process. With the help of the editing module the descriptions of the criteria and constraints, as well as the type and limits of the variables alterations are entered, changed and saved. With the help of another interface module two types of graphical presentation of the information for the values of the criteria at different steps are displayed, as well as the possibilities for their comparison. There is dynamic Help, which provides specific information of the designation and the way to use each one of the fields and radio buttons.

MKO-1 system is installed under MS Windows, registered the extension "*.mlp" and associated with it. Thus on double click on a valid "*.mlp" file, the system will be started and this file will be loaded. There is a menu in the main window (Fig. 5) with the standard for MS Windows applications drop down menus and commands.

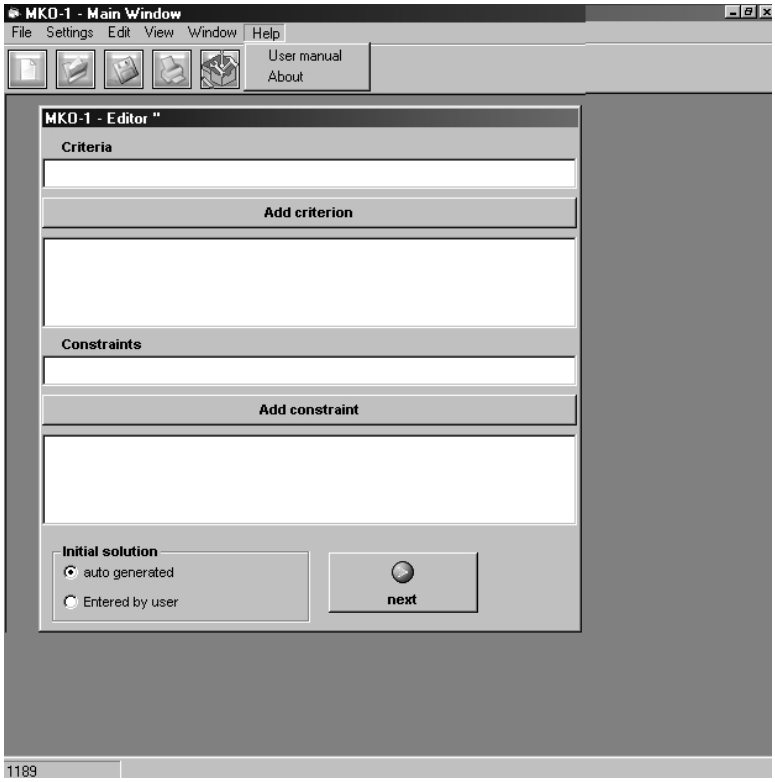


Fig. 5. MKO-1 main window

With their help the work with a new file is started or an existing "*.mlp" file is loaded and the operation will continue with the information it contains. The entry and correction of the problem criteria and constraints is done in the window of MKO-1 Editor. The syntax of entry of the initial problem is close to the mathematic description of a MO problem.

In order to generate an initial feasible solution, the DM is offered two possibilities (Fig. 5): In the group of radio buttons *Initial solution* either *Automatic generation* or *Entered by user* is selected. In case the button for automatic generation is activated, by *Next* button the main window for interactive solution of the problems is opened and the generated continuous initial solution is shown. If "*Entered by user*" radio button is activated, the pressing on *Next* button will open a window for setting the criteria initial values, after which the main window MKO-1 Solving appears. This window, presented on Fig. 6, is partitioned into several zones. In its upper part a bar with some buttons is located, with the help of which the main functions of the process of interactive solution of the linear and linear integer problems of MO, are accomplished. These buttons are: *Solve* – starts the optimization module for finding a new current solution by the system, solving the scalarizing problem, generated at this iteration; *Info* – visualizes in a separate window the values of the variables for the current solution considered; *Back* and *Forward* – navigation buttons. They give the DM the possibility to go back to previous steps and to review the solutions found. If the DM estimates, he/she can

start the process of search for any solution, previously found; *Var. Opt.* – opens a window with information and provides possibility to change the type and limits of alteration of the variables.

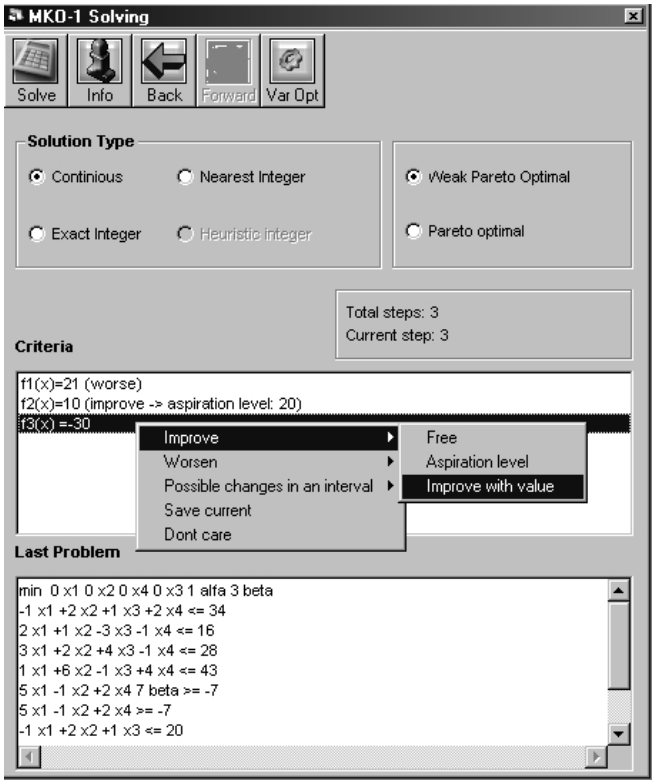


Fig. 6. Solving window of MKO-1

The next field of MKO-1 Solving window contains radio buttons for setting the solution sought: continuous, integer, approximate integer, nearest integer, and also weak Pareto optimal or Pareto optimal solution. Below them information is displayed with the number of the current step considered and the total number of executed steps.

After that two textual fields follow. In the first one the values of the criteria, obtained at the current step are displayed. It is also an operational field for setting DM's preferences when seeking a new solution. When any one of these criteria is selected, mouse right button clicking opens a contextual menu, where the DM sets the desired alteration in the value of this criterion for the next iteration. In case the choice is connected with the necessity to enter a concrete value, MKO-1 system opens an additional dialogue window and waits for the entry of the corresponding numerical information. In the second textual window the scalarizing problem, constructed by the algorithm and used to find the solution at the current step, is visualized. This information is useful for research and educational purposes.

In the menu of the main window with the help of buttons *Graphic*, *Settings*, *Print*, *Open* and *Store* some windows are displayed, in which the following is

realized: graphic comparison of the results, obtained at the different steps (Fig. 7), alteration of system parameters, printing of current and final results, saving of the results obtained. Fig. 7 shows the visual comparison of the criteria values, found at two selected steps with the help of the upper bar graphic.

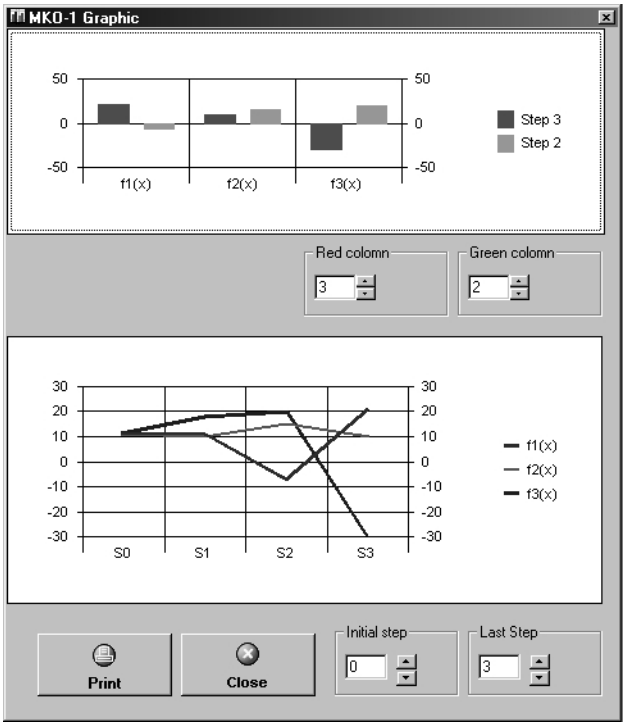


Fig. 7. Visualization of the results in MKO-1

The lower graphic indicates the alteration of the values of the separate criteria in a selected interval of steps during the process of search for a better solution.

When using interactive methods for solving MO problems, it is important to present the DM the information not only of the last solution found, but also about solutions, found at previous steps. Very often the DM should be able to "certify" how he/she has come to the most preferred solution. That is why the information of the input data of the problem solved, of the solutions, obtained at each step, of DM's preferences and of the constructed scalarization problems, saved in the files, associated with MKO-1 system, serves not only to restart an interrupted computing process, but also for documentation. With the help of the *Print* button in the main menu (Fig. 5), selective printing of information, pointed by the DM, can be realized.

MKO-1 software system is developed in C and Visual BASIC programming languages. The latter enables very qualitative interface with the DM. The classification-oriented interactive methods, included in the system, give the DM wide possibilities to set his/her preferences about the qualities of the most preferred solution. The user interface of MKO-1 system enables its operation by decision makers with different degree of qualification with respect to the methods and

software tools used. MKO-1 system can be applied both for education purposes and for real life problems solution as well.

3.2. MKO-2 decision support system

MKO-2 software system is developed on the basis of the generalized interactive method GENWS-IM [19, 30], developed at the DSS department of IIT-BAS and it is an extension of MKO-1 system. All functions of MKO-1 system, concerning the entry, correction, visualization, saving and printing of the input and current data, are preserved in MKO-2 system. In MKO-2 system the DM has the possibility to set his/her preferences about the criteria values in the search for new (weak) Pareto optimal solutions with the help of criteria weights, of ε-constraints, of desired and acceptable levels of the criteria values, of desired and acceptable directions of change in the criteria values, of desired and acceptable levels, directions and intervals of alteration of the criteria values. In order to realize these possibilities in MKO-2 system, different types of scalarizing problems are automatically generated. These scalarizing problems are automatically generated by the generalized scalarizing problems GENWS and GENS, altering their structure and the corresponding parameters. The structure and the organization of access to the file storing the data at the separate steps of the solution process, are more complex. From the viewpoint of the DM the differences between the software systems MKO-1 and MKO-2 consist only in the presence of additional windows in MKO-2 system, which give some supplementary possibilities to set his/her preferences. Figs. 8 and 9 show two of these windows. The window, presented on Fig. 8, is intended for selection of the way of setting DM's preferences. The DM may choose among five ways to set his/her preferences. Let us assume that he/she has decided to give the preferences by aspiration levels (reference point).

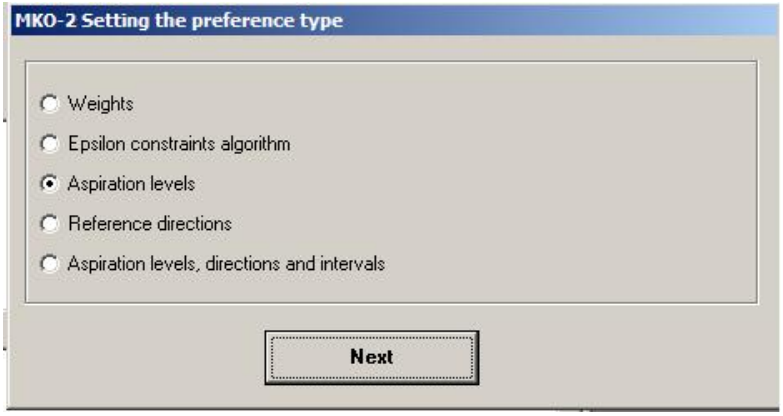


Fig. 8. Setting the DM's preferences in MKO-2

The window, shown on Fig. 9, gives a possibility to select the scalarizing problem from the set of scalarizing problems of the reference point – STOM [5], RP [28], GUESS [3] and MPR [18]. If the DM meets any difficulty in his/her choice, then by default he/she is proposed to select the well known nowadays scalarizing problem RP.

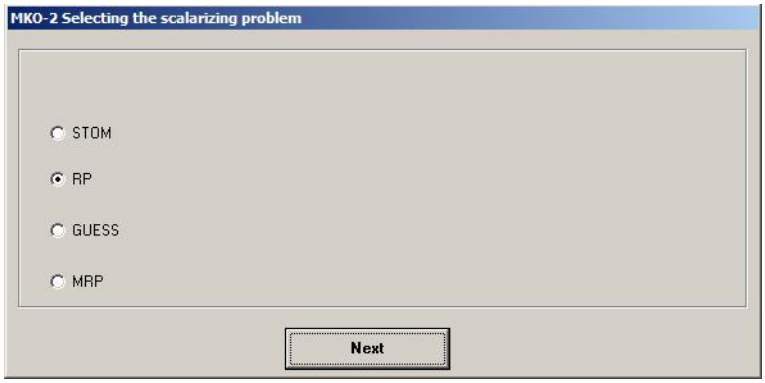


Fig. 9. Selection of the scalarizing problem in MKO-2

After that, by checking every one of the criteria, right-clicking on the mouse opens a contextual menu. Depending on the type of the scalarizing problem selected, the DM is asked to set the desired alteration of the value of this criterion for the next iteration (Fig. 10). In case the selection is connected with the necessity to enter a given value, MKO-2 system presents an additional dialogue window and waits for the entry of the corresponding numerical information by the DM.

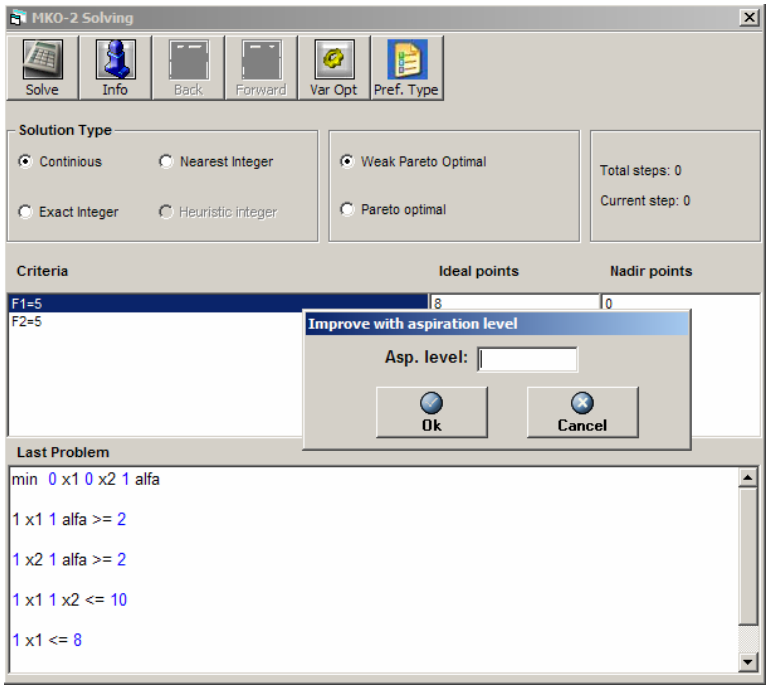


Fig. 10. Change of the DM's preference information in MKO-2

The interactive method GENWS-IM gives still more possibilities to improve the interface with the DM, in relation to the class of MO problems solved, and also in relation to the possibilities to set his/her preferences. It might also become the basis for creating an intelligent system supporting MO problems solving.

4. Multicriteria decision support systems of MKA family

The idea to develop the software systems of MKA family, supporting decision making of MA problems, is connected with the investigations and developments in IIT-BAS in the area of interactive methods for solving such class of problems [7]. The interactive methods are particularly appropriate for MA problems with a large number of alternatives and a small number of quantitative criteria, which are close to MO integer problems in their structure. The advantages of these methods are connected with the possibility given to the DM to control the process of search for the most preferred alternative, by expanding DM's possibilities to describe his/her local preferences and to evaluate the solutions obtained. Two versions of software systems, intended to solve MA problems are developed MKA-1 and MKA-2 [21]. In MKA-1 system, besides the interactive CBIM method [7], a weighting method is also included – AHP (Analytic Hierarchy Process) [9] and an outranking method – PROMETEE II [2], which belong to two of the most popular approaches for solving this class of multicriteria problems. MKA-1 system works with two types of criteria – quantitative and qualitative. MKA-2 system is an extension of MKA-1 system. One well known outranking method ELECTRE III [8] is added to it, and also the possibility to work with weighting and arranging criteria is expanded. That is why in order to describe the advantages and possibilities for operation with these MDMSS systems, only MKA-2 system will be discussed. It is programmed in MS Visual Basic and works under the operating system MS Windows. MKA-2 system consists of internal system modules, computing modules and interface modules

Internally the system modules contain all the global definitions of variables, functions and procedures of general purpose. The object possibilities of Visual Basic are applied in MKA-2 system, creating several classes, referring to internal-system structure. They are: a class for messages, which capsulates the output of error messages, of dynamic contextual help information and events registering in a debug window; a class of matrices with some specific procedures, necessary for AHP method; a class for storing specific information about the criteria in the methods PROMETHEE II and ELECTRE III; and also a class for storing the elements of the history of the interactive method functioning. The interface modules enable the interaction between MKA-2 system, the DM and the operating system. This interaction includes the entry of the data for the multictriteria problems, the entry of information, specific for the separate methods, visualization of the current solutions and of the final solution, graphical presentation of the solutions, printing, files read and write, multilingual support, etc. Four methods are realized in the computing modules – AHP, PROMETHEE II, ELECTRE III and CBIM.

The interface with the DM is realized on the principle of an advisor – successive windows (steps), each one with a distinctly defined function, which considerably aids and facilitates DM's operation with the system. The DM has the possibility to move forward to the next step, and also backward, to information already entered. The windows, that have to be accessed in more than one stage of DM's work with the system, are included in the menu or in the tools bar. MKA-2

system provides dynamic contextual help information. It gives brief description of each visual component just by dragging the mouse on it.

The system gives the possibility to store in a file the input data of every multiciteria problem and the data of the solution process as well. In this way the process of the multicriteria problem solution may be interrupted at every phase and activated at any time from the place of interrupt. MKA-2 system has relatively rich functions for printing. Every section of the data, entered or computed, may be printed.

The main window (Fig. 11) contains a drop down menu with the following commands: *File* (*New problem*, *Open*, *Save*, *Print and Exit*); *Settings* (*Language and Starting*); *Review* (*Wizard*, *Messages*, *Method selection and Graphics*); *Window* (*Horizontal view*, *Vertical view and Cascade view*); *Help* (*User's guide and About the program*). The main window contains a bar with the buttons *New problem*, *Open*, *Save*, *Print*, *Settings* and *Graphics* for quick access to the most frequently used system functions.

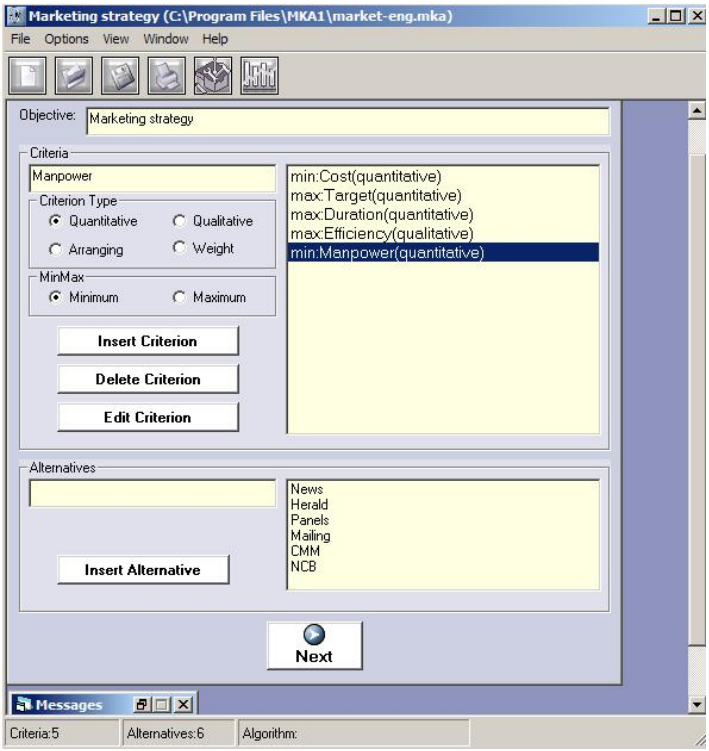


Fig. 11. The main window of MKA-2

The system creates and opens files with "*.mka" extension. The data entry of a new problem is started by the command *New problem* in *File* menu, and *Open* command loads an already existing "*.mka" file and continues the work with the information, saved in it. Saving the currently solved problem in "*.mka" file is done by *Save* command. When a solution of the problem is obtained by any of the

methods, this solution can be stored in a file, saving also the information about DM's preferences, used for its finding. In this way the selection of every solution can be documented.

By pressing *Next* button on window *Initial entry of criteria and alternatives*, the windows for successive entry of the values of the alternatives with respect to every criterion are invoked. The entry of a quantitative criterion is done, setting numerical values of the separate criteria. The entry of the values for the qualitative criteria is done by apriori defined qualitative evaluations, accessed in a drop down list.

Fig. 12 shows the entry of the evaluations of the alternatives with respect to a qualitative criterion.

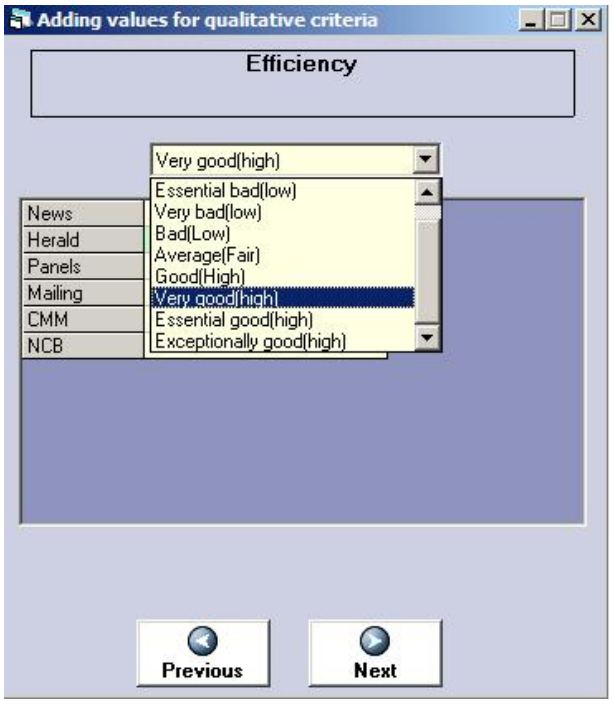


Fig. 12. Entering the values of a qualitative criterion

When entering the values of a weighting criterion, a window *Relative importance of the alternatives* is opened, with the help of which the DM has to compare all the alternatives in pairs in relation to the current criterion. For the arranging criterion the alternatives are ranked by their importance with respect to the criterion considered.

After filling in the whole information about the alternatives, a window is automatically opened, displaying the names of the dominated alternatives and the window *Method selection* appears. The method needed is selected with the help of a group of four radio buttons. The work with each one of the methods is done in a separate window, in which the DM can set the information of his/her preferences required for the respective methods in the most convenient and comprehensible way.

If Analytic Hierarchical Method (AHP) is selected, a window *Relative importance of the criteria* appears (Fig. 13), with the help of which the DM must compare in pairs all the criteria on the basis of their importance for him/her. A table is presented on the screen, the left column of which contains all the criteria pairs, and the right column indicates the relative importance of the first criterion in a given criteria pair with respect to the second one. The relative importance is defined with the help of a slider, which is located to the right, below an image of scales. In case the slider is to the left, this means that the first criterion is more important than the second one, and if it is to the right – the opposite. The *Next* button calls the next window, where the information already entered about the relative importance of the criteria is displayed and the relative criteria weights, computed on its basis. The final result is alternatives ranking in accordance with the preferences entered.

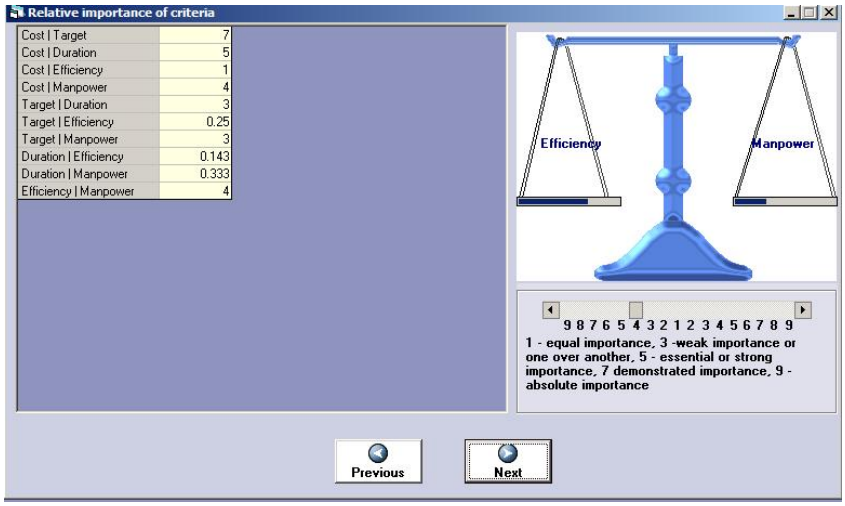


Fig. 13. Estimation of the relative importance of criteria by the DM

When CBIM method is selected, there are two possibilities to set the initial solution. In the first case, if *Automatic generation* is opened, the window *Preferences setting* appears, in which the automatically selected currently preferred alternative is shown. If *Entered by user* is selected, the window *Generated currently preferred alternative* is opened, in which the DM chooses the initial currently preferred alternative. Pressing of *Next* button opens window *Preferences setting* (Fig. 14), in which the alternative selected is shown.

In window *Preferences setting*, the values of the criteria for the current preferred alternative are visualized and the DM sets his/her preferences for alteration of the criteria values. After selecting a given criterion, by right clicking on the mouse, a contextual menu appears, in which the DM sets the desired or acceptable alteration in the value of this criterion for the next iteration in the search for a better alternative. The desired or acceptable alterations in the values of this criterion may be: *Improvement* – free, *Improvement* – with an aspiration level; *Improvement* – with a maximal value; *Deterioration* – free; *Deterioration* – with an aspiration level; *Deterioration* – with a maximal value; *Alteration in an interval* – Add/Subtract value; *Alteration in an interval* – Select aspiration value; *Save current*

value; *Free alteration*. In case the choice is connected with the necessity to enter a given value, an additional dialogue window appears and the input of the corresponding numerical information is expected. The button *Next* executes one iteration of the method and window *Generated currently preferred alternative* appears.

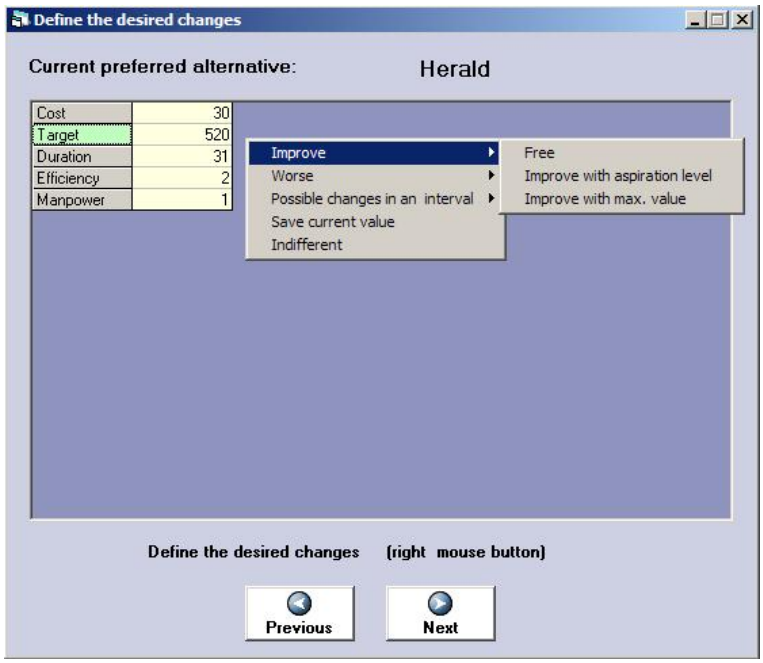


Fig. 14. Defining by DM the changes in the preferences information

A table with alternatives is presented, among which the DM has to make his choice. The alternatives, that are unfeasible with respect to the preferences set and cannot be selected, are coloured in blue. The alternative, which meets to the greatest extent DM's preferences, given at the previous iteration, is pointed out. If the DM wishes, he may see the feasible alternatives, ranked according to their closeness to the desired criteria values, with the help of the *Result* button. From these alternatives the DM selects the new currently preferred alternative, that may be different from the one suggested by the system. The *Next* button leads to window *Preferences setting* for execution of the next iteration.

MKA-2 system provides the possibility to store in a file the input data of every multicriteria problem and the data of its process solution. Thus the process of the multicriteria solution may be interrupted at every stage and activated at any time from the place of the interrupt. MKA-2 system has comparatively large functions for print. Every section of the data, entered or computed, can be printed.

MKA-1 and MKA-2 software systems are characterized by their user friendly interface. With their help various MA problems can be modeled and solved. MKA-1 and MKA-2 can be used for educational purposes and for real life problems solving as well.

5. Directions for future developments

The algorithmic insurance of MDSS on one side, and the user-friendly interface suggested – on the other, enable DMs with different degree of qualification to solve interactively a wide class of linear, nonlinear, linear integer and convex nonlinear integer problems of MO, and MA problems as well. MO problems might contain a different number and type of the criteria, a different number and type of the variables (continuous and integer) and a significant number of constraints. MA problems might contain a different number and type of the criteria and a considerable number of alternatives. In the separate software systems the algorithms are included in such a way, that from a DM's viewpoint they are an integrated SOLVER. The systems include interface modules that facilitate the DM in describing his/her local preferences, in evaluating the obtained Pareto optimal or weak Pareto optimal solutions (alternatives), in the analysis of the solution process of the multicriteria problems. The control programs of the systems ensure the functioning of the optimization (computing) and interface modules. Integrated software systems are developed at the DSS department at IIT-BAS [24, 25, 26], which combine some software tools, providing possibilities for the solution of MO, as well as of MA problems.

The future attempts will be directed to the development of web-based versions of these software systems that will make them up-to-date tools, supporting the solution of various problems in different areas of business and economy. The applying of new, more efficient algorithms will also expand the possibilities for their usage.

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