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## A MULTICRITERIA DECISION SUPPORT SYSTEM *MULTIDECISION-1*<sup>1</sup>

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**Abstract:** *The present paper describes some basic elements of the software system developed (called MultiDecision-1), which consists of two separate parts (the systems MKA-1 and MKO-1) and which is designed to support decision makers in solving different multicriteria analysis and multicriteria optimization problems. The class of the problems solved, the system structure, the operation with the interface modules for input data entry and the information about DM's local preferences, as well as the operation with the interface modules for visualization of the current and final solutions for the two systems MKA-1 and MKO-1 are discussed.*

**Author Keywords:** *Multicriteria analysis, Multicriteria optimization, Multicriteria decision support system.*

**ACM Classification Keywords:** *H.4.2 Information Systems Applications: Types of Systems: Decision Support.*

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### Introduction

Multicriteria decision making problems can be divided [Vincke, 1992] into two separate classes depending on their formal statement. In the first class of problems, a finite number of alternatives are explicitly given in a tabular form. These problems are called discrete multicriteria decision making problems or multicriteria analysis problems. In the second class, a finite number of explicitly set constraints in the form of functions define an infinite number of feasible alternatives. These problems are called continuous multicriteria decision making problems or multicriteria optimization problems.

Different methods have been developed to solve multicriteria analysis problems, which can be divided into several groups. A great number of the methods developed up to now can be grouped in three separate classes: weighting methods, outranking methods and interactive methods. Each one of these methods has its advantages and shortcomings, connected mostly with the ways of deriving information by the decision maker (DM) regarding his/her local and global preferences. The main element in the weighting methods is the way of determining the criteria weights, which reflect DM's preferences to the highest degree. Many methods for criteria weighting have been developed. A value tradeoff method is proposed in [Keeney and Raiffa, 1976]. Several versions of the analytic hierarchy process (AHP method) are developed in [Saaty, 1980], [Saaty, 1994], using pair-wise criteria comparison. A direct ranking and rating method is proposed in [Von Winterfeldt and Edwards, 1986], in which the DM first ranks all the criteria according to their importance. The weighting methods use a DM's preference model, which does not allow the existence of incomparable alternatives and the preference information obtained by the DM (different types of criteria comparison) is sufficient to determine whether one of the alternatives must be preferred or whether the two alternatives are equal for the DM. The outranking methods use a DM's preference model, which allows the existence of incomparable alternatives and the preference information obtained by the DM may be insufficient to determine whether one of the alternatives is to be preferred or whether the two alternatives are equal for the DM. The criteria and the alternatives are not compared by the DM in these methods,

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but he/she has to provide the so-called inter- and intra-criteria information. Some of the well-known representatives of the outranking methods are TACTIC method [Vansnick, 1986], PROMETHEE I-II methods [Brans and Mareschal, 1990], ELECTRE I-IV methods [Roy, 1991] and others. In order to solve multicriteria analysis problems with a large number of alternatives and a small number of criteria, the "optimizationally motivated" interactive methods have been suggested [Korhonen, 1988], [Sun and Steuer, 1996], [Narula et al., 2003].

One of the most developed and widespread methods for solving multicriteria optimization problems are the interactive methods [Gardiner and Vanderpooten, 1997], [Miettinen, 1999]. This is due to their basic advantages – a small part of the Pareto optimal solutions must be generated and evaluated by the DM; in the process of solving the multicriteria problem, the DM is able to learn with respect to the problem; the DM can change his/her preferences in the process of problem solution. The interactive methods of the reference point (direction) and the classification-oriented interactive methods [Miettinen, 1999] are the most widely spread interactive algorithms solving multicriteria optimization problems. Though the interactive methods of the reference point are still dominating, the classification-oriented interactive methods enable the better solution of some chief problems in the dialogue with the DM, relating to his/her preferences defining, and also concerning the time of waiting for new non-dominated solutions that are evaluated and selected.

The software systems supporting the solution of multicriteria analysis and multicriteria optimization problems can be divided in two classes – software systems with general purpose and problem-oriented software systems. The general-purpose software systems aid the solution of different multicriteria analysis and multicriteria optimization problems by different decision makers. One method or several methods from one and the same group are usually realized in them for solving multicriteria analysis and multicriteria optimization problems. This is due to the following two reasons:

- in the methods from the different groups, different types of procedures are used to get information from the DM, which leads to considerable difficulties in the realization of appropriate user's interface modules in the software systems;
- the designers of the software systems are usually interested in the realization of their own method (methods) or have distinct preferences towards methods from one and the same group.

The problem-oriented multicriteria analysis systems are included in other information-control systems and serve to support the solution of one or several types of specific multicriteria analysis problems. Hence, some simplified user's interface modules are usually realized in them. That is why methods from different groups of multicriteria analysis methods are included in some of these systems.

Well-known general-purpose software systems supporting the solution of multicriteria analysis problem are the following systems VIMDA [Korhonen, 1988], ELECTRE III-IV [Roy, 1991], Expert Choice [Saaty, 1994], HIVIEW [Peterson, 1994], PROMCALC and GAIA [Brans and Mareschal, 1994], Decision Lab [Brans and Mareschal, 2000], Web-HIPRE [Mustajoki and Hamalainen, 2000]. One representative of the problem-oriented systems, called Agland Decision Tool, is discussed in [Parsons, 2002].

Some well-known general-purpose software systems, which solve problems of multicriteria optimization, are the following systems VIG [Korhonen, 1987], CAMOS [Osyczka, 1988], DIDAS [Lewandowski and Wierzbicki, 1989], DINAS [Ogryczak et al., 1992], MOLP-16 [Vassilev et al., 1993], MONP-16 [Vassilev et al., 1993], LBS [Jaszkiwicz and Slowinski, 1994], MOIP [Vassilev et al., 1997], NIMBUS [Miettinen and Makela, 2000]. The first type comprises the interactive algorithms of the reference point and of the reference direction [Wierzbicki, 1980], [Korhonen, 1987]. These are systems such as DIDAS, VIG, CAMOS, DINAS and LBS. The second type of interactive algorithms includes the classification-oriented algorithms [Benayoun et al, 1971], [Narula and Vassilev,

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1994], [Miettinen, 1999], [Vassileva et al., 2001]. These interactive algorithms are built in the systems NIMBUS, MOLP-16, MONP-16 and MOIP.

The present paper describes some basic elements of the software system developed (called *MultiDecision-1*), which consists of two separate parts (the systems *MKA-1* and *MKO-1*) and which is designed to support decision makers in solving different multicriteria analysis and multicriteria optimization problems. The class of the problems solved, the system structure, the operation with the interface modules for input data entry and the information about DM's local preferences, as well as the operation with the interface modules for visualization of the current and final solutions for the two systems *MKA-1* and *MKO-1* are discussed.

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### Functions, Structure and User's Interface of *MultiDecision-1* System

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The system *MKA-1*, the first part of the system *MultiDecision-1*, is designed to support decision makers in solving different multicriteria analysis problems. In *MKA-1* system an attempt has been made to realize three methods – a weighting method, an outranking method and an interactive method. These methods are respectively AHP method [Saaty, 1994], PROMETHEE II method [Brans and Mareschal, 1990] and CBIM method [Narula et al., 2003]. They are the most often used methods in the three groups of methods. The interface modules in the system allow the successful realization of different types of procedures for obtaining information by the DM and also for the entry of different types of criteria – quantitative, qualitative and ranking criteria.

The system *MKO-1*, the second part of the system *MultiDecision-1*, is designed to support decision makers in solving linear and linear integer problems of multicriteria optimization. Three classification-oriented interactive algorithms [Vassilev et al., 2003], [Vassileva, 2004] are included in *MKO-1* system, which enable the DM to define not only desired and acceptable levels of the criteria (as in reference point interactive algorithms), but also desired and acceptable intervals and directions of alteration in the values of the separate criteria. The first interactive algorithm, called GAMMA-L is intended to solve linear problems of multicriteria optimization. The second and the third algorithms, called GAMMA-I1 and GAMMA-I2 respectively, are designed to solve linear integer multicriteria optimization problems. In solving integer problems of multicriteria optimization, the dialogue with the DM is influenced largely by the time, during which he/she is expecting new non-dominated solutions for evaluation and choice. This is so, because the single-criterion integer problems [Nemhauser and Wolsey, 1988], solved at a given iteration, are NP-problems and the time for their exact solution is an exponential function of their dimension. When the solution time proves to be much longer, the DM may lose patience and interrupt the dialogue, refusing to look for a new solution. The classification-oriented interactive algorithms GAMMA-I1 and GAMMA-I2 allow the solving of single-criterion problems at each iteration, with the following two basic properties: a known initial feasible solution and a comparatively "narrow" feasible region. The properties of this type of single-criterion problems, above indicated, facilitate their solution, and also enable the use of approximate single-criterion algorithms. There exists at that high probability that the solutions found will be close to or coincide with the non-dominated solutions of the multicriteria problem.

The system *MKA-1* consists of solving modules, interface modules and internal-system modules. This modularity enables greater flexibility when including new methods or new interface realizations. The *MKA-1* system contains three solving modules. Every module encloses a software realization of one of the three methods - AHP method, PROMETHEE II method and CBIM method and help procedures for each method as well.

The system modules contain all global definitions of variables, functions and procedures of general purpose. The object possibilities of Visual Basic are utilized in *MKA-1* system, creating several classes with respect to internal system structures. They are: a class for messages, which capsules the output of error messages; dynamic context help information and registering of events in the debug window; a class matrix with some specific

procedures, necessary for AHP method; a class for storing the information specific for the criteria in PROMETHEE method and a class for storing system site. The renewal function starts the installation procedure.

The screenshot shows the 'PROMETHEE II Method' software interface. It is divided into several sections:

- Evaluation Table:** A table with 6 columns: Cost, Target, Duration, Efficiency, and Manpower. The rows represent different marketing actions: News, Herald, Panels, Mailing, CMM, and NCB. Each cell contains a numerical value and a qualitative rating in parentheses.
- Properties of criterion: Cost:** A panel on the right with various settings:
  - Criterion Type: Quantitative
  - Min/Max: Minimum
  - Weight: 1
  - Preference Function: V-Shape with indiff. (indicated by a 'V' icon)
  - Indifference Threshold: 10 (with a 'Max Val - Min Val' label)
  - Preference Threshold: 40 (with a '62' label)
  - Gaussian Threshold: (empty)
  - Threshold Unit:  Absolute,  Percent
  - Average Performance: 59
  - Unit: 1 000 USD
- Legend:** A section at the bottom left with a green square for 'Min value(rating)' and a red square for 'Max value(rating)'. It also includes a 'Quantitative's Scale' with 9 levels: 1- Exceptionally bad(low), 2- Essential bad(low), 3- Very bad(low), 4- Bad(Low), 5- Average(Fair), 6- Good(High), 7- Very good(high), 8- Essential good(high), 9- Exceptionally good(high).
- Navigation Buttons:** 'Previous', 'Set Values', and 'Solve' buttons are located at the bottom right.

Fig. 1. MKA-1 system PROMETHEE solving windows

The interface modules ensure the interaction between *MKA-1* system, the DM and the operating system. This interaction includes the entry of the data for the multicriteria problems, the entry of information specific for every method, information about DM's preferences, visualization of the current results and of the final result, graphical presentation of the solutions, print out, reading and storing of files, multi-language support, etc. Fig. 1 shows a window with DM's preferences in operation with PROMETHEE II method for one real multicriteria analysis problem, concerning the selection of an appropriate marketing action for advertising of bicycle manufacturing company products [Brans and Mareschal, 2000].

The interface with the DM is realized on the principle of an adviser – a sequence of windows (steps), each one with a distinctly expressed function, which considerably assists and facilitates DM's work. The DM has the possibility to move forward to a following step and also backward; returning for some corrections to the information already entered. The windows, which must be accessible in more than one stage of DM's operation with *MKA-1* system, are included in the menu or in the instruments band. *MKA-1* system possesses dynamic context help information. It gives a brief description of every visual component just by dragging the mouse over it. In addition to this, a debug window is used, that outputs service information about the system internal processes. It can be printed out or stored in a text file. This allows the obtaining of exact debug information when an error occurs. *MKA-1* enables the storing in a file of the input data for every multicriteria problem and of the data about the solution process. Thus, the solution process of a multicriteria problem can be interrupted at any stage and activated from the place of its interruption at any time. *MKA-1* system has comparatively rich printing functions – every piece of the data (entered or computed) may be printed. In this way the entire process of decision making

is documented – you can review the input data of the multicriteria problem being solved, the DM's preferences entered, the current values obtained, and the final result also, which on its turn can be printed out in the form of values or graphics.

*MKO-1* system consists of the following three main parts: a control program, optimization modules and interface modules. The control program is an integrated software environment for creating, processing and saving of files associated with *MKO-1* system (ending by *\*.mko* extension) and also for linking and executing different types of software modules. The basic functional possibilities of the control program can be divided into three groups. The first group includes possibilities to use the standard for MS Windows applications menus and system functions – "File", "Edit", "View", "Window", "Help" and others in system own environment. The second group of control program facilities includes the control of the interaction between the modules realizing: creating, modification and saving of *\*.mko* files associated with *MKO-1* system, which contain input data and data concerning the process and the results from solving multicriteria linear and linear integer problems; interactive solution of the multicriteria linear and linear integer problems which have been entered; localization and identification of the errors occurring during the system operation. The third group of the functional features of the control program includes possibilities for visualization of important information, concerning the DM and the system operation as a whole.

The optimization modules realize three classifications oriented interactive algorithms GAMMA-L, GAMMA-I1 and GAMMA-I2, and also exact and approximate single-criterion algorithms solving problems of linear and linear integer programming.

The interface modules realize the dialogue between the DM and *MKO-1* system during the entry and correction of the input data necessary for the multicriteria problems during the interactive process of these problems solution, and also for the dynamic visualization of the main parameters of the process. An editing module serves to enter, alter and store the descriptions of the criteria, of the constraints, and also of the type and bounds of variables alteration. Another interface module enables the setting of DM's local preferences for alteration in the values of the separate criteria. A third interface module realizes two types of graphic presentation of the information about the values of the criteria at different steps and the possibilities for comparison. Dynamic Help is provided, which outputs specific information about the purpose and way of use of the fields and radio buttons in a separate window.

*MKO-1* system is working under MS Windows. It can be added to *Programs* group and/or with a *Desktop* icon, from where it can be started. The system registers the *\*.mko* extension and associates it. Thus, at double clicking on a valid *\*.mko* file, the system will be started and this file will be loaded. There is a menu in the main window with the standard for MS Windows drop-down menus and commands. With their help, the operation of a new file is started or an existing *\*.mko* file is loaded and the operation may continue with the information stored in it.

The entry and correction of the problem criteria and constraints is realized in *"MKO-1 Editor"* window. Every criterion and every constraint is entered separately in the respective text field for edition. Syntax check is accomplished when they are added to the data already entered. The syntax accepted is similar to the mathematical record of this class of optimization problems. The type of the optimum looked for is entered first – "min" or "max". After that, the digital coefficient with its sign is entered, followed by the variable name it refers to. The variables names can be an arbitrary set of letters and numbers. Each one of these elements is separated by a space. The constraints have similar syntax – digital coefficients and variables names are successively entered. The type of the constraints is defined by some of the symbols " $\leq$ ", " $\geq$ " or " $=$ ". By double clicking on the constraint or criterion already entered, they are transferred to the editing field again, if subsequent corrections are necessary.

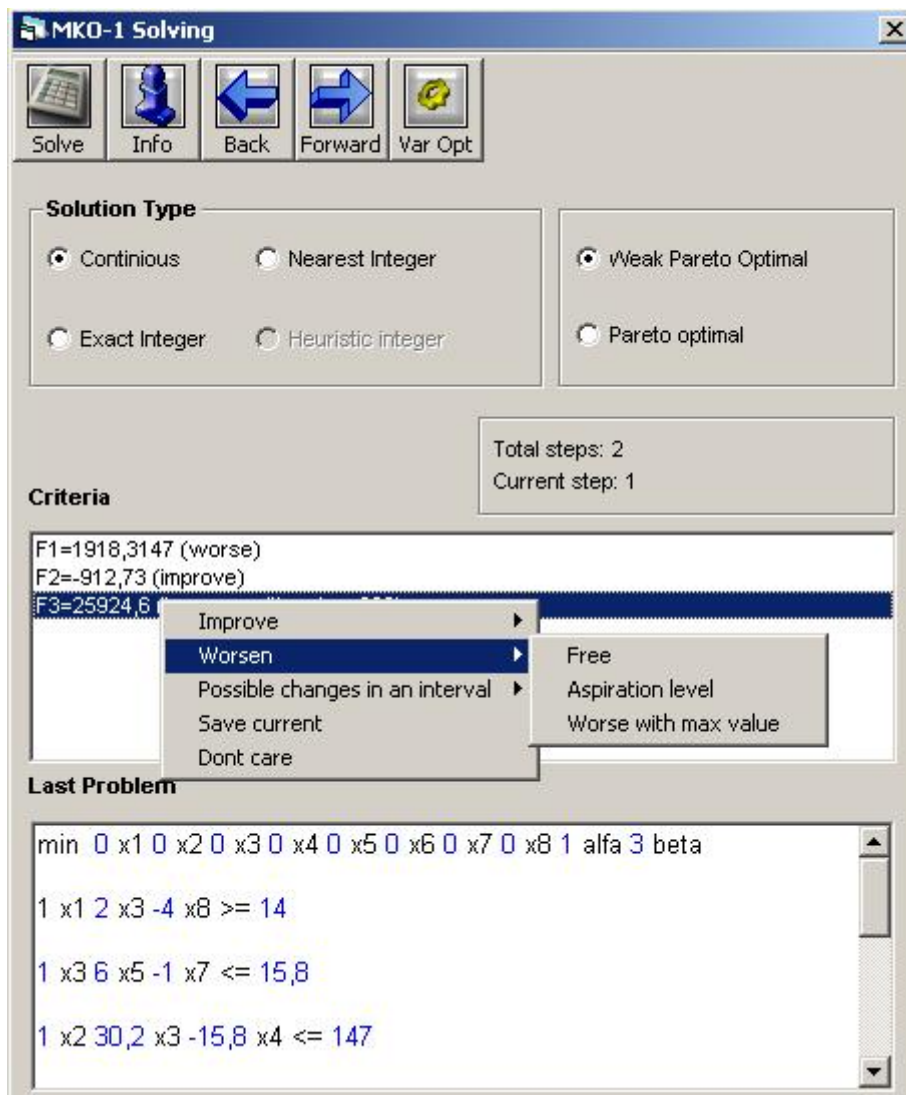


Fig. 2 MKO-1 Solving window

The interactive problems solving is realized in "MKO-1 Solving" window. "MKO-1 Solving" window is divided into several zones (Fig. 2). Its upper part contains a band with buttons that realize the main functions of the process for interactive solution of multicriteria linear and linear integer problems.

The next field of "MKO-1 Solving" window contains radio buttons for setup of the MKO-1 solution looked for: continuous, integer, approximate integer, the closest integer, as well as weak Pareto optimal or Pareto optimal. Below them information is found about the time of the system operation for the current problem in seconds, the number of the step being currently considered and the total number of the executed steps.

Two text fields follow. The first one outputs successively the values of the criteria obtained at the current step. It is an operating field where DM's preferences relating to the search of the next solution are set. After marking each one of the criteria, a context field is opened with the help of the mouse right button, where the DM sets the desired alteration in the value of this criterion at the following iteration. In case the selection is connected with the necessity to enter a particular value, MKO-1 system opens an additional dialogue window and waits for the entry of the corresponding digital information.

When interactive algorithms are used for multicriteria optimization problems solving, it is an advantage to present information not only about the last solution found, but also about the process of search, as well as about all the previous steps. Given that some significant solutions are made on the basis of these results, it is important for the DM to be able to "testify" how he has reached this solution. That is why the information about the interactive process of multicriteria optimization problem considered, which consists of the problem input data, the solutions obtained at each step, the preferences set by the DM for a new search and the constructed scalarizing problems, saved in "\*.mko" files, associated with *MKO-1* system serve not only for restarting an interrupted solution process, but also for documentation. "Print" command from the main menu can be used for selective print of the type of information chosen by the DM.

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## Conclusion

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*MultiDecision-1* system is designed to support the DM in solving different multicriteria analysis and multicriteria optimization problems. *MKA-1* system is designed to support the DM in modeling and solving problems of multicriteria ranking and multicriteria choice. The integrating of three different types of methods expands DM's possibilities to set his/her preferences about the quality of the most preferred solution. *MKO-1* system is designed to model and solve linear and linear integer problems of multicriteria optimization. The interactive classification-oriented algorithm included in the system offers to the DM wide possibilities to set his/her preferences about the qualities of the most preferred solution. The user-friendly interface of *MKA-1* system and *MKO-1* system facilitates the operation of DMs with different qualification level relating to the analysis and the optimization methods and software tools. *MKA-1* and *MKO-1* systems can be used for the purposes of education and for experimental and research problems solving as well.

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## GENERALIZED SCALARIZING PROBLEMS *GENS* AND *GENSLEX* OF MULTICRITERIA OPTIMIZATION<sup>1</sup>

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**Abstract:** *Generalized scalarizing problems, called GENS and GENSLEX, for obtaining Pareto optimal solutions of multicriteria optimization problems are presented in the paper. The basic properties of these scalarizing problems are described. The existence of single-criterion problems with differentiable objective functions and constraints, which are equivalent to GENS and GENSLEX scalarizing problems, are pointed out.*

**Keywords:** *Multicriteria optimization, Interactive methods, Multicriteria decision support systems.*

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### Introduction

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Various real problems can be modelled as multicriteria optimization problems. In multicriteria optimization problems several criteria are simultaneously optimized in the feasible set of alternatives. In the general case, there does not exist one alternative, which optimizes all the criteria. There is a set of alternatives however, characterized by the following: each improvement in the value of one criterion leads to deterioration in the value of at least one other criterion. This set of alternatives is called a set of the Pareto optimal alternatives (solutions). Each alternative in this set could be a solution of the multicriteria optimization problem. In order to select one alternative, it is necessary to have additional information set by the so-called decision maker (DM).

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