

Multiobjective Optimization Software System

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1. Introduction

Among the well-known systems, which solve problems of multicriteria optimization, the systems VIG, NIMBUS, DIDAS, CAMOS, LBS, DINAS, ADBASE, MOLP-16, MONP-16, MOIP, MKO-1 can be pointed out [2, 8]. Each multicriteria optimization system contains control modules, interface modules and optimization modules. The optimization modules realize different multicriteria and single criterion algorithms. In most of the multicriteria optimization systems developed up to now, basic attention is paid to the interactive multicriteria algorithms. Two types of interactive multicriteria algorithms are included in these systems: the first type comprises interactive algorithms of the reference point and of the reference direction. These are systems such as DIDAS, VIG, CAMOS, DINAS, LBS. The second type of interactive algorithms includes classification based algorithms. These interactive algorithms are built in systems NIMBUS, MOLP-16, MONP-16, MOIP, MKO-1.

The new programming languages and operating systems make possible the considerable improvement of the control programs and interface modules of the multicriteria decision support systems, so that the possibilities above described are realized. The description of DM's local preferences and the generating of new solutions for evaluation however depend to a higher degree on the type of the multicriteria and single-objective optimization methods and algorithms included in the system. As shown in [2], the major part of the systems developed up to now include multicriteria methods of the reference point and are intended to solve continuous problems of the multicriteria optimization. This has significantly influenced the design of these systems with respect to the input data entry, the interactive solution of the multicriteria problems and the visualization of the current and final results.

In order to solve a multicriteria optimization problem, a (weak) Pareto optimal solution has to be obtained (this is a solution where it is impossible to improve the value of one criteria without worsening the value of some other).

Starting from the current (weak) Pareto optimal solution, the generalized scalarizing [5] problem GENWS may be used. Altering some parameters of the

generalized scalarizing problem GENWS the following known scalarizing problems can be obtained: the scalarizing problem of the weighted sum WS; the scalarizing problem of ε -constraints EO; the scalarizing problem STEM; the scalarizing problem STOM; the scalarizing problem of the reference point RP; the scalarizing problem GUESS; the scalarizing problem MRP; the external reference direction scalarizing problem RD3; the classification-oriented scalarizing problem NIMBUS; the classification-oriented scalarizing problem DALDI.

On the basis of the generalized scalarizing problem GENWS, a generalized interactive [6] algorithm GENWS-IM with variable scalarizations and parameterization could be designed, having the following characteristics:

- ◆ the DM may set his/her preferences with the help of the criteria weights, ε -constraints, desired and acceptable levels of change of the criteria values, desired and acceptable levels, directions and intervals of alteration in the criteria values, etc.;
- ◆ during the process of the multicriteria problems solving, the DM may change the way of presenting his/her preferences;
- ◆ starting from one and the same current Pareto optimal solution and applying different scalarizing problems (with respective alteration of GENWS), the DM may obtain different new Pareto optimal solutions at a given iteration, and this opportunity is especially useful in education and in comparison of different scalarizing problems.

2. MKO-2 software system

MKO-2 software system is developed on the basis of the generalized interactive algorithm GENWS-IM. The first version of the system MKO-2 software system is designed to aid the solution of linear and linear integer problems for multicriteria optimization only and it is oriented towards operation under the control of MS Windows operating system. MKO-2 software system consists of three main groups of modules – a control program, optimization modules and interactive modules.

The control program is integrated software environment for creation, processing and storing of files associated with MKO-2 system, as well as for linking and execution of different types of software modules. The basic functional possibilities of the control program may be separated in three groups. The first group includes the possibilities to use the applications, menus and system functions being standard for MS Windows – “File”, “Edit”, “View”, “Window”, “Help”, in the environment of MKO-2 system. The second group of functional possibilities encloses the control of the interactions between the modules realizing: creation, modification and storing of files, associated with MKO-2 system, which contain input data and data connected with the process of solution of linear and linear integer multicriteria optimization problems entered; localization and identification of the errors occurring during the process of operation with MKO-2 system. The third group of functional possibilities of the control program includes the possibilities for visualization of essential information about the DM and information of the system operation as a whole.

The optimization modules realize the generalized interactive algorithm GENWS-IM, two simplex algorithms solving continuous single-criterion problems [3] an algorithm of “branches of bounds” type for exact solution of linear integer single-criterion problems [9] and an algorithm[4] for approximate solution of linear integer single-criterion problems.

The interface modules provide the dialogue between the DM and the system during the entry and correction of the input data of the multicriteria problems solved, during the interactive process of these problems solution and for dynamic numerical

and graphical visualization of the main parameters of this process. With the help of an ending module the descriptions of the criteria and constraints are input, altered and stored, and also the type and limits of the variables alteration. Another interface module serves to supply two types of graphic presentation of the information about the values of the criteria at the different steps, as well as the possibilities for their comparison.

One of the main functions of MKO-2 system is to enable the extension of DM's possibilities to set his/her preferences with the help of criteria weights, ε -constraints, desired and acceptable directions of change of the criteria values, desired and acceptable levels, directions and intervals alteration of the criteria values. Twelve scalarizing problems are generated in MKO-2 system in order to realize these possibilities. Depending on DM's preferences, these scalarizing problems are automatically generated by the generalized scalarizing problem GENWS with the help of a change in their structure and their parameters.

MKO-2 system presents the DM different windows intended for entry and correction of the problem criteria and constraints, for setting his/her preferences. Figs.1-4 shows four of these windows. The window presented in Fig.1 is the basic window of the editor for input data entry – “MKO-2 Editor”. It was used to set the data of a real multicriteria problem for operative planning of the production program of a spinning department in a textile enterprise (V a s s i l e v a [6]), a part of this data being indicated on the screen.

The window presented in Fig. 2, is designed to identify the type of DM's preferences. The DM may select among five types of preferences and let assume that he/she has selected to set the preferences by aspiration levels (reference point). The window shown in Fig. 3 is intended for selection of the scalarizing problem from the set of already known scalarizing problems of the reference point.

In order to enter the different types of DM's preferences, different windows are used. The window presented in Fig. 4, is designed to enter DM's preferences with the help of desired or acceptable levels of the criteria values (operating with the reference point scalarizing problem). The screen shows the setting of a new aspiration level for the value of the third criterion. The window presented in Fig. 5, is designed to enter DM's preferences in the form of desired and acceptable levels, directions and intervals of alteration in the criteria values (operating with COSP scalarizing problem). The screen indicates the defining of free improvement for the value of the third criterion.

MKO-2 software system is designed to aid the solution of linear and linear integer problems of multicriteria optimization. It may be used both for education and for solving real problems. MKO-2 system could also be extended to solve nonlinear problems of multicriteria optimization. For this purpose some algorithms, solving nonlinear continuous single-objective problems will be included and new interface modules will be added as well, connected with the solution of nonlinear problems of multicriteria optimization.

3. Structure and functionality of the main modules of MKO-2 system

MKO-2 system consists of three main modules: a control module, optimization modules and interface modules.

The control module is an integrated software environment for creating, processing and storing of files associated with the system (with “*.mlp” extension), as well as for linking and execution of different types of software modules.

The basic functional possibilities of the control module may be separated into three groups. The first group includes the possibilities to use the standard for MS Windows applications menus and system functions – *File, Settings, Edit, View, Window, Help* and others in the system own environment.

The second group of functional possibilities includes the control of the interaction between the modules realizing:

- creating, modification and storing of “*.mlp” files associated with the system, which contain input data and data for the intermediate and final results from the solution of the linear and linear integer multicriteria optimization problems;
- interactive solution of the multicriteria optimization problems entered;
- localization and identification of the errors occurring in the process of operation with MKO-2 system.

The third group of functional possibilities of the control module consists in the possibilities to visualize significant information about the DM and the operation of MKO-2 system as a whole.

The control module is designed in Multy Document Interface style. There is one main form (window), containing the main menu, and all the other forms (windows) are its “daughter” forms. Several “daughter” forms can be visualized at one and the same time.

4. Solving multicriteria problems with MKO-2 system

MKO-2 system operates in MS Windows environment. It can be added to the Programs group and/or a Desktop icon, from where it is started. When starting it, “MKO-2 Main window” is opened (Fig. 1), containing a band with six main menus – *File, Settings, Edit, View, Window* and *Help* and a second band with quick access icons – *New, Open, Save, Print, Settings* and *Graphic*.

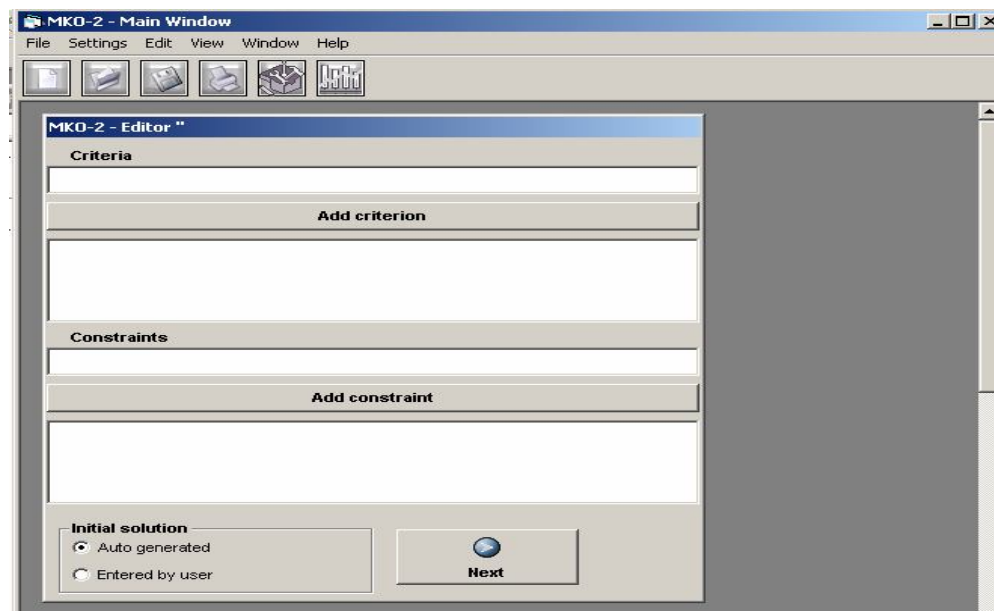


Fig. 1

With the help of “New” command, a window is opened for a new problem, its data being stored by the system in a file with “.mlp” extension. The storing is accomplished by commands “Save” or “Save as”. In case the data about the problem, contained in this file, are not entirely entered or the process of this problem solution is not started, the window “MKO-2 Editor” is opened with the help of “Open” command. Otherwise, the window “MKO-2 Solver” is opened.

4.1. Data input for the multicriteria problem

The entry and correction of the criteria and constraints of the problem is completed in two separate fields of “MKO-2 Editor” window (Fig. 2). Every criterion and every constraint is entered separately in the corresponding text fields for input and edition. Syntactic check is done after their adding to the already entered criteria or constraints. The syntax accepted is similar to the mathematical record of this class of optimization problems. For each criterion the name of the criterion is entered at first, followed by the equality sign. In case the name of the criterion is not specified, the name F_i is automatically assigned to it, where i is a number, indicating the sequence of the criteria input. After that the type of the optimum sought is written – “min” or “max”. Later on a digital coefficient with its sign is entered, followed by the name of the variable it concerns. The variables names can be arbitrary strings of letters and digits. 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 variables is defined by any of the symbols “<”, “<=” or “=”). By double clicking on an already entered constraint or criterion, they are transferred again to the editing field, if some corrections are necessary.

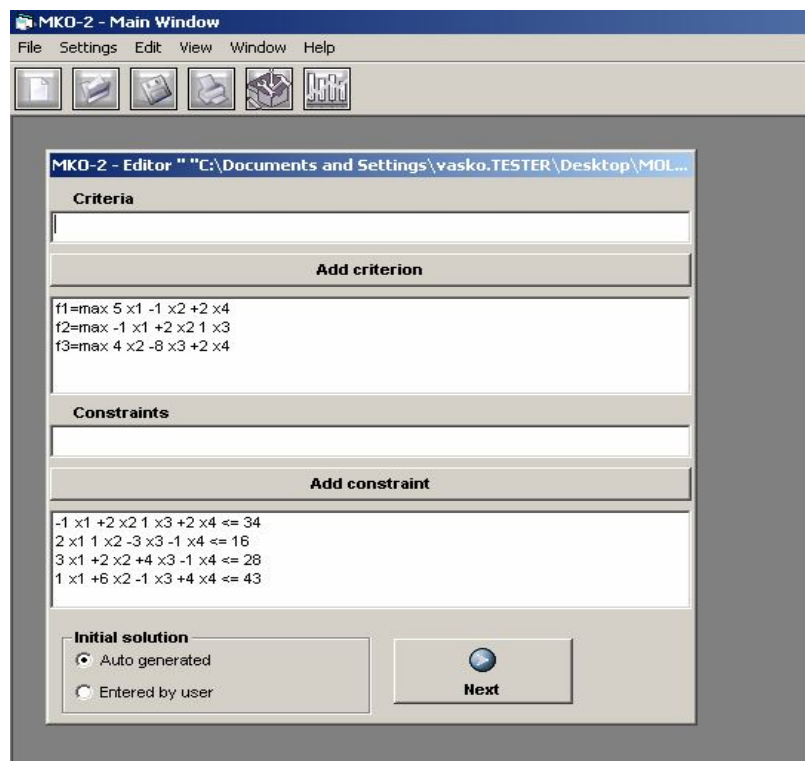


Fig. 2

Fig. 2 shows a screen of a linear integer multicriteria problem with three criteria, four constraints and four variables. In “MKO-2 Editor” window, the window “Variable Info” is opened with the help of *Next* button (Fig. 3), in which information is given about the type and the bounds of variables alteration. All the variables are of *Integer* type by default, with *Lower Bound* = 0 and *Upper Bound* = 1E + 24, which is accepted ∞ .

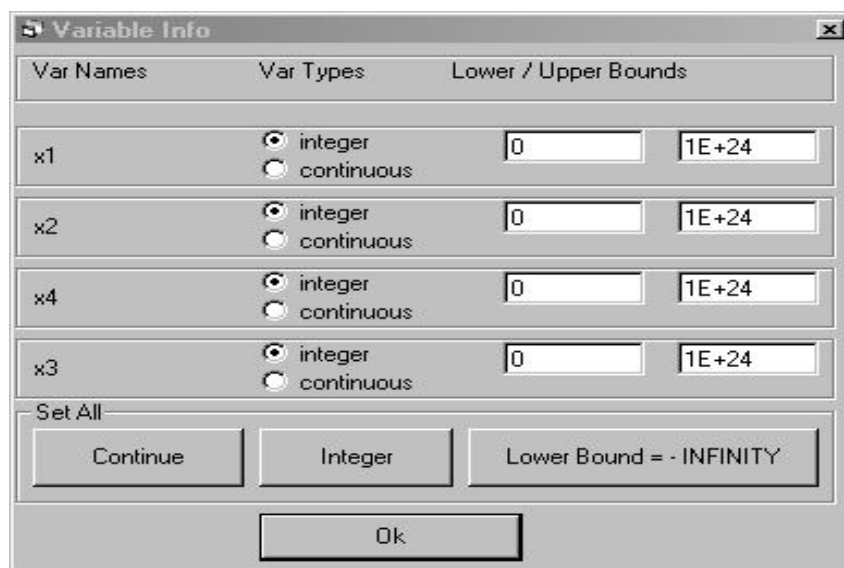


Fig. 3

The solving of linear and linear integer multicriteria problems is realized with the help of 12 “MKO-2 Solving” windows, intended to work with the 12 interactive algorithms.

Solving of linear and linear integer multi criteria problems is carried out with the help of 12 “MKO-2 Solving” windows, intended to work with the 12 interactive algorithms. The “MKO-2 Solving” window, shown in Fig. 6 is intended to work with a classification-based interactive algorithm, and in Fig.7 – for work with the reference point interactive algorithm. Every windows “MKO-2 Solving” is divided into several zones. In its upper part the band with the buttons is located, in which the main functions of the process of interactive solution of linear and linear integer multicriteria optimization problems are realized.

4.2. Problem tuning and solving interfaces

MKO-2 system provides few interfaces for setting up the additional problem data and solving algorithms.

– Information about the type and bounds of the variables alteration is given (Fig. 3).

– Defining the type of decision maker’s preferences at searching for new solutions (Fig. 4) and selection of an algorithm, oriented to such type of preferences (Fig. 5). If the DM is troubled with the choice of a algorithm, one is automatically selected representative for the given group of algorithms. The DM’s choice of his/her

preferences and the respective algorithm is done at the first iteration. The choice may be changed at each iteration or over arbitrary number of iterations.

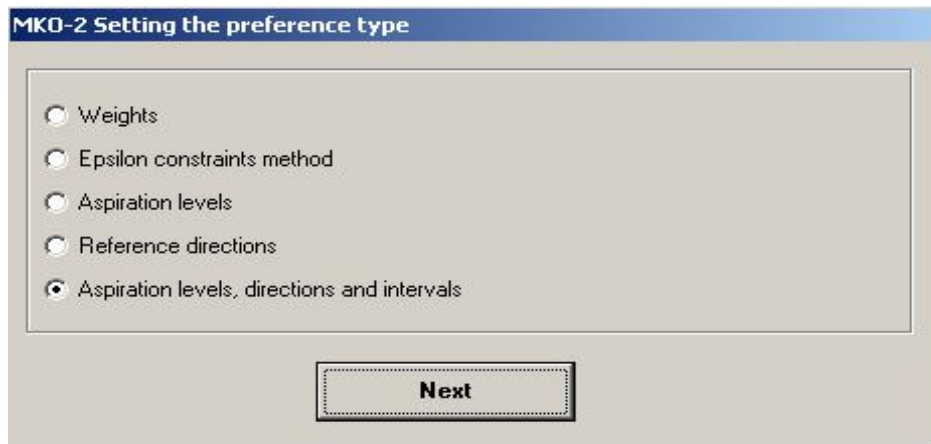


Fig. 4

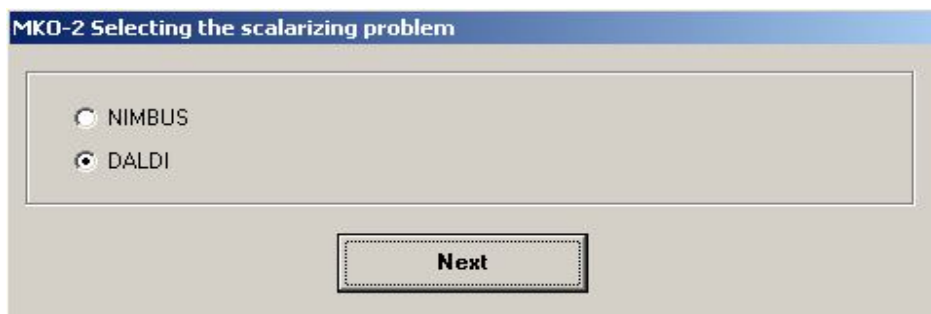


Fig. 5

Two text fields follow, indicated in Fig. 6, which are for the window, corresponding to the classification oriented interactive algorithm DALDI. In the first field the values of the criteria obtained at the current iteration, are successively output. It is also a working field for setting DM's preferences in the search for a next solution. When clicking on each one of the criteria with the mouse right button, a context menu is opened, where the DM defines the desired alteration in the values of this criterion for the next iteration. In case the selection is connected with the necessity to enter a certain value, MKO-2 system opens an additional dialogue window and waits for the input of the corresponding digital information.

In the second text field the scalarizing problem is visualized, during the solution of which the respective solution at the current iteration is found. This information could be useful for beginners and for persons working in the field of multicriteria optimization.

For the remaining 11 algorithms these two fields are of similar appearance.

When solving multicriteria optimization problems, it is important to provide information not only about the last solution found, but also about the solutions found at previous iterations. It is important that the DM could "testify" how he/she has reached the last solution. Hence, the information about the interactive process of the multicriteria optimization problem solving, comprising not only the problem input

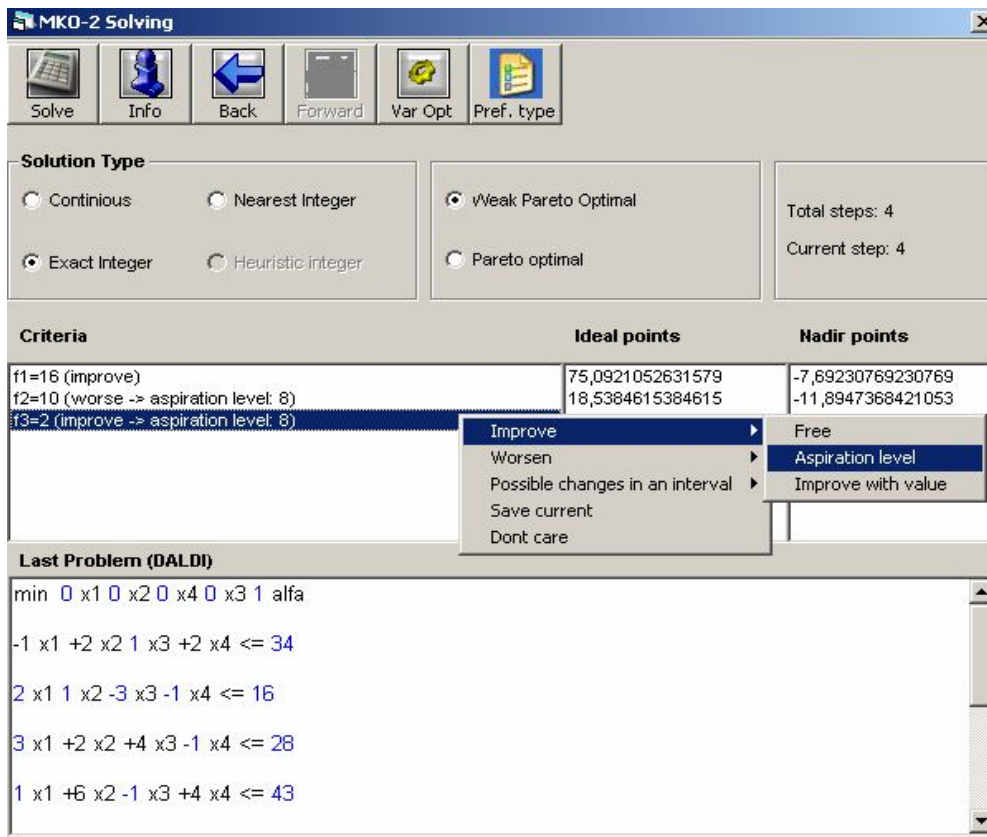


Fig. 6

data, the solutions obtained at each iteration, the preferences set by the DM for a new search and the scalarizing problems constructed, stored in “*.mlp” files associated with MKO-2 system serve not only to restart an interrupted solution process, but also for documentation.

Messages

“Messages” window provides internal system information about the process of solving. The window content can be deleted or stored in a file by a context menu.

Graphics

“Graphic” window visualizes two types of graphical information about the process of problem solution (Fig. 7). With the help of the upper bar-graphic, visual comparison can be made of the solutions found at two iterations, selected in the fields below it for iterations selection. The lower graphic can trace visually the alteration of the values of the separate criteria at different iterations of the interactive process of search for a better solution. With the help of the selection buttons, the initial and the final iteration of the iterations interval are defined, in which the values of all the criteria are traced.



Fig. 7

5. Conclusion

The multicriteria optimization software system MKO-2 is designed to aid the solution of linear and linear integer problems of multicriteria optimization. The generalized interactive algorithm GENWS-IM, included in the system offers the DM wide possibilities to set his/her preferences about the quality of the most preferred solution. The user- friendly interface of MKO-2 system facilitates the operation of decision making persons of different qualification level relating to the optimization algorithms and software tools used. MKO-2 system can be used for the purposes of education and for solving real-life problems as well.

References

1. Gardiner, R., D. Vanderpooten. Interactive Multiple Criteria Procedures: Some Reflection. – In: Multicriteria Analysis (J. Climaco, Ed.), Springer, 1997, 290-301.
2. Miettinen, K. Nonlinear Multiojective Optimization. Boston, Kluwer Academic Publishers, 1999.
3. Vanderbei, R. Linear Programming: Foundations and Extensions. Kluwer Academic Publishers, 1966.

4. V a s s i l e v, V., K. G e n o v a. An Algorithm of Integer Feasible Directions for Linear Integer Programming. – European J. of Oper. Res., **52**, 1991, 203-214.
5. V a s s i l e v a, M. Generalized Scalarizing Problem of Multicriteria Optimization. – Comp. Rend. Acad. Bulg. Sci., **58**, 2005, No 5, 537-544.
6. V a s s i l e v a, M. Generalized Interactive Algorithm for Multicriteria Optimization. – Problems of Engineering Cybernetics and Robotics, **56**, 2006, 69-77.
7. V i n c k e, P. Multicriteria Decision-Aid. New York, John Wiley & Sons, 1992.
8. W e i s t r o f f e r, H., S. N a r u l a. The State Of Multiple Criteria Decision Support Software. – Annals Of Operations Research, **72**, 299-313, 1997.
9. W o l s e y, L. A. Integer Programming. Wiley-Interscience, 1998.

Программная система многокритериальной оптимизации

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(Р е з ю м е)

В статье представлена программная система МКО-2, предназначенная для моделирования и решения линейных целочисленных задач многокритериальной оптимизации. Описаны структура, функции и интерфейс пользователя системы.