

MOLIP: A Multiobjective Optimization Software System*

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Introduction

The systems supporting multiobjective optimization problems solving [6] are part of multiobjective decision support systems. Multiobjective optimization problems [2, 5] are problems, in which a finite number of explicitly set constraints define a set of a finite number (in integer problems) or infinite number (in continuous problems) alternatives. The quality of a given multiobjective decision support system depends on the possibilities it offers to the DM in the entry and editing of the input data; in the description of his/her local and global preferences; in generating new (weak) non-dominated or non-dominated solutions for evaluation; in the visualization of different types of information, necessary for his/her learning with respect to the multiobjective problem solved and in the control of the multiobjective problem solution process, including alteration of separate parameters, storing of the current solutions obtained; in computing process interruption; in multiple restarting of the computing process from different intermediate solutions, etc.

The new programming languages and operating systems make possible the considerable improvement of the control programs and interface modules of the multiobjective 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 multiobjective and single-objective optimization methods and algorithms included in the system. As shown in [4, 8], the major part of the systems developed up to now include multiobjective methods of the reference point and are intended to solve continuous problems of the multiobjective optimization. This has significantly influenced the design of these sys-

* This paper is partially supported by NSF of the MES, contract "Interactive Algorithms and Software Systems Supporting Multicriteria Decision Making" and ICT Development Agency of the MTC, contract "Multiobjective Optimization Software System".

tems with respect to the input data entry, the interactive solution of the multiobjective problems and the visualization of the current and final results.

The present paper describes some basic elements of the system developed (called MOLIP), which supports the solution of linear and linear integer problems of the multiobjective optimization. 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, and also the operation with the interface modules for visualization of the current and final solutions are discussed, as well as the help information, given in a digital and graphical form.

Purpose of MOLIP system

MOLIP system is designed to help the DM in solving the following linear and linear integer problems of the multiobjective optimization.

To optimize simultaneously the functions

$$(1) \quad \{f_k(x), k \in K\}$$

under the constraints:

$$(2) \quad \sum_{j \in N} a_{ij} x_j \leq b_j, \quad i \in M,$$

$$(3) \quad 0 \leq x_j \leq d_j, \quad j \in N,$$

$$(4) \quad x_j - \text{integers}, j \in N', \quad N' \subset N,$$

where to optimize simultaneously means that some of the functions may be maximized, and the rest – minimized;

$$f_k(x), k \in K, \text{ are linear objective functions, } f_k(x) = \sum_{j \in N} c^k_j x_j;$$

$x = (x_1, \dots, x_j, \dots, x_n)^T$ is the variables vector;

$f(x) = (f_1(x), \dots, f_k(x), \dots, f_p(x))^T$ is the vector of the objective functions;

$K = \{1, 2, \dots, p\}$, $M = \{1, 2, \dots, m\}$, $N = \{1, 2, \dots, n\}$;

$N' = \{1, 2, \dots, n', n' \leq n\}$ are sets of the indices of the linear objective functions, the linear constraints, the variables and the integer variables.

If the set N' is an empty set, then problem (1)–(4) is a linear problem of the multiobjective optimization, otherwise it is an integer (mixed integer) problem of the multiobjective optimization.

In almost all multiobjective optimization decision support systems [1], some interactive multiobjective algorithms are included. The interactive algorithms of the reference point (direction) and the classification-oriented interactive algorithms are the most widely spread interactive algorithms solving multiobjective optimization problems. Though the interactive algorithms of the reference point are still dominating, the classification-oriented interactive algorithms enable the better solution of some chief problems in the dialogue with the DM, related to defining his/her preferences, and also concerning the time of waiting for new non-dominated solutions that are evaluated and selected. Three classification-oriented interactive algorithms [7, 8] are included in MOLIP system, which enable the DM to define not only desired and acceptable levels of the objective functions (as in reference point interactive algorithms), but also de-

sired and acceptable intervals and directions of alteration in the values of the separate objective functions. The first interactive algorithm, called GAMMA-L is intended to solve linear problems of the multiobjective optimization. The second and third algorithms, called GAMMA-I1 and GAMMA-I2 respectively, are designed to solve linear integer problems. In solving integer problems of the multiobjective optimization, the dialogue with the DM is influenced to a large extent 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 [3], 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 new solutions. The classification-oriented interactive algorithms GAMMA-I1 and GAMMA-I2 allow at each iteration the solving of single-criterion problems with 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. It is highly probable that the solutions found will be close to or coincide with the non-dominated solutions of the multiobjective problem.

Basic features of MOLIP system

MOLIP multiobjective decision support system consists of the following three main parts: control program, optimization modules and interface modules.

The control program is an integrated software environment for creating, processing and saving of files associated with MOLIP system (ending by the “.mlp” extension) and also for linking and executing different types of software modules. The basic functional possibilities of the control program can be divided in 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 “.mlp” files associated with MOLIP system, which contain input data and data concerning the process and the results from solving multiobjective linear and linear integer problems; interactive solution of the multiobjective 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 control program is developed in Multi Document Interface style, which means that it has one basic form, containing the main menu, and all the other forms are its “daughter” forms. Different daughter forms can be simultaneously visualized. In order to communicate with the libraries for dynamic connection of different single-criterion optimization modules, the independent “Csolver” class is applied, which is in fact a data processor. The class contains modules for data input, output data obtaining and execution of the corresponding setups for the type of the variables and the type of the solution required. It works after the principle of a black box – an optimization problem in a given format and syntax is set at its input as a parameter, then syntax analysis is implemented, the names and the type of the variables (continuous/integer) are defined,

the type of the solution (continuous/integer) is also defined and the optimization problem is transformed into a format required by the corresponding single-criterion optimization module. The information about the solutions obtained is saved in the output points of the class, from where it can be obtained.

Another main class used by the control program is “CHistory” class. The purpose of this class is to create a structure, in which the results obtained at every iteration of the interactive algorithm, are saved – the objective functions and the variables values, the requirements set by the DM and the scalarizing problem used at the current iteration. This enables the interruption and the restarting of the interactive process during each multiobjective problem solution from the place of interruption. The DM has also the possibility to go back and to seek solutions in another direction and with other preferences.

The interface modules realize the dialogue between the DM and MOLIP system during the entry and correction of the input data necessary for the multiobjective 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 objective functions, 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 objective functions. A third interface module realizes two types of graphic presentation of the information about the values of the objective functions at different steps and the possibilities for comparison. Dynamic Help is provided, which outputs in a separate window specific information about the purpose and way of use of the fields and radio buttons.

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

MOLIP system works under MS Windows. It can be added to *Programs* group and/or with a *Desktop* icon, from where it is started. The system registers the “.mlp” extension and associates it. Thus, at double clicking on a valid “.mlp” 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 “.mlp” file is loaded and the operation may continue with the information stored in it.

The entry and correction of the problem objective functions and constraints are realized in “MOLIP 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 mathematic 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 “<=”, “>=” 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. 1 shows a screen with entered test problem with three objective functions and four constraints.

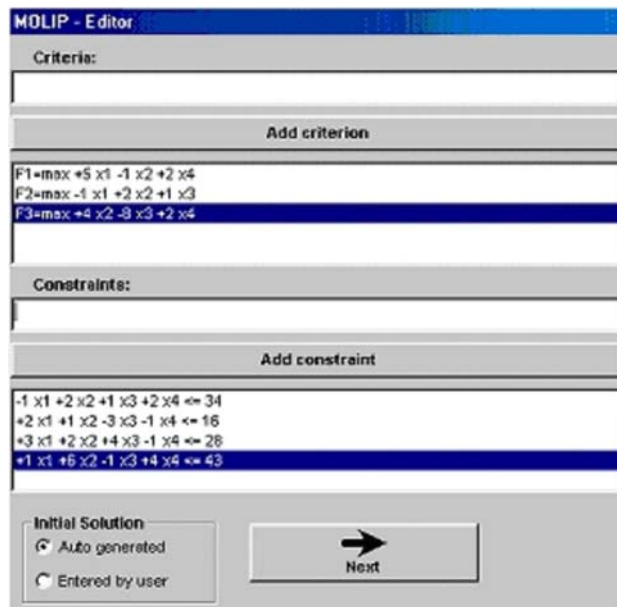


Fig. 1

Variable Info form can be opened in the window, where information concerning variables type and limits of alteration is entered. All the variables are of “Integer” type by default, with “Lower Bound”=0 and “Upper Bound”=1E+30, which is considered as ∞ . The information about all the variables can be automatically altered with the help of two buttons – Continue and Lower Bound = INFINITY. The closing of “Variable Info” window and the corrections made are saved, pressing the Accept button.

The interactive problems solution is realized in “MOLIP Solving” window. “MOLIP Solving” window is divided into several zones. Its upper part contains a band with buttons that realize the main functions of the process for interactive solution of multiobjective linear and linear integer problems. The buttons are the following:

Solve – for starting the optimization module in order to find a new current solution of MOLIP, solving the scalarizing problem generated at this iteration;

Info – for visualization of the variables values at the current solution in a separate window;

Graphic – for opening the window for graphic comparison of the results obtained at the separate steps. The upper bar-graphics provides the possibility for visual comparison of the solutions found at two iterations, selected by the rotating fields below it. The low graphics can trace the alteration of the values of the different objective functions at different steps of the interactive process for better solution search. The buttons for rotation enable the selection of an initial and final step of the interval, in which the values of all the objective functions are observed;

Back and *Forward* – buttons for navigation. They allow the DM go back to preceding steps and reconsider the solutions found. In case the DM wishes, he/she can change his/her own preferences concerning the objective functions alteration at any of the previous steps and restart the process for better solution search from there on;

Options – for opening different system setups of the data file, which is active at the moment – it can be associated with “.mlp” extension; changing the names of the

system variables if “alfa” and “beta” have another user’s meaning in the problem being solved; changing the values of the default parameters of the scalarizing problems solved;

Help – for output of help information with basic directions about the input, editing and solving of multiobjective linear and linear integer problems in the system environment;

About – for providing information about the team and system information about the computer system used;

Exit – for MOLIP system exiting with or without storing in a file of the data and the results from the recent work.

The next field of MOLIP Solver window contains radio buttons for setup of the MOLIP 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 objective functions 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 objective functions, 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 a following iteration. In case the selection is connected with the necessity to enter a particular value, MOLIP system opens an additional dialogue window and waits for the entry of the corresponding digital information. Fig. 2 shows a screen in case the DM agrees the value of the second criterion to be deteriorated.

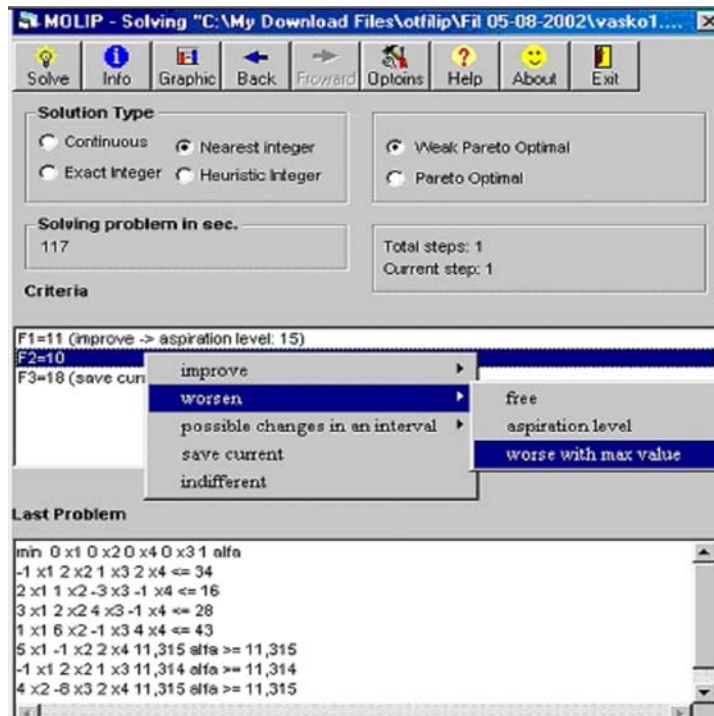


Fig. 2

When interactive algorithms are used for multiobjective problems solving, it is an advantage to present information not only about the last solution found, but also about the process of search and 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 MO 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 *.mlp files associated with MOLIP system, serves not only for restarting an interrupted solution process, but also for documentation. The “Print” command from the main menu can be used for selective print of the type of information chosen by the DM.

Fig. 3 shows a screen with the final results obtained concerning the objective functions and the integer variables for the test example.

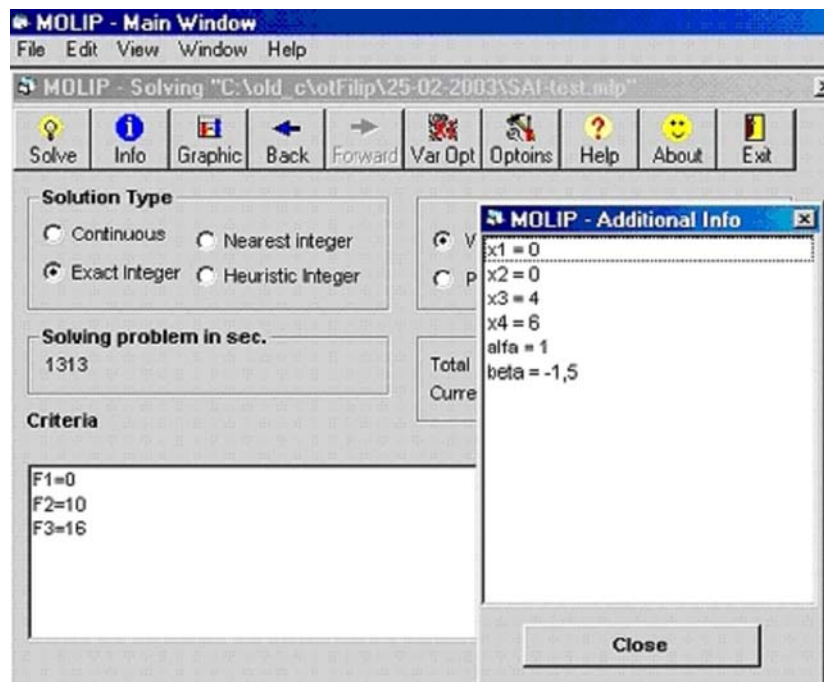


Fig. 3

Conclusions

The MOLIP system described is designed to help the solution of linear and linear integer problems of the multiobjective optimization. The algorithmic insurance of the system developed on one side, and the proposed design of the system – on the other, allow DMs with different degree of qualification to solve interactively a wide class of linear multiobjective problems. These problems may contain a different number and type of the objective functions, different number and type of the variables and different number of the linear constraints. The three multiobjective interactive algorithms GAMMA-L, GAMMA-I1 and GAMMA-I2 are included in MOLIP system in such a

way, that from the viewpoint of the DM they are just an integrated SOLVER. MOLIP system includes interface modules, which aid the DM in describing his/her local preferences, in the evaluation of the local non-dominated or (weak) non-dominated solutions obtained and in the analysis of the multiobjective problem solution process. The control system of MOLIP enables the operation of the optimization and interface modules. The user-friendly interface of MOLIP system facilitates the operation of decision making persons of different qualification level relating to the optimization methods and software tools used. MOLIP system can be used for the purposes of education and for experimental and research problems solution as well.

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MOLIP: программная система для многокритериальной оптимизации

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(Резюме)

В работе рассматривается программная система для многокритериальной оптимизации. Система создана с целью помогать лицам, принимающим решений (ЛПР) при моделировании и решении линейных и нелинейных целочисленных многокритериальных задач. Разработанные интерактивные алгоритмы и подходящий интерфейс позволяют расширить возможности ЛПР при введении данных, при задании их предпочтений и при оценивании полученных решений.