A GENERAL PURPOSE SOFTWARE SYSTEM FOR LINEAR OPTIMIZATION AND DECISION SUPPORT "OPTIMA-PLUS"

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Abstract: The paper presents a general purpose software system for optimization and decision support, called Optima-Plus. It consists of two independent parts   LIOP-1 system and MKO-2.1 system. Optima-Plus system is designed to support the decision maker (DM) in modeling and solving different problems of linear and linear integer single-criterion and multicriteria optimization. The system implements three methods for single-criterion optimization, as well as an innovative generalized interactive method for multicriteria optimization with variable scalarization and parameterization, which can apply most of the well-known scalarizing problems and is applicable for different ways of defining preferences by the DM. The class of the problems solved, the system structure, the implemented methods and the graphical user interface of the system are discussed in the paper. Optima-Plus system can be used for education, research and for solving a great variety of real-life problems.

Keywords: Decision Support Systems, Linear, Integer Optimization, Multicriteria Optimization, Interactive Methods.

ACM Classification Keywords: H.4.2. Information Systems - Information Systems Applications – Types of Systems

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Introduction

Many application problems are related to one criterion, which has to be optimized or multiple conflicting criteria, which should be optimized simultaneously. Optimization is a problem of finding one or more solutions which are optimizing (minimizing or maximizing) one or more objective functions (criteria) in a feasible set of solutions, determined by preliminary given constraints. A single-objective optimization problem includes a single objective function (criterion) and if the problem has a solution, usually results in one final solution, which is called an optimal solution. The solution obtained is not subjective and does not depend on decision makers' preferences. There does not exist one optimal solution of multicriteria optimization problems, which optimizes simultaneously all the objective functions (criteria). There is a set of feasible alternatives with different trade-offs [Ehrgott and Wiecek, 2005], characterized by the following property: 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 non-dominated or Pareto optimal alternatives (solutions). Each alternative in this set could be a solution of the multicriteria decision making problem being solved. Usually in practice only one of these multiple Pareto optimal solutions has to be chosen as the final solution of the problem being solved. In order to select one alternative, it is necessary to have additional information set by the decision maker (DM). In other words, compared to the single-objective optimization, in a multiobjective optimization problem there are two (instead of one) phases: an optimization one (for finding Pareto optimal solutions with the help of the software system), and a decision one (for choosing a single most preferred Pareto optimal solution as the final solution). The solutions obtained are to a great extent subjective and depend on DM's preferences.

Many real-life problems in planning, control, analysis and monitoring in economy, transport, industrial production, education, ecology and other spheres may be modelled as single-criterion or multicriteria optimization problems

[Pardalos and Resende, 2002, Korhonen, 1998, Joos, 1999, Rajesh et al., 2001, Thibault et al., 2002, Hämäläinen et al., 2003, Kaleta et al., 2003].

The developed software systems supporting the solution of optimization problems may be divided in two classes – problem-oriented software systems and software systems of general purpose. The problem-oriented software systems serve to support the solution of one or several types of specific optimization problems and very often they are included in other information-control systems. The interface of these systems has been developed in terms of the particular problem solved and depending on the users' preferences, either an exact method is chosen, or a heuristic method is developed especially for the problem solution. That is why, every change in the model or in some of the users' preferences leads to additional investments in new software development and education. The general purpose software systems aid the solution of different optimization problems realized by different types of users or decision makers. These types of systems are oriented to solving optimization problems, which are described in a general (standard) form of the particular class. In general, several algorithms (exact and heuristic) are included in these systems. Each of these algorithms has different advantages and disadvantages, depending on the requirements for high speed, accuracy and necessity to set different input information and parameters, etc. Users with different qualification can work easily with these systems and solve various real-life problems, modeled in terms of the corresponding class of problems, without additional software development.

Various types of software systems [Fourer and Goux, 2001, Pardalos and Resende, 2002, Mittelmann and Spellucci, 2005] have been developed for solving linear and linear integer programming problems. The greater part of the professional (commercial) general purpose systems (CPLEX, LINDO, Xpress-MP, and others) are too expensive, but they are intended to solve problems of hundred of thousands continuous variables and constraints, and thousands integer variables and constraints. In some of them, e.g. LINDO system, some modeling languages are included, which enable the entering process of variables, constraints and objective functions to be done in a simple and intuitive way, close to the models developed by the users. Others, like CPLEX and Xpress-MP have their own algebraic input format. There are also libraries of solvers, realizing separate algorithms for solving linear and linear integer programming problems (e.g. LINDO Callable Library). The interface to such software is through subroutine calls, which are used to build up the model, to modify the input data in the corresponding format (usually MPS), to solve the problem and to present the results. Such solvers are used for building in bigger or problem-oriented systems.

Some well known general purpose software systems [Vassileva et al., 2008, Weistroffer et al., 2005], which solve problems of multicriteria optimization, are the following: MKO-2, PROMOIN, VIG, DIDAS, DINAS, MOLP-16, LBS, WWW-NIMBUS, NLPJOB and MOMILP. The Multicriteria Decision Support System for River Water-quality Planning [Lotov et al., 1997] and the ADELAIS system for portfolio selection [Zopounidis et al., 1998] are two attractive problem-oriented multicriteria optimization systems. The development of web-based systems in recent years is quite intensive. They are oriented to remote solving of problems. Users submit data to the server and receive results through an e-mail or Web interface to Internet.

The paper describes the basic features of the general purpose software system for optimization and decision support, called *Optima-Plus.* This system is designed to support the DM in solving different single-criterion and multicriteria linear and linear integer optimization problems and it works under MS Windows operating system. *Optima-Plus* consists of two separate parts – *LIOP-1* system and *MKO-2.1* system. The basic idea for developing the system is the traditional users of single-criterion general purpose software systems to be able to make experiments during the solution process of the problem in terms of adding new additional criteria. This basic feature of such a system is innovative and important, because real-life problems for optimization and decision support can be modeled more realistically when using multiple criteria. The class of the solved problems, the system structure, the operation with the interface modules for entering information about DM's local preferences and for visualization of the current and final solutions, as well as the help information, given in a digital and graphical form, are discussed.

LIOP-1 system

LIOP-1 system, which is the first part of *Optima-Plus* system, is designed to solve a broad class of problems of linear, linear integer and mixed integer programming problems.

The formal statement of the Mixed Integer Programming problem (MIP) is the following:

$$F_1 = \sum_{j=1}^{n} c_j x_j \rightarrow \max \quad (\min)$$

s.t.
$$\sum_{j=1}^{n} a_{ij} x_j \overset{>}{\underset{<}{=}} b_i, i = 1,..,m$$

$$l_j \leq x_j \leq d_j \quad, j = 1,...,n,$$

$$x_j - \text{integers}, \quad j = 1,...,n_1,$$

where: $n_1 \leq n$; F_1 is an objective function (criterion); $x_j, j = 1,..., n$ are the problem variables; $a_{ij}, b_i, i = 1,..., m$, $j = 1,..., n$, are respectively coefficients and the right –hand side of the constraint of index i; $l_j, u_j, j = 1,..., n$, are upper and lower bounds of the variable x_j; n_1 *is the number of the integer variables.* If n_1 is equal to n, the problem is said to be an integer programming problem (IP), while at n_1 equal to zero, the problem is a linear programming problem (LP)

LIOP-1 system is realized in Visual Basic and C programming languages. It 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 a "*.lip" 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", "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 saving of "*.lip" files, which contain input data and data for the intermediate and final results of the solution of linear and linear integer programming problems;
- solving of the linear and linear integer programming problems entered;
- localization and identification of the errors occurring in the process of operation with *LIOP-1* system.
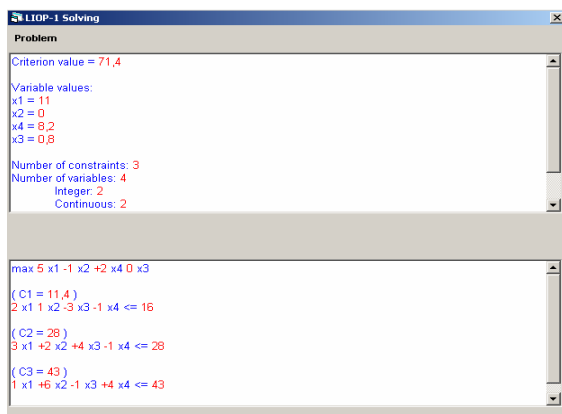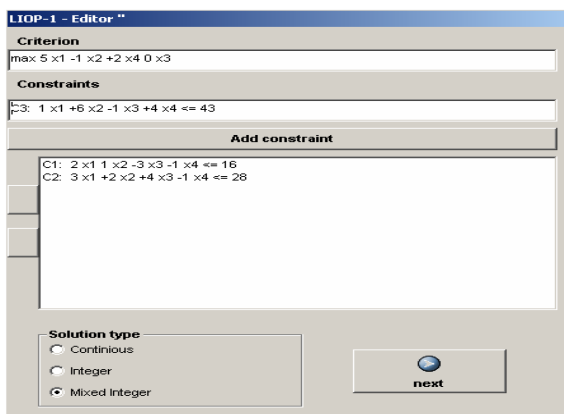
The third group of functional possibilities of the control module consists in the possibilities to visualize significant information about the operation of *LIOP-1* system as a whole.

The control module is designed in Multi 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. In order to accomplish communication with the libraries for dynamic linking of different single-criterion optimization modules, the independent "CSolver" class is used, which is a data processor. It includes modules for input data entry, for output data obtaining and for different setups of the type of the variables and the type of the solution required. It works after the black box principle – an optimization problem in certain format and syntax is set at its input as a parameter, syntactic analysis is done, the names and the type of the variables (continuous/integer) are defined, the type of the solution (continuous/integer) is also determined and the optimization problem is transformed in a format, required by the corresponding single criterion optimization module. The information about the solutions obtained is recorded at the output points of the class, from where it can be obtained. The optimization modules realize two simplex methods of linear programming and the branch and bounds method of linear integer programming.

The interface modules guarantee the dialogue with the system during the input and correction of the input data of the problems being solved, during the interactive process of their solution and also during the digital and graphical visualization of the main parameters of this process. With the help of the editing module, the descriptions of the criteria, of the constraints, as well as the type and bounds of alteration of the variables are

entered, changed or preserved. Another interface module realizes two types of graphical presentation of the information about the values of the criteria at different steps and the possibilities to compare them. Dynamic information is supplied about the purpose and the ways to use the fields and radio buttons.

LIOP-1 system presents to the DM different windows intended for entry and correction of the problem objective function and constraints and for visualization of the results obtained. Figs. 1 and 2 show two of these windows. The window, presented in Fig. 1, is the basic window of the editor for input data entry, called *LIOP-1*-Editor. Entering of the linear and linear integer models can be done in a standard algebraic form, which is more comfortable for the users, because it allows setting of the wanted names of the objective function, of the constraints and variables.

Fig. 1. *LIOP-1*-Editor   Fig. 2. *LIOP-1*-Solving

The results obtained are shown in "*LIOP-1* Solving" window (Fig. 2). "*LIOP-1*-Solving" window contains two text fields. In the first field the values of the criterion and of the variables for the obtained solution are shown. In this field the iterations number and some parameters of the problem solution are also given. In the second field the problem being solved is viewed again, but the constraint values for the obtained solution are shown in addition. When solving linear integer problems of larger dimension, some messages for possible breaking of the solution process can be shown periodically (including information about the feasible solutions found). The time of the messages display is fixed in advance, but it can be changed.

The printing of short or detailed information about the problem currently solved is done with the help of "Print" command. A form is opened for selecting the information to be printed. Printing of the solution, the problem being solved, the input variables type and bounds, and detailed information about the process solution may be selected. Requirements about the quality of printing, the number of copies and the character style can also be set.

MKO-2.1 SYSTEM

MKO-2.1 system, which is the second part of *Optima-Plus* software system, is developed on the basis of *MKO-2* system [Vassileva et al., 2007]. It is realized in Visual Basic and C programming languages and designed to aid the DM in the solution of linear and linear integer problems of multicriteria optimization.

The linear and linear integer multicriteria optimization problem may be formulated as follows:

To maximize simultaneously the criteria: $\left\{ f_k(x), \ k \in K \right\}$

$s.t.:$ $\sum_{j \in N} a_{ij} x_j \le b_i, \ i \in M$

$0 \le x_j \le d_j, \ j \in N$

x_j - integers, $j \in N'; \ N' \subset N,$

where: $f_k(x)$, $k \in K$ are linear criteria of the type: $f_k(x) = \sum_{j \in N} c_j^k x_j$; $x = (x_1,...,x_j,...,x_n)^T$ is the vector of the variables; $K = \{1,2,...,p\}$, $M = \{1,2,...,m\}$, $N = \{1,2,...,n\}$ and $N' = \{1,2,...,n'/n' \leq n\}$ are the sets of the indices of the linear criteria, linear constraints, variables and integer variables, respectively.

The main approach in solving multicriteria optimization problems is the scalarizing approach [Miettinen, 2003]. The interactive methods are the major representatives of the scalarizing approach. The multicriteria optimization problem is treated in these methods as a decision making problem and the emphasis is put on the real participation of the DM in the process of its solution. The interactive methods are the most developed and widespread 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 solving; the DM feels more confident in his/her preferences concerning the final solution of the problem being solved.

MKO-2.1 system is developed on the basis of the generalized interactive method with variable scalarization and parameterization GENWS–IM [Vassileva, 2005, Vassileva, 2006]. This method is a generalization of a large part of the multicriteria optimization interactive methods developed up to the present moment. The generalization is with respect to the classes of the problems solved, the type of the defined preferences, the number and type of the applied scalarizing problems, and the strategies used in the search for new Pareto optimal solutions. Starting from the current (weak) Pareto optimal solution, the generalized scalarizing problem GENWS may be used. Altering some of its parameters the following twelve scalarizing problems can be obtained: the scalarizing problem of the Weighted Sum, the scalarizing problem of ε-constraints, the Chebyshev scalarizing problem, the scalarizing problem STEM, the scalarizing problem STOM, the scalarizing problem of the Reference Point, the scalarizing problem GUESS, the scalarizing problem of the Modified Reference Point, the External Reference Direction scalarizing problem, the Reference Direction scalarizing problem, the classification-based scalarizing problem NIMBUS, and the classification-based scalarizing problem DALDI. The generalized interactive method GENWS-IM has the following main characteristics: the DM may set his/her preferences in very different ways – 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; 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 (weak) Pareto optimal solution and applying different scalarizing problems (with respective alteration of GENWS parameters), the DM may obtain different new Pareto optimal solutions at a given iteration, and this opportunity is especially useful in the education process and in the comparison of different scalarizing problems.

MKO-2.1 software system consists of three main groups of modules – a control program, optimization modules and interface modules. The control program is integrated software environment for creation, processing and saving of files associated with *MKO-2.1* system, as well as for linking and executing 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", and "Help" in the environment of *MKO-2.1* system. The second group of functional possibilities encloses the control of the interactions between the modules realizing the creation, modification and saving of files associated with *MKO-2.1* system, which contain input data and data connected with the process of solution of linear and linear integer problems of multicriteria optimization, the interactive solution of linear and linear integer multicriteria optimization problems entered, as well as the localization and identification of the errors occurring during the process of operation with *MKO-2.1* 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 for solving continuous single-criterion problems [Vanderbei, 1996], an algorithm of "branches and bounds" type for exact solution of linear integer single-criterion problems [Wolsey, 1998].

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 being solved, during the interactive process of these problems solution, as well as the dynamic numerical and graphical visualization of the main parameters of the solving process. With the help of an editing module the formulations 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 different steps of the solving process, as well as the possibilities for their comparison.

In addition to *MKO-2* system, when using the extended version *MKO-2.1*, the DM could use a variety of new ways for defining the preference information and for choosing the most appropriate method, concerning the problem being solved. In such a way, the DM could build and execute different solving scenarios for a certain multicriteria optimization problem, using, for example, different solving methods starting from a current Pareto optimal solution at a given iteration and compare the results in order to decide in which direction to search for the final solution. The DM could also use another new feature of *MKO-2.1* system – he/she could use different searching strategies at each iteration, as well as he/she could return to a Pareto optimal solution found at a previous iteration and start a new search with a different method, using the same or different preference information.

MKO-2.1 system presents to the DM different windows intended for entry and correction of the criteria and constraints of the multicriteria problem being solved, for setting his/her preferences, for choosing the solving method and for visualizing the current and the final solutions. Figs. 3-6 show four of these windows.

Fig. 3 shows the main window of *MKO-2.1*. It is intended for entering and editing of the initial data of the problem being solved. The same algebraic form for setting the objective functions, the constraints and variables, similar to the one in *LIOP-1* is used, and it is also possible to use the data already entered, to edit or complement them. The window, presented in Fig. 4, is designed to identify the type of DM's preferences. The DM may select among five types of preferences, it is assumed that he/she has selected to set the preferences in the form of desired and acceptable (aspiration) levels, directions and intervals of alteration in the criteria values.

The screen, presented in Fig. 5 shows setting of information for improvement in the value of the first criterion.

Choosing "Graphic" command enables the visualization of two types of graphical information about the process of problem solution. For this purpose, a window with two types of graphics is opened (Fig. 6). With the help of the upper bar-graphic, visual comparison can be made of the solutions found at two iterations, selected in the fields for step selection, given at the bottom of the window.
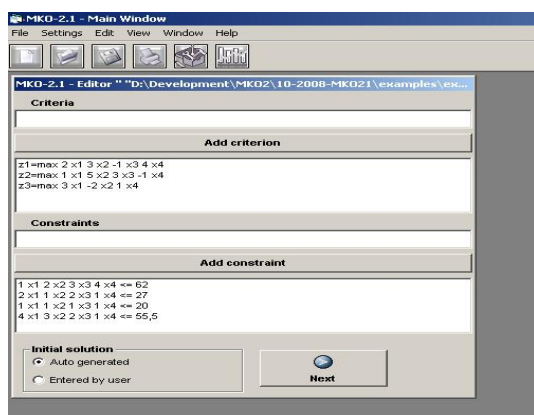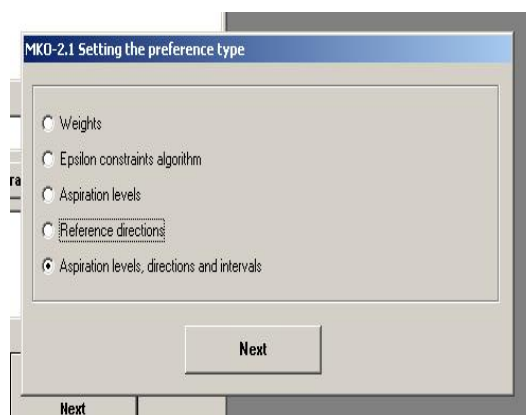

Fig. 3. MKO-2.1-Main Window   Fig. 4. Selecting the type of DM's preferences
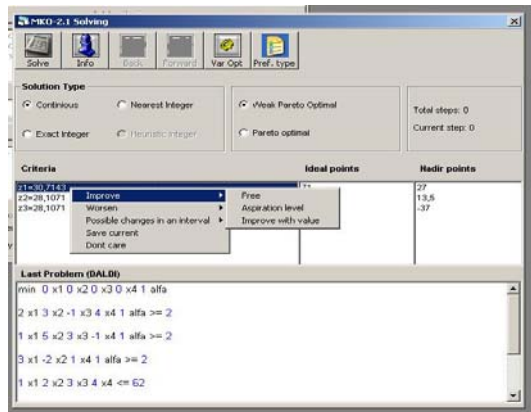
Fig. 5. Setting of an improvement

Fig. 6. Two types of graphics

Conclusion

The general purpose system *Optima-Plus* is designed to support DM in solving different single-criterion and multicriteria optimization problems. The first part of the system – *LIOP-1*, is designed to model and solve a broad class of problems of linear and linear integer programming. The second part of the system – *MKO-2.1*, is designed to model and solve linear and linear integer problems of multicriteria optimization. The DM can solve one and the same problem for one or several criteria. The user friendly interface of *MKO-2.1* and *LIOP-1* systems facilitates the operation of decision makers with different qualification level relating to the single-criterion and multicriteria optimization methods and the software tools. *MKO-2.1* and *LIOP-1* systems can be used for education and for real-life problems solving as well. A number of Bulgarian and European universities use the system for the purposes of education, as well as for experimental and research problems solving. A number of Bulgarian ministries, governmental and private organizations use the system to solve real-life single-criterion and multicriteria decision making problems. The future development of *Optima-Plus* system will be realized in two directions. The first one is connected with the implementing and adding of new methods (including heuristic methods) for single-criterion and multicriteria optimization. The second direction refers to the development of a web-based version of the system, enabling distant decision making.

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