LITERATURE CITED

2. Computations in Algebra and in Theory of Numbers [Russian translation], Mir, Moscow (1976).

DISPRO: A DISCRETE PROGRAMMING PACKAGE

V. S. Mikhalevich, I. V. Sergienko, T. T. Lebedeva, V. A. Roshehin, A. S. Stukalo, V. A. Trubin, and N. Z. Shor

INTRODUCTION

Theoretical work on automatic programming at the Ukrainian Academy of Sciences, Institute of Cybernetics, began in the late 1950s with the publication of [1]. In a series of subsequent publications, Glushkov and his group developed the main ideas presented in [1], including development of application packages for solution of various classes of optimization problems. This has led, in particular, to the introduction of a whole range of highly developed interactive application packages, including the DISPRO package which is the subject of this article. Note that in some cases the interactive features of application packages provide a highly efficient tool for solving and analyzing optimization problems [2], especially when the problem requires a preliminary analysis of the mathematical model, including the effect of various parameters on the optimization process by the particular method chosen for the solution of the problem. The interactive solution mode for complex optimization problems in a certain sense not only shortens the solution seeking time but also allows a novel approach to the solution seeking procedure. It may be used as one of the possible implementations of the ideas of system approach [3] to formulation and solution of optimization problems.

THE OBJECT ENVIRONMENT OF THE PACKAGE

The DISPRO package developed at the Ukrainian Academy of Sciences, Institute of Cybernetics [4, 5], is intended for solution of a wide range of general and special problems of discrete optimization. Different package components are coded in Assembler, FORTRAN IV, and PL/1. The package is supported by all compatible models of ES computers (ES-1022 and up) under OS/ES (versions 4.1 and 6.1) in MVT and MFT modes. The size of the package software is 1800 kbyte.

Numerous theoretical and applied subjects involve optimization problems in which all or some of the variables take on integer values or values from a given discrete set. Problems of this kind are encountered in production planning, in connection with location, development and reconstruction of plants and whole industries, design of technical systems and machines, transportation management, job scheduling under limited resources, and in many other cases [11, 22, 56].

Discrete programming models cover problems with physically indivisible variables, combinatorial problems selecting, subject to constraints, an optimal subset from a given set of elements, and "continuous" problems with nonconvex objective functions and nonconvex or unconnected feasible sets.

While in problems with indivisibilities the integer variables in the optimal solution in general may take on fairly large integer values, in all other problems the discrete variables are generally either 1 or 0. In this case, the attempts to construct an optimal (and sometimes simply feasible) solution by rounding off the values of the variables in the optimal solution of the corresponding continuous problem run into fundamental difficulties. It is the awareness of these difficulties that has stimulated the development of special solution methods for discrete optimization programs.

A fairly developed theory of discrete optimization is currently available, which includes investigation of the structure and properties of various classes of problems, appropriate solution methods, complexity estimating techniques, and other aspects. Solution methods have been developed for both general and special discrete (mainly linear) programming problems, which can be classified into the following groups.


2. Branch-and-bound methods [8, 9] for exact and approximate (with a given accuracy in the functional) solution of general and special classes of discrete problems.


4. Methods of successive evaluation of alternatives and dynamic programming [12-15], which provide the most universally applicable schemes for solution of a wide class of optimization problems (including discrete problems as a particular case). They can be efficiently used to solve discrete problems of special classes. In combination with nonsmooth optimization methods [16] they are used to solve the bounding problems in branch-and-bound methods; they are also used in combination with cutting-plane methods [17] in order to improve their convergence.

5. Special methods for solution of classes of discrete optimization problems with special properties. Examples of such classes include problems on a polymatroid and on intersection of two polymatroids [18], problems on balanced matrices [19], transportation problems [20], matching problems [21], location and synthesis of networks [22], traveling-salesman problem [23], partitioning [24] and covering of matrices, integer allocation problems, etc. Special methods are generally more efficient than general methods for the corresponding classes of problems. For some of them, polynomial complexity bounds are available.

6. Approximate methods for solution of large and special problems. They can be divided into four main groups:
   a) local optimization methods [11],
   b) random search methods [26],
   c) combinations of methods in a and b,
   d) methods of solution of special problems with specified accuracy [25, 27].

The methods in group a start with some feasible solution and attempt to find a "near" (in the sense of some metric) solution with a better value of the objective function. If such a solution is found, the process is repeated for the new solution. Otherwise, it is terminated with the last solution as the local optimum. The methods of group b construct a random set of points with different selection probabilities assigned to the various points depending on whether they are feasible or infeasible. For some special problems, such as the traveling-salesman problem with distance matrix satisfying the triangle inequality, location problem, set packing problem, and others, approximate methods have been developed with known bounds on the maximum deviation of the functional in the approximate solution from the exact solution. These methods have polynomial complexity and therefore may be efficiently used for approximate solution of problems and also for constructing the exact solution in branch-and-bound methods.

Although the theory of discrete optimization methods is fairly developed, the various available methods at this stage cannot be said to apply to a wide range of practical problems. Moreover, the results of complexity theory [27, 28] for optimization problems show that there is apparently no real hope of developing exact methods capable of solving discrete optimization problems in acceptable time. Although there are examples of solutions for such problems with a few hundred variables, it is difficult to speak with certainty of obtaining optimal solutions for general problems with 30-40 integer variables. Most special discrete optimization problems are theoretically as complex as the general linear integer programming problem. Analysis of 9000 special problems in control theory [29] has shown that only 9% of these problems are effectively solvable, 77% belong to the class of universal (NP-complete) problems, and 14% remain unclassified by complexity. The class of effectively solvable problems naturally includes only the simplest specimens. Similar proportions probably