Mathematical Modelling and Analysis
Volume 4, 1999, pages 79–86

APPLICATION OF COMPUTER NETWORK IN INTERACTIVE OPTIMIZATION

G. DZEMYDA[1], T. PETKUS[2], J. ŠINKŪNAS[2]

[1] *Institute of Mathematics and Informatics*
Akademijos 4, 2600, Vilnius
[2] *Vilnius Pedagogical University, Department of Informatics*
Studentų 39, Vilnius
E-mail: [1]dzemyda@ktl.mii.lt, [2]tomaspet@pub.osf.lt

Received September 24, 1999

ABSTRACT

An interactive optimization method for multiple criteria problems by using computer network has been developed. The advantages are as follows: the problem can be solved by many computers in parallel; the researcher is active in the optimization process that makes it possible to discover a new knowledge of the problem.

1. INTRODUCTION

The intensive development of new technologies requires to solve complex problems of computer-aided design and control. Here the search for optimal solution acquires an essential significance. World investigations in this area are carried out in two directions: development of new optimization methods as well as software that would embrace various realizations of the methods developed. Currently, computer networks have been widely spread and permit to solve complex optimization problems by using simple computers. Furthermore, the networks permit significantly more complex problems, that can be solved by using the aggregate power of many computers. The method for a complex interactive optimization problem by using computer network has been suggested.

2. FORMULATION OF THE OPTIMIZATION PROBLEM

In everyday life we often deal with problems of multiple criteria [8]. In common case, the ideal solution with respect to one criterion can be absolutely unacceptable with respect to another. Thus, it is necessary to seek an optimal solution, that could satisfy all the criteria.

Let us analyze a multiple criteria problem:

$$\min_{X=(x_1,\ldots,x_n)\in\bar{A}} f_j(X), \quad j=\overline{1,p}, \tag{2.1}$$

where $\bar{A}$ is a bounded domain in n-dimensional Euclidean space $\mathbb{R}^n$; p is a number of criteria making problem (2.1), the functions $f_j(X): \mathbb{R}^n \to \mathbb{R}^1$ are criteria.

One of the possible ways to solve the system of problems (2.1) is to make a single criterion problem by summing up all the criteria, that are multiplied by positive coefficients $\lambda_j, j=\overline{1,p}$ [9]:

$$\min_{X=(x_1,\ldots,x_n)\in\bar{A}} \sum_{j=1}^{p} \lambda_j f_j(X). \tag{2.2}$$

Then, the solution of problem (2.2) has been iterated by selecting different coefficient values, $\lambda_j, j=\overline{1,p}$. As a result, we get the points of Pareto set [9] and the most acceptable of them are selected.

3. INTERACTIVE USE OF THE COMPUTER NETWORK

3.1. Computer software and hardware

Problem (2.2) has been solved by using computer network under a software package PVM (Parallel Virtual Machine) [5, 6, 7]. Recent experiments are carried out by using package MPI (Message Passing Interface) [10]. The packages are designed to link computing resources and provide users with a parallel platform for running their computer applications, irrespective of the number of different computers they use and where the computers are located. In our case, the virtual machine runs on 15 Pentium II computers that are interconnected to the local network (see Fig. 1). The operating system Windows NT is used.

3.2. Special software

The problem has been solved by creating a special graphic environment that provides a rapid and visually acceptable results. Simultaneous interface of multiple results (Fig. 2 top windows) and an interactive replacement of the initial data (Fig. 2 bottom window) is permissible. Thus, the process of solving the problem is facilitated. The example bellow is an obvious illustration

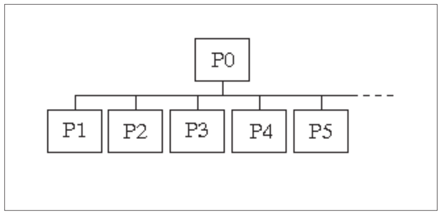

Figure 1. Computer network.

of relatively great violations of the recommended permissible minimal and maximal amounts of the nutritive characteristics in feed at a lower price. In this case, the violations of the recommendations decrease when the price is rising.

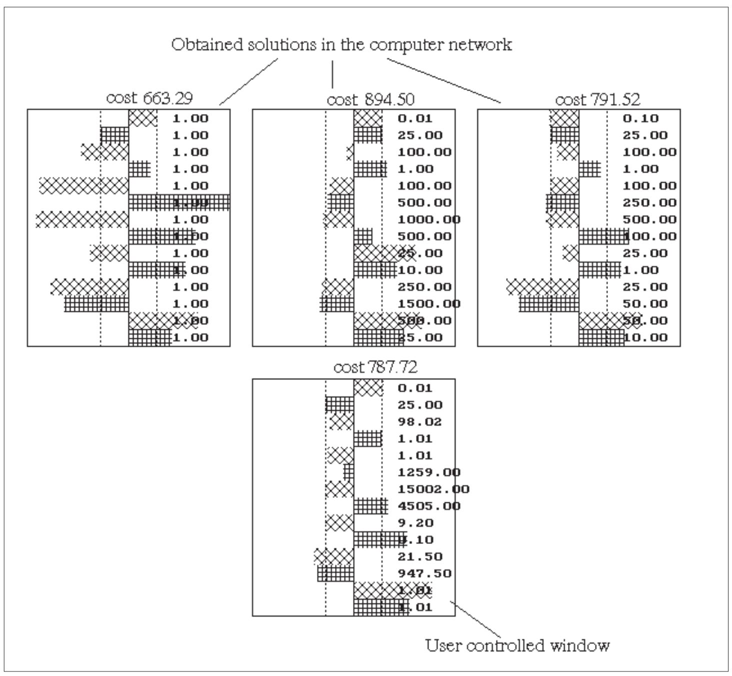

Figure 2. The window of an interactive comparison of the solutions.

3.3. The interactive optimization algorithm

Computer network offers new methods and tools to solve problem (2.2) (also (4.3)). Two possible methods are presented bellow:

- Parallelisation of the optimization algorithm (in our case – variable matrix).

- Interactive decision making on the basis of several solutions of problem (2.2) obtained by using local optimization by different computers with various values of the coefficients λ_j (in the case of problem (4.3) – the coefficients r_j).

The shortcoming of the first method is a sufficiently complex optimization algorithm and the corresponding software is based on authors' great background knowledge. Thus, it is considerable to use acclaimed optimization means without any alteration. As a result, the efficiency of the second method is higher as there is human participation in it. The following interactive optimization method is proposed:

- The solving of the optimization problem with different initial data is performed in parallel: different computers solve the same problem (2.2), with a different coefficients λ_j combination. The process is organized by designating the computers as the *host* and the *workers*. The *host* controls the process of computer members, i.e. *workers*, that execute the *host* tasks (see Fig. 3).

- Any solution returned to the *host* by any *worker* is compared visually with solutions returned earlier by the workers, and new tasks are allocated for the computer network combining the new combination of coefficients λ_j.

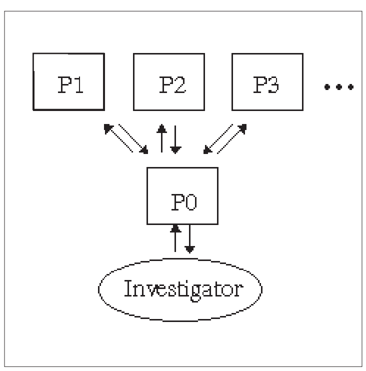

Figure 3. The structure of interactive analysis.

The investigator starts up by organizing all the computers to solve the problem with various initial data. During the time moment t_l the problem is solved only once by using either one or more computers. From the time moment t_l, the efficiency of the problem calculation increases (see Fig. 4) as the user has a greater number of various solutions for the interactive decision making.

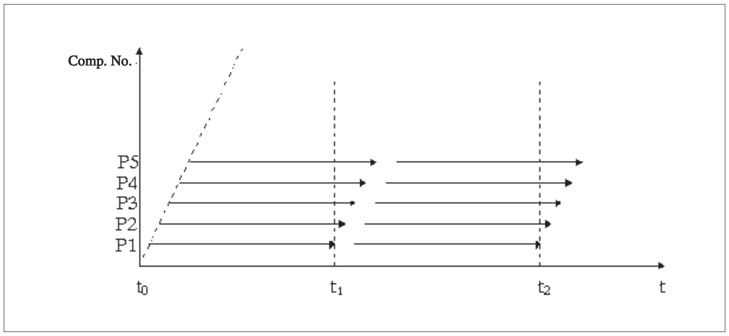

Figure 4. The efficiency conditions of the computer network application.

4. APPLICATION

The problem of this type is solved in papers [1, 2]. This is a problem of selection of the optimal nutritive value. The criteria groups are as follows:

1) feed cost price $\varphi(x_1, \ldots, x_n) = \sum\limits_{i=1}^{n} x_i k_i$,

2) recommended permissible maximal and minimal violation of the requirements $\Psi_j(x_1, \ldots, x_n), j = \overline{1, m}$:

$$\Psi_j(x_1, \ldots, x_n) = \begin{cases} 0, \\ \quad \text{if } R^j_{\min} \le \sum\limits_{i=1}^{n} x_i A_{ij}(x_l, \ldots, x_n) \le R^j_{\max}, \\ \sum\limits_{i=1}^{n} x_i A_{ij}(x_l, \ldots, x_n) - R^j_{\max}, \\ \quad \text{if } \sum\limits_{i=1}^{n} x_i A_{ij}(x_l, \ldots, x_n) - R^j_{\max} > 0, \\ R^j_{\min} - \sum\limits_{i=1}^{n} x_i A_{ij}(x_l, \ldots, x_n), \\ \quad \text{if } R^j_{\min} - \sum\limits_{i=1}^{n} x_i A_{ij}(x_l, \ldots, x_n) > 0, \end{cases}$$

where x_i is the constituent part of the i-th ingredient in feed;

$R^j_{\min}$ is the recommended permissible minimal amount of the j-th nutritive characteristics in feed;

R^j_{max} is the recommended permissible maximal amount of the j-th nutritive characteristics in feed;

A_{ij} is a non-linear function, expressing the value of the j-th nutritive characteristics of the i-th ingredient;

k_i is the price of the i-th ingredient for a weight unit.

The criteria of the first and the second groups are contradictory – when the violation of permissible amount of nutritive characteristics increases, the price of feed is falling.

Taking into consideration, that the sum of ingredient constituent parts x_i must be equal to 1 and the ratio of the nutritive characteristics affect the feed intake (see [1, 2]), the following equations in the definition domain $\bar{A}$ may be considered:

$$1) \qquad \sum_{i=1}^{n} x_i = 1, \tag{4.1}$$

$$2) \qquad \sum_{i=1}^{n} x_i (A_{it_1^\nu}(x_l, \dots, x_n) - c_\nu A_{it_2^\nu}(x_l, \dots, x_n)) = 0, \; \nu = \overline{1, w}, \tag{4.2}$$

where: c_ν is the required ν-th ratio of the nutritive characteristics;

(t_1^ν, t_2^ν) is the ν-th combination of the nutritive characteristics that are restricted in pairs;

w is the number of combinations of the nutritive characteristics that are restricted in pairs.

In [1, 2] the following formulation of the selection of the optimal nutritive value problem is considered:

$$\min_{x_1, \dots, x_n} f(x_1, \dots, x_n) =$$

$$\min_{x_1, \dots, x_n} \left\{ \sum_{j=1}^{m} r_j \Psi_j^2(x_1, \dots, x_n) + \sum_{i=1}^{n} x_i k_i + s(\sum_{i=1}^{n} x_i - 1)^2 + \right. \tag{4.3}$$

$$\left. + \sum_{\nu=1}^{w} s_\nu (\sum_{i=1}^{n} x_i (A_{it_1^\nu}(x_l, \dots, x_n) - c_\nu A_{it_2^\nu}(x_l, \dots, x_n)))^2 \right\},$$

$$z_{\min}^j \le x_i \le z_{\max}^j, \; i = \overline{1, n}.$$

Here constraints (4.1) and (4.2) are included into the object function with positive weight coefficients s and $s_\nu, \nu = \overline{1, w}$. Thus, the problem has been simplified as the definition domain of problem (4.3) transferred into the rectangular.

In comparison with problem (2.2), the coefficients r_j of problem (4.3) correspond to the coefficients λ_j of problem (2.2); the coefficient at the criterion $\varphi(x_l, \dots, x_n)$ is equal to 1, i.e. $\lambda_{m+1} = 1$. The peculiarity of problem (4.3) is the use of squared criteria Ψ_j in the object function. Likewise the transformation of determined area to rectangular one, it broadens the scale of potential local optimization algorithms.

The authors in [1, 2] suggest to solve problem (4.3) by using variable matrix algorithm [3], that presents in the optimization software MINIMUM [4]. The values of the coefficients s and $s_\nu, \nu = \overline{1, w}$, have been fixed relatively great. Selecting different values of the coefficients r_j as well as the initial values of the argument $X = (x_l, \dots, x_n)$ during some consecutive iterations, the solutions are different. The interactive selection of the coefficients like this enables us to find the solution that satisfies the technological needs.

5. CONCLUSIONS

An interactive optimization method by using computer network has been proposed. The advantages of the method are as follows:

- The problem is solved by more than one computer. Thus, the computer time for optimal solution may be economized.
- The investigator participates actively in the optimization process.
- The investigator discovers a new knowledge of the problem in the process of calculation. Thus, it may result a new and more efficient optimization strategy to be designed or applied.

Further investigations seek to estimate experimentally the efficiency of the computer network application depending on:

- single duration of the local optimization;
- strategy of visual presentation of a set of results (solutions) of the local optimization (acceptable various result treatment, for instance, memorizing all the solutions, some of them, the optimal and etc.);
- simultaneous communication of multiple investigators by using common computer network.

REFERENCES

[1] G. Dzemyda and T. Petkus. Selection of the optimal nutritive value. In: *Proc. of the Special IFORS Conference*, Organizational Structures, Management, Simulation of Business Sectors and Systems, KTU, Technologija, Kaunas, 1998, 73 – 77.

[2] T. Petkus and G. Dzemyda. Optimal nutritive value design. In: *Proc. of XXXIX Conference of the Lithuanian Mathematical Society*, VGTU, Vilnius, 1998, 441 – 446.

[3] V. Tiešis. The variable metric method for local minimization of multivariate functions subject to simple bounds. In: *Proc. of the Conference Vyczislitelnaja Technika*, R. Chomskis (ed.), Kaunas Polytechnic Institute, Kaunas, 1975, 111 – 114.(in Russian)

[4] G. Dzemyda (ed.). *The Package of Applied Programs for Dialogue Solving of Multiextremal Problems MINIMUM: A Description of Using.* The State Fund of Algorithms and Programs (reg.No50860000112), Inst.Math.Cybern., Vilnius, 1985, 1 – 41. (in Russian)

[5] A. Geist, A.Beguelin, J. Dongarra, W. Jiang, R. Manchek and V. Suderam. *PVM 3 Users Guide and Reference Manual.* Oak Ridge, 1994.

[6] A. Geist, A. Beguelin, J. Dongarra, W. Jiang, R. Manchek and V. Suderam. *PVM: Parallel Virtual Machine. A Users' Guide and Tutoral for Networked Parallel Computing.* Cambridge, 1994.

[7] A. Beguelin, J. Dongarra, A. Geist, R. Manchek and V. Suderam. *A Users' Guide to PVM (Parallel Virtual Machine).* Oak Ridge, 1991.

[8] B. Karpak and S. Zionts. (eds.). *Multiple Criteria Decision Making and Risk Analysis Using Microcomputers. NATO ASI Series, Series F: Computer and Systems Sciences*, **56**, Springer, 1989.

[9] S. Zionts. Multiple criteria mathematical programming: an updated overview and several approaches. *Multiple Criteria Decision Making and Risk Analysis Using Microcomputers. NATO ASI Series, Series F: Computer and Systems Sciences*, **56**, Springer, 1989, 7 – 60.

[10] P.B.Hansen. An evaluation of the message-passing interface. *ACM SIGPLAN Notices*, **33** (3), Mar. 1998, 65 – 72.

KOMPIUTERIŲ TINKLO PANAUDOJIMAS INTERAKTYVIAM OPTIMIZACIJOS UŽDAVINIŲ SPRENDIMUI

G. DZEMYDA, T. PETKUS, J. ŠINKŪNAS

Daugelio kriterijų optimizavimo uždavinys yra dažnai sutinkamas sprendžiant taikomuosius uždavinius. Tačiau jo sprendimas reikalauja pakankamai didelių kaštų. Pastaruoju metu aktyviai vystomi interaktyvūs optimizacijos metodai. Jie leidžia sprendėjui aktyviai valdyti sprendimo procesą. Algoritmo vykdymui spartinti pateikiama lygiagrečiojo metodo versija. Lygiagretieji optimizavimo algoritmai leidžia ne tik išspręsti uždavinį greičiau, bet ir išspręsti daug sudėtingesnius uždavinius, kai panaudojami suminiai daugelio procesorių resursai. Skaičiavimai atlikti 15 Pentium II kompiuterių tinkle, naudota PVM ir MPI bibliotekos ir Windows NT operacinė sistema.