TEMPUS JEP - 0438 - 90

COMPUTER AIDED DESIGN
OF STRUCTURES
INCLUDING COMPLEX MATERIAL BEHAVIOUR
AND OPTIMIZATION

COORDINATOR: PROF. GUY GUERLEMENT
Polytechnic Faculty of Mons, Belgium

TEACHING OF CIVIL ENGINEERING STUDENTS ON COMPUTER AIDED ANALYSIS AND DESIGN OF STRUCTURES

22 - 24 June 1992, Cracow

Workshop organized by Cracow University of Technology
24 Warszawska St., Cracow, Poland

Workshop organizer prof. Zenon Waszczyszyn

COMPUTER AIDED OPTIMUM DESIGN OF METAL STRUCTURES

Dr. Károly JARMAI
associate professor
University of Miskolc, Hungary, H-3515 Miskolc-Egyetemváros

INTRODUCTION

Single- and multiobjective optimization techniques are good tools for finding the best results of the design problem both in education and research fields. The optimization techniques force the designer to collect all constraints in the analysis stage to be able to make the synthesis, the real design of the structure. The computer code, developed at the University of Miskolc, contains seven various type multiobjective and five single-objective optimization techniques [1]. The following single-optimization programs are built into the system: Flexible Tolerance method of Himmelblau [2], the Direct-Random Search method of Weisman [3], the Rosenbrock's Hillclimb procedure [4], the Complex method of Box [5], the Variable Metric method of Davidon, Fletcher and Powell [6].

The general formulation of a single-criterion nonlinear programming problem is as follows:

$$\begin{aligned} &\text{minimize} \quad f(x), && x = x_1, x_2, .., x_N, \\ &\text{subject to} \quad g_j(x) \geq 0, && j = 1,2,.....,P, \\ &\qquad h_k(x) = 0, && k = P+1,...,P+M. \end{aligned}$$

There are seven different multiobjective optimization techniques used: the Min-max technique, the Weighted min-max method, two types of Global criterion techniques and a Weighted global criterion technique. The Pure weighted and the Normalized weighted techniques are also included in the system [1,7].

A multicriteria optimization problem can be formulated as follows :

$$\begin{aligned} &\text{Find } f(x^*) = \text{opt } f(x), \\ &\qquad \text{such that} \quad g_j(x) \geq 0, && j = 1,....,M, \\ &\qquad\qquad h_i(x) = 0, && i = 1,....,P. \end{aligned}$$

where x is the vector of decision variables defined in N-dimensional Euclidean space and $f_k(x)$ is a vector function defined in K-dimensional Euclidean space. $g_j(x)$ and $h_i(x)$ are inequality and equality constraints. The solutions of this problem are the so called Pareto optima.

The efficiency of the computer code is shown at the design of single-bay plane frame, with I-cross section with continuously increasing web height, taking account 3 objective functions and 35 inequality constraints. The second application is the design of a welded, stiffened box girder as a main girder of an overhead travelling crane with 4 objectives and 16 inequality constraints. The third application is the design of a spindle-bearing system with 3 objectives and 10 inequality constraints. The fourth application is the design of cellular plates with 3 objectives and 14 inequality constraints, the fifth application is design of compressed columns with 1 objective and 9 inequality constraints.

In these cases the optimization techniques had different efficiencies, one or two is better to use for that problem than the others, regarding the single-objective optimization techniques. At the multiobjective optimization techniques the main difference is, what kind of Pareto optima can be found and how close is it to the ideal solution. The great number of Pareto optima gives the possibility for the designer to choose the "best" from them [1,8,9,10,11]. See Table 1.

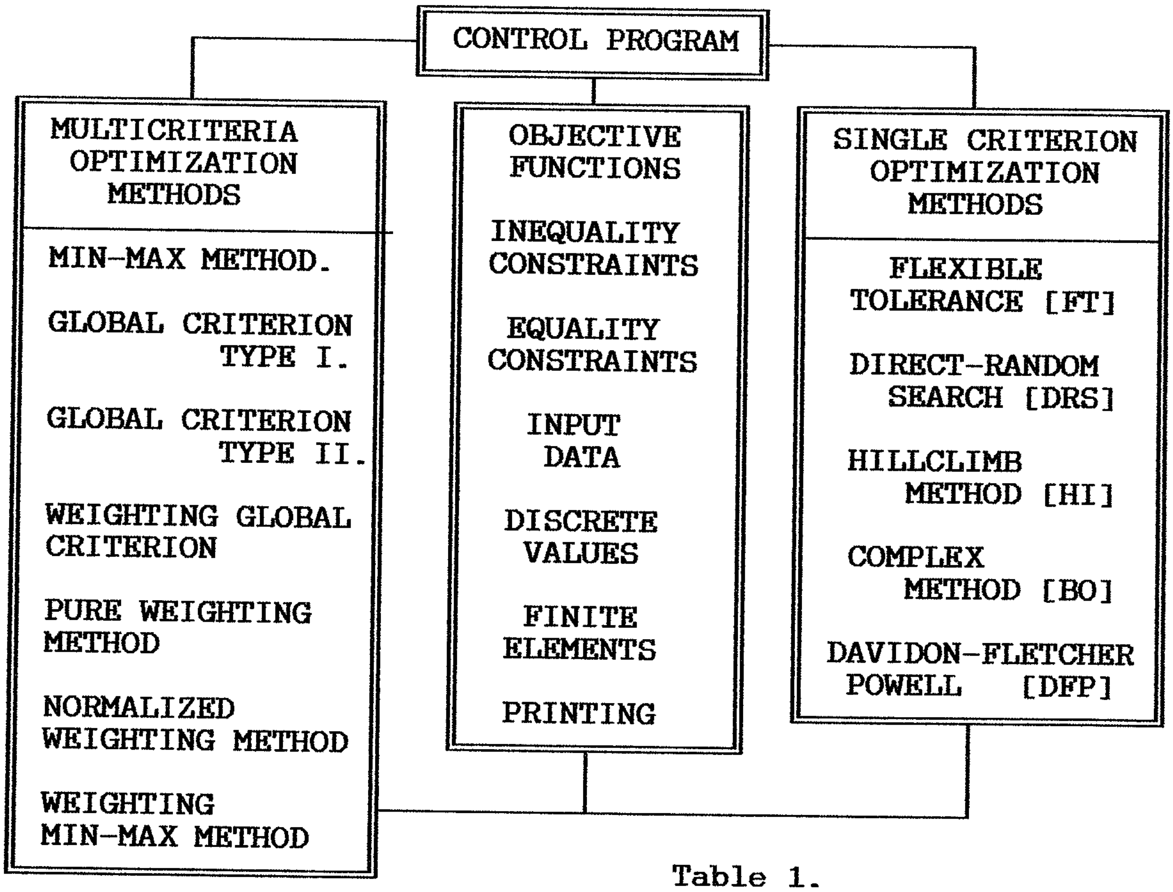

Table 1.

The program system was made in MS FORTRAN 5.0 on PC/AT/386 compatible computer. If we write the programs for example in Turbo C language, at that case the Complex method was quicker than the Hillclimb, but in FORTRAN the Hillclimb method was the quickest one, but usually gave local optimum. We have made some of the optimization programs in Quick Basic and the developing time was much smaller, but the runtime was longer. All the single-objective methods can find a feasible starting point, and give an optimum with unbounded and with discrete values. There are ranges of discrete values given for every variables.

REFERENCES

[1] Jármai,K.: Single- and multicriteria optimization as a tool of decision support system. Computers in Industry, 1989, Vol.11. No.3. p.249-266.

[2] Himmelblau,D.,M.: Applied nonlinear programming. McGraw-Hill , New York, 1972.

[3] Weisman,J.: MINIMAL, a combined optimization technique. Phd Dissertation, University of Pittsburgh, PA, 1968.

[4] Rosenbrock,H.,H.: An automatic method for finding the greatest or least value of a function. Computer Journal, 1960, Vol.3. No.3. p.175-184.

[5] Box,M.,J.: A new method of costrained optimization and a comparison with other methods. Computer Journal, 1965, Vol.8. p.42-52.

[6] Fletcher,R.,Powell,M.,J.,D.: A rapidly convergent descent method for minimization. Computer Journal, 1963, Vol.6. No.2. p.163-168.

[7] Osyczka,A.: Multicriterion optimization in engineering. Ellis Horwood, Chichester, United Kingdom, 1984.

[8] Jármai,K.: Application of decision support system on sandwich beams, verified by experiments. Computer in Industry. 1989, Vol.11. No.3. p.267-274.

[9] Farkas,J.,Jármai,K.: Minimum cross-sectional area of centrally compressed struts of square section with longitudinal stiffeners. Stability of Steel Structures Colloquium, Budapest, Apr. 25-27. 1990, Preliminary report, Vol.III. p.261-268.

[10] Jármai,K.: Decision support system on IBM PC for design of economic steel structures, applied to crane girders. Thin-walled structures, Elsevier Applied Science Publishers, 1990, Vol. 10. p.143-159.

[11] Farkas,J.: Optimum design of steel structures. Ellis Hoorwood Ltd. Chichester, 1984.