New inclusion functions in interval global optimisation of engineering structures

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ABSTRACT

Summary The problem of optimal design consists in finding the optimum parameters according to a specified optimality criterion. Existing optimization methods usually are not reliable or cannot use the nondifferentiable, not continuous objective functions or constraints. An interval global optimization method is very stable and robust, universally applicable and fully reliable. The interval algorithm guarantees that all stationary global solutions have been found. The convergence of this method depends on choice of a good inclusion function. In this paper a method of constructing the inclusion function is presented. This method is based on special monotonicity tests. The algorithm is applied to optimization of mechanical systems. Other examples of application in mechanics are described in [6].

Algorithms for solving global optimization problems can be classified into heuristic methods that can find the global optimum only with high probability, and methods that guarantee to find a global optimum with some accuracy. The most important class of methods of the second type are branch and bound methods [1]. They originate from combinatorial optimization, where global optima are also wanted but the variables are discrete and take several values only. Branch and bound methods guarantee to find a global optimum with a desired accuracy after a predictable (though often exponential) number of steps. The basic idea is that the configuration space is split repeatedly by branching into smaller and smaller parts. This is not done homogenously, but instead some parts are preferred and others are eliminated. The details depend on bounding procedures. Lower bounds on the objective allow to eliminate large portions of the configuration space early in the computation so that only a (usually small) part of the branching tree has to be generated and processed. The lower bounds may be obtained by techniques of the interval analysis [1], or methods based on the knowledge of Lipshitz constants. In many engineering structures relation between the solutions and uncertain parameters is monotone. For monotone functions extreme values of the solution can be calculated using only the endpoints of given intervals [2]. Monotonicity of the solution can be checked by using Taylor series [3] or interval method [1]. Using monotonicity tests we can build a very good inclusion function for very large problems [2]. In this paper a new inclusion functions are applied in global optimisation method. This inclusion function can be applied for nonlinear problems of computational mechanics [3].

We can also accelerate the speed of calculation by using hybrid algorithms [5]. In this case first we find approximate solution using another optimisation method. Then we can check if the particular solution is a global solution of the optimisation problem by using interval global optimisation algorithms. In the first part of this algorithm we can apply any optimisation method particularly gradient method, genetic algorithms, sequential linear or quadratic programming method and many others [5].

This method can be applied also to modelling of structures with uncertain parameters [3]. It can be shown that exists relation between fuzzy sets theory and probability theory [4]. Using α-level-cut method we can transform problem with fuzzy parameters into problem with interval parameters. Then we can solve interval equation using monotonicity tests. Interval solution can be transform into fuzzy solution by using resolution identity [4]. If we know membership function of the solution upper and lower probability of some event can be calculated [4]. In this paper above described method can be applied to optimisation of structures with uncertain parameters.

Examples of applications will be presented at the conference.

This work was supported by the grant No. 8T11F00615 from the Committee of Scientific Research (KBN).

REFERENCES

[1] Hansen E.R., *Global Optimization Using Interval Analysis*, Marcel Dekker, New York (1992)

[2] Pownuk A., Applications of sensitivity analysis for modelling of structures with uncertain parameters. *International Conference on Interval Methods in Science and Engineering Interval'2000*, Germany, Karlsruhe (2000)

[3] Pownuk A., Calculation of displacement in elastic and elastic-plastic structures with interval parameters. *33 rd Solid Mechanics Conference (SolMech2000)*, Poland, Zakopane (2000)

[4] Pownuk A., Calculation of reliability of structures using fuzzy sets theory. *The 32nd Symposium on Mathematical Physics with special session "Symmetries in Nonlinear Systems"*, Poland, Toruń (2000)

[5] Pownuk A., Hybrid interval method for global optimisation of engineering structures. *III slovensko-posko-české sympózium "Nelineárna mechanika"*, Slovakia, Bratislava (2000)

[6] Pownuk A., Optimization of mechanical structures using interval analysis. *CAMES*, (submitted for publication)