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BRANCH AND BOUND METHOD FOR GLOBAL OPTIMA OF SIZE OPTIMIZATION BENCHMARKS

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Abstract: *This contribution focuses on searching for global optima of size optimization benchmarks utilizing a method based on branch and bound principles. The goal is to show the process of finding these global optima on several examples. To minimize computational demands a suitable parallelization is used. Optima which can be found in available literature and optima obtained in this work are compared.*

Keywords: ***benchmarks, discrete sizing optimization, branch and bound method, global optima, parallel programming***

1. Introduction

A numerical optimization is nowadays a very popular tool for obtaining a different view on structures and materials. Shape of the structure, cross-sections, amount of reinforcement, thicknesses of sheets, design of concrete mixture and many other properties can be optimized. Recently, many heuristic algorithms are developed, tested on benchmarks and their efficiency is compared. To compare distinct optimization methods, it is appropriate to know the global optima of these benchmarks. The closer to the global optimum the gained value is, the better the method is. In the past, it was not possible to obtain these optima because of large computational demands. A computational power is growing every year therefore now seems to be the right time to deal with this issue.

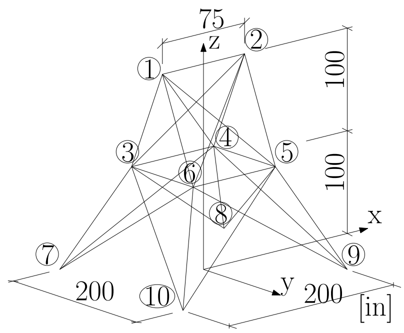

Fig. 1: The 25-bar truss

This paper is trying to outline a process of searching for global optima of sizing discrete optimization benchmarks. Various optimization methods can be used for obtaining optima such as gradient methods, heuristics methods, or evolutionary algorithms. These methods do not guarantee that the gained optimum is the global one because only a portion of the space is explored. Nevertheless, the advantage of these methods is that the optimum is found in a real time and the ability to obtain or at least approach a vicinity of a global optimum is considered as a sign of quality. In our work, we used a method based on branch and bound principles (Pospíšilová (2011)) to obtain global optima and appropriate cross-sections. A good estimate of a lower and upper bounds reduces the searched space but still ensures that the global

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Tab. 1: A comparison of results for the 25-bar truss discrete case from literature and the present work where m is the final weight

Variable	Units	this paper	Kripka	Lemonge & Barbosa	Li & Liu	Wu & Chow	Coello	Rajeev & Krishnamoorthy
		B & B	SA	GA	PSO	GA	GA	GA
m	lb	**484.33**	**484.33**	484.85	484.85	486.29	539.78	546.01

optima can be found. The algorithm presented in our paper is universal, i.e. it is applicable to other truss structures or a similar type of problems. We hope that the knowledge of global optima of studied benchmarks will improve the development of optimization methods.

2. Results

Tab. 1 shows the optimum gained with the branch and bound method as well as optima obtained by heuristic algorithms found in literature for 25-bar truss problem, see Fig. 1. The obtained result by the branch and bound method is identical to the solution presented by author Kripka (Kripka (2004)). He used the Simulated Annealing method. However, he did not search the whole subspace of possible solutions so he could not be sure that the obtained optimum is the global one. It can be seen that the results of the discrete and continuous case of the optimization problem are near to each other, see Tab. 2 and Tab. 1. Therefore, the solution is potentially correct. However, we can be sure that we have found the global optimum because we have systematically explored the whole space where the global optimum is located.

Tab. 2: Comparison of results for the 25-bar truss continuous case where m is the final weight

Variable	Unit	Perez & Behdinan	this paper
m	lb	483.84	**483.82**

3. Conclusions

The branch and bound method is suitable for bigger structures. It does not enumerate all potential solutions of the optimization problem contrary to the enumeration method. The space is restricted to the subspace between the lower and the upper bound where the global optimum is located. The lower bound is obtained e.g. with some continuous optimization method. The constrained nonlinear programming using sequence of parameterized unconstrained optimization was used in this paper. The upper bound can be gained with some heuristic method which is fast and quite effective. The more accurate the value is, the efficient the branch and bound method is. The task will not be branched to so many subproblems.

Global optima for computational demanding tasks such as the 25-bar truss problem have not been published yet to the best authors' knowledge. We hope that by publishing the algorithm as well as the value of the global optimum we will introduce a standard of quality that will help to improve new optimization methods.

References

Kripka, M. (2004), Discrete Optimization of Trusses by Simulated Annealing. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, Vol 26, No.2, pp 170-173.

Pospíšilová A. (2011). *Search for global optima of sizing optimization benchmarks* (in Czech), Diploma Thesis, CTU in Prague, FCE, Department of mechanics, Prague.