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ADVANCES ON PARALLEL COMPUTING IN STRUCTURAL TOPOLOGY OPTIMIZATION

J. París, I. Colominas, F. Navarrina and *M. Casteleiro

Group of Numerical Methods in Engineering, GMNI
Department of Applied Mathematics
School of Civil Engineering, University of A Coruña
Campus de Elviña 15071, A Coruña, Spain
jparis@udc.es, *web: http://caminos.udc.es/gmni*

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ABSTRACT

Topology optimization of structures is a relatively new discipline of optimization. Since the first formulations were established in 1988 several contributions have been published. The most of this works state a maximum stiffness objective due to the computational advantages that they offer. However, in engineering applications it is much more appropriate to use different formulations that include stress constraints because this criterion is the most widely used in real structures and, since the elastic limit is not exceeded, the feasibility of the solution is assured. According to that, different approaches have been proposed to solve topology optimization problems with stress constraints [1], [2], [3].

These minimum weight with stress constraints approaches produce very good results but require higher computational requirements than maximum stiffness approaches. Thus, it is necessary to analyze different techniques in order to reduce the computing time. In this paper we propose to develop a parallel code with OpenMP directives to solve the topology optimization problem with stress constraints. As it can be observed in the minimum weight formulations proposed ([2] or [3] for example) there are three keypoints in the optimization process that require almost the total computing time.

The first keypoint is the calculation of the structural analysis with the Finite Element formulation. This algorithm requires a considerable amount of computing time because it must be recalculated in every iteration. However, the structural analysis means a reduced percentage of the total computing time. In addition, the parallelization of the Finite Element model is much complicated and does not usually produce appropriate speed-up.

The second keypoint corresponds to the first order stress sensitivity analysis. This procedure is, computationally, very expensive because the number of stress constraints and design variables is usually very high in topology optimization problems. These computing time requirements can be reduced by using the Adjoint Variable technique. In addition, this algorithm can be easily parallelized because the sentivity analysis of each stress constraint over the design variables can be calculated independently. Thus we can divide the steps of the loop that computes this sensitivity analysis between the threads of the computer.

This parallelization of the stress sensitivities produces very high performance because it is fully parallel and does not require to compute some parts of the calculus in sequential mode. In addition, the loop parallelization produces almost the theoretical speed-up because each iteration of the loop is independent of the other ones.

The third keypoint corresponds to the optimizer of the solution. In this problem we have used a Sequential Linear Programming algorithm with Quadratic Line Search. The most expensive step of this procedure is to find the most appropriate search direction with the Simplex Algorithm. The parallelization of this algorithm is not possible because the steps to develop in each internal iteration depends on the solution of the previous internal iteration. However, one of the internal steps in each iteration of the Simplex algorithm (the diagonalization of the matrix of the problem) requires more than 95 % of the total computing time of the Linear Programming methodology and it can be easily parallelized. This parallelization is not as efficient as the one developed in the sensitivity analysis because it requires to calculate some parts of the algorithm sequentially and it is necessary to impose some barriers of parallelization to syncronize all the threads. However, the total speed-up obtained is very satisfactory (figure 1).

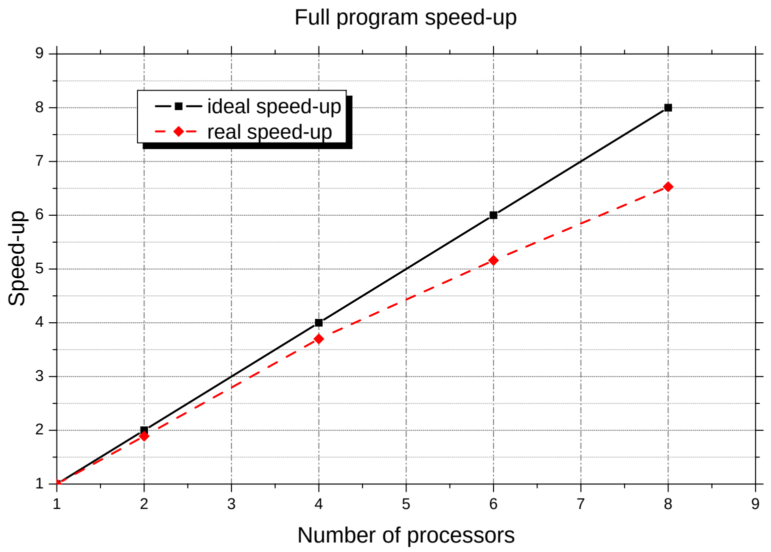

Figure 1: Total Speed-up in a problem with 1688 design variables and 1688 constraints.

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