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BENCHMARKING OPTIMIZATION METHODS FOR STRUCTURAL TOPOLOGY OPTIMIZATION PROBLEMS

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Structural topology optimization problems are today mostly solved using sequential convex approximation methods such as the Method of Moving Asymptotes (MMA). This method was especially designed to be used in optimal design and is extensively used in commercial software and in academic research codes [5]. However, as topology optimization problems are categorized as the large-scale non-linear optimization problems, it is possible to solve them with general software, and mathematical programming methods.

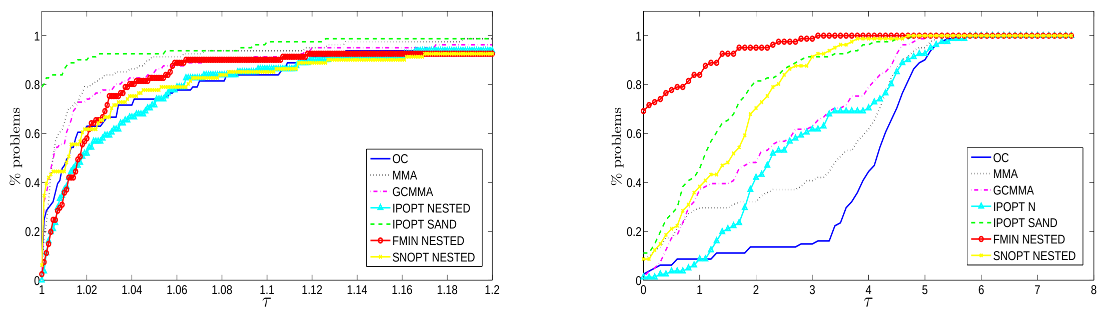
The goal of this paper is to perform extensive numerical tests and compare the commonly used first-order structural topology optimization algorithms such as MMA, GCMMA and the Optimality Criteria method [1], with existing state-of-the-art general purpose non-linear optimization methods such as the interior point methods in IPOPT [6] and MATLAB, and the sequential quadratic programming method in SNOPT [4].

We consider three of the most popular structural design problems under study: minimal compliance, minimal volume, and mechanism design. We introduce the topology optimization problems in their most popular formulation by using SIMP (Solid Isotropic Material with Penalization) scheme for penalizing the intermediate material values and density filters to ensure existence of solutions and avoid checkerboards in the design [2]. In this paper we introduce several equivalent reformulations of the problem. We choose NESTED (the nodal displacements depends on the density variable) and SAND (Simultaneous Analysis and Design) approach to compare their performance when second order information is available to solve the problem.

Furthermore, extensive numerical results are presented using performance profiles [3]. This tool shows the results in a graphical way by comparing the value m for a certain criteria for each solver s, to the best value of all the solvers. More specifically, the criteria considered to evaluate the solvers are the number of iterations, objective value, number of stiffness assemblies, and CPU time. For a test set P of problems, the performance of the solvers is measured by the function ρ:

$$\rho_s(\tau) = \frac{1}{n_p}\text{size}\{p \in P : r_{p,s} = \frac{m_{p,s}}{\min\{m_{p,s} : s \in S\}} \leq \tau\}.$$

It produces a general vision of the performance because it shows how they behave for all the problems and not only when they are the best. Among all the results, we highlight the performance of IPOPT in SAND formulation for minimal compliance problems, shown in Figure 1. It outperforms the rest of solvers. In a small range of τ, it achieves optimal objective values for the 80% and 100% of the problems. The faster increase of ρ the better performance of the method. IPOPT shows also good behavior for the number of iterations. Although fmincon is the best, it has a very poor performance for objective value. The performance for the rest of the solvers are far from the optimal in both cases.



(a) Objective function value

(b) Number of iterations (logarithmic scale)

Figure 1: Performance profiles for a set of 80 medium-size topology optimization problems

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