A NOVEL HEURISTIC ALGORITHM FOR MINIMUM COMPLIANCE TOPOLOGY OPTIMIZATION

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1. Motivation

Topology optimization of structures is a permanently developing research area. Since the early papers from late eighties of twentieth century one can find in the literature numerous approaches to generating optimal topologies based both on optimality criteria and evolutionary methods. A general overview as well as a broad discussion on topology optimization concepts are provided by many survey papers and books, e.g. [1], [2]. At the same time hundreds of papers present numerous solutions including classic Michell examples as well as complicated spatial engineering structures, implementing specific methods ranging from gradient based approaches to evolutionary structural optimization, biologically inspired algorithms, material cloud method, spline based topology optimization and level set method. One of the most important issues stimulating this progress nowadays is implementation of efficient and versatile methods to generation of optimal topologies for engineering structural elements. Among them there are many heuristic algorithms. Heuristic optimization techniques are gaining widespread popularity among researchers because they are easy for numerical implementation, do not require gradient information, and one can easily combine this type of algorithm with any finite element structural analysis code.

2. Algorithm

In topology optimization one searches for a distribution of material within a design domain that is optimal in some sense. The design process consists in redistribution of material and parts that are not necessary from objective point of view are selectively removed. The power law approach defining solid isotropic material with penalization (SIMP) if often adapted with design variables being relative densities of material. The elastic modulus E of each element is modelled as a function of relative density d_n using power law: $E_n = d_n^p E_0$, $d_{min} \leq d_n \leq 1$. The power p penalizes intermediate densities and drives design to a material/void structure.

The idea of original heuristic concept proposed in this paper is as follows. Based on results of structural analysis values of local compliances are evaluated for N elements/design elements. Next compliances are sorted in ascending order, N_{min}, N_{max} are specified and value of C is assigned to each design element n according to relation:

$$C(n) = \begin{cases} -1 & \text{if} \quad n < N_{min} \\ \dfrac{2}{N_{max} - N_{min}} n - \dfrac{N_{max} + N_{min}}{N_{max} - N_{min}} & \text{if} \quad N_{min} \leq n \leq N_{max} \\ 1 & \text{if} \quad n > N_{max} \end{cases} \tag{1}$$

The local update rule applied to design element d_n is now constructed based on values of function $C(n)$ evaluated for this element and for M neighboring elements forming selected neighborhood. The quantity m stands for a move limit.

$$d_n^{(t+1)} = d_n^{(t)} + \delta d_n, \qquad \delta d_n = \frac{1}{M+1} \left[\sum_{k=1}^{M} C(k) + C(n) \right] m \tag{2}$$

3. Results

Selected optimal topologies obtained within the framework of this paper illustrate the proposed concept. First is a square structure presented in Fig.1: 120 $\times$ 120 elements, load P = 50 N, a = 60 mm, material data: E = 10 GPa, ν = 0.3, volume fraction 0.3. Minimal compliance 116.6 Nmm has been obtained for final topology. Second example is a bridge-like structure shown in Fig.2: 240 $\times$ 80 elements, load p = 1 N/mm, a = 80 mm, material data: E = 10 GPa, ν = 0.3, volume fraction 0.3, for which final topology of compliance 43.2 Nmm has been found. For comparison, the same tasks have been solved using algorithm described in [3]. In both cases final compliances have larger values than the ones obtained within approach of this paper, namely 127.8 Nmm and 46.1 Nmm, respectively.

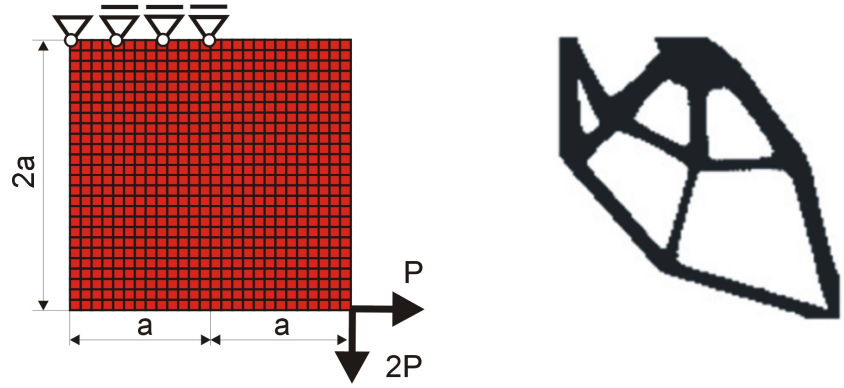

Figure 1. Initial structure (left), minimal compliance topology (right)

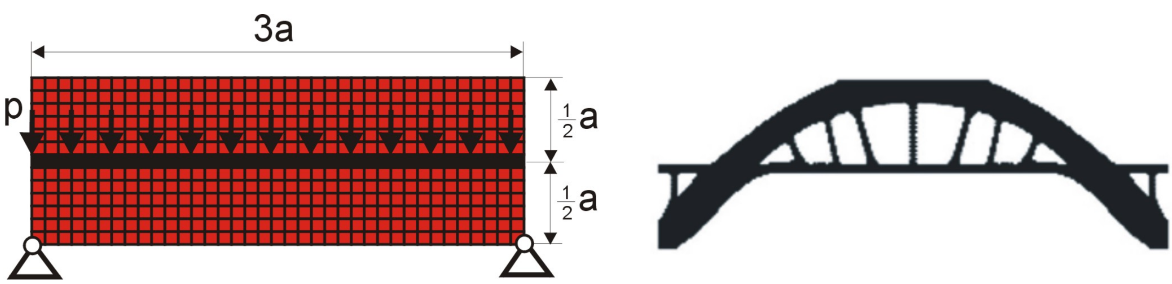

Figure 2. Initial structure (left), minimal compliance topology (right)

4. Closure

The results obtained using novel heuristic topology generator are very promising. Proposed technique is easy to implement, there are not many parameters to adjust. What is also important it does not require any additional density filtering and generated topologies are free from checkerboard effect. Finally, algorithm can be applied to both plane and spatial structures.

5. References

[1] M.P. Bendsoe and O. Sigmund (2003). *Topology optimization. Theory, methods and applications*. Springer, Berlin Heidelberg New York.

[2] J.D. Deaton and R.V. Grandhi (2014). A survey of structural and multidisciplinary continuum topology optimization: post 2000, *Struct. Multidisc. Opt.*, **49**, 1-38.

[3] O. Sigmund (2001). A 99 line topology optimization code written in Matlab, *Struct. Multidisc. Opt.*, **21**, 120-127.