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SHAPE OPTIMIZATION BY PARTICLE SWARM ALGORITHM UTILIZING ISOGEOMETRIC ANALYSIS

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Abstract: *The present paper describes the application of the particle swarm optimization (PSO) to the shape optimization of two-dimensional domains described by NURBS (non-uniform rational B-splines) and analyzed by the NURBS-based Isogeometric analysis (IGA). The regularization of the optimization problem, preventing undesirable clustering of control points of the underlying geometry leading to invalid geometry or parametrization, is achieved by controlling the magnitude of perturbation of design variables within the Particle Swarm Optimization (PSO) method using a background mesh produced by Matlab* `Distmesh` *tool. The capabilities and performance of the developed optimization strategy are demonstrated on a standard benchmark problem.*

Keywords: ***Shape Optimization, Particle Swarm Optimization, Nurbs, Isogeometric Analysis, Distmesh***

1. Isogeometric analysis

Isogeometric analysis (IGA) (Hughes, 2005) is a recently introduced method which builds upon the concept of isoparametric elements and upgrades it to the geometry level. Although the original intention was to span the gap between the computer aided design (CAD) and the finite element method (FEM), the various advantages and range of applicability make the IGA an interesting alternative to the widely used FEM. It has been shown that the IGA outperforms the classical FEM in various aspects (accuracy, robustness, system condition number, etc.). Another distinct advantage of the IGA over the FEM consists in the conciseness of the parametrization of the design variable space, which makes the IGA attractive for the shape optimization problems.

2. Particle swarm optimization

Particle swarm optimization (PSO) (Kennedy, 1995) is a nature-inspired method for simulation of social behavior of several particles by mimicking e.g. bird flocks or fish schools. Its main advantage is the simplicity of updating rules for particle's position and velocity terms. The geometrical meaning of the moving particles predetermines this method for solving geometrical problems as well as constrained problems where e.g. boundary problem can be tackled as elastic collisions of particles against a wall.

3. Shape optimization method

The present paper describes the application of the PSO to the shape optimization of two-dimensional domains described by NURBS and analyzed by the NURBS-based IGA. The regularization of the optimization problem, preventing undesirable clustering of control points of the underlying geometry leading to invalid geometry or parametrization, is achieved by controlling the magnitude of perturbation of design variables within PSO using a background mesh. This mesh, however, does not have to comply with

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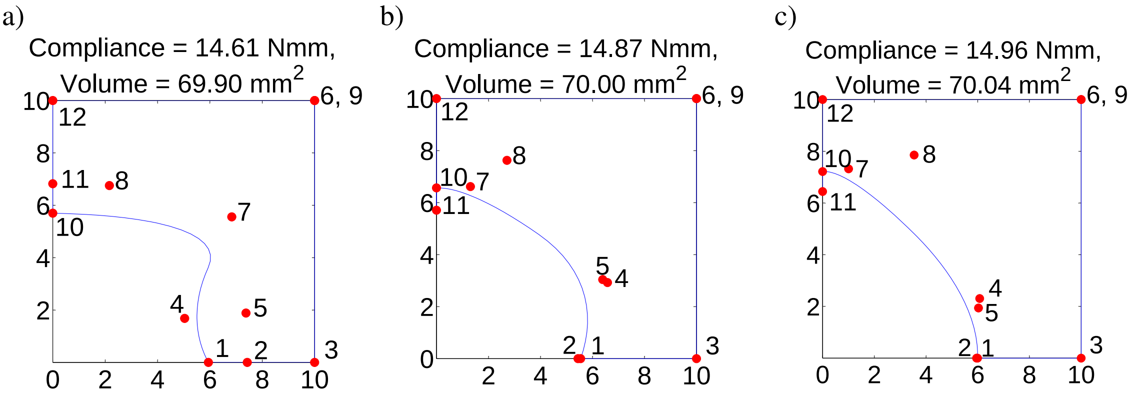

Fig. 1: Best solutions obtained in three runs of the PSO

requirements on a standard (e.g. FEM) computational mesh, as it does not have to follow the exact geometry. Meshes on individual NURBS patches of the geometry need not match in a compatible way, the mesh does not have to respect small features on those parts of the domain, which is not optimized etc. Thus construction of such mesh (MATLAB Distmesh tool (Persson, 2004) is utilized) is simple and does not introduce a bottleneck to the whole process. Although the proposed approach can be applied for the optimization of both location of control points of the geometry and weight of those control points (since the mesh can be generally of higher spatial dimension than the optimized domain), only the location of control points is currently considered in the optimization.

A combination of all methods mentioned above is applied on the benchmark structure taken from (Norato et al, 2004). Three optima of the benchmark presented in Fig. 1 are obtained with the proposed methodology. It is clearly visible, that the problem is ill-posed since there are several local optima.

4. Conclusion

The presented contribution shows a nice combination of three methods. The Isogeometric analysis is a step towards a CAD which, as an addendum, has several advantages over the classical FEM analysis in obtaining mechanical responses of a structure. The precise description of the geometry predetermines IGA as a solution to the shape optimization problem. The Particle Swarm Optimization algorithm is then characterized by a physical meaning of a group of flying particles which can utilize the inner properties of the dynamics of particles. The shape optimization problem is difficult from the regularity point of view. Therefore, not only limitations within the PSO have been used in this work, but also the second, background mesh produced by the `Distmesh` tool has been utilized. The obtained solutions indicate the used benchmark as ill-conditioned. However, solutions closed to a symmetric analytical solution have been observed as well.

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