Title:
Mesh Generation and Transformation towards the Integration of Topology Optimization with CAD

Authors:
Jean-Christophe Cuillière, jean-christophe.cuilliere@uqtr.ca, Université du Québec à Trois-Rivières
Vincent François, vincent.francois@uqtr.ca, Université du Québec à Trois-Rivières
Jean-Marc Drouet, jean-marc.drouet@usherbrooke.ca, Université de Sherbrooke

Keywords:
CAD/FEA integration, topology optimization, SIMP, BREP, mesh generation, multiple domains

DOI: 10.14733/cadconfP.2014.164-166

Introduction:
The development of Topology Optimization Methods (TOM) in 3D has been a very important subject of research for the last years [1]. These methods are aimed at automating the process of design optimization and thus, they are based on applying analysis iterations on 3D geometries that are automatically modified throughout these iterations. The objective function of the optimization problem, the way the analysis is performed (FEM, XFEM, meshless methods, etc.) and the way the geometry is modelled and modified along the process are the key issues that differentiate the great number of topology optimization methods that have been proposed in the literature. The next step in the development of TOM is its integration within CAD platforms. Ideally the process should start from an initial CAD model along with boundary conditions (BCs) and optimization objectives, and automatically end with an optimized CAD model that fulfills these objectives, all of this without any other user interaction. Completing this integration is likely to establish a new paradigm in the way we see the design activity and in the way we are likely to build and use CAD systems in the future. This integration faces many challenges among which:

- Geometry modelling in TOM should both handle geometry and topology modifications.
- Geometry modelling in TOM must allow discriminating non-design material (material that should not be affected by the optimization process) and design material (material that is to be affected by the optimization process).
- The topology optimization process should produce designs that can be manufactured at a reasonable cost.

The presentation proposed falls within this objective and brings about a contribution to the integration of TOM with CAD.

Main idea:
In our work [2, 3], the integration of TOM within CAD uses the FEM for analysis and the SIMP method as the optimization method. It is important to mention that this choice of the SIMP method is arbitrary and that many other TOM could have been used successfully as well. This platform's key features are a close integration between FEA and BREP modelling along with the adaptation of mesh generation concepts [4] to derive specific mesh generation and transformation algorithms [2]. The process starts with an initial part and BCs. Two BREP models are derived from this starting point, one for the whole material (in grey in Fig. 1) and the other one for non-design material (in red in Fig. 1). Thus, design material is not defined explicitly at the geometry stage. It will, in fact, be defined once the mesh generated (in green in Fig. 1). A specific and original mesh process [2] is used to make sure that finite elements are tagged as design (green) of non-design (red) elements and that the interface between design and non-design elements is conformal.

Proceedings of CAD'14, Hong Kong, June 23-26, 2014, 164-166

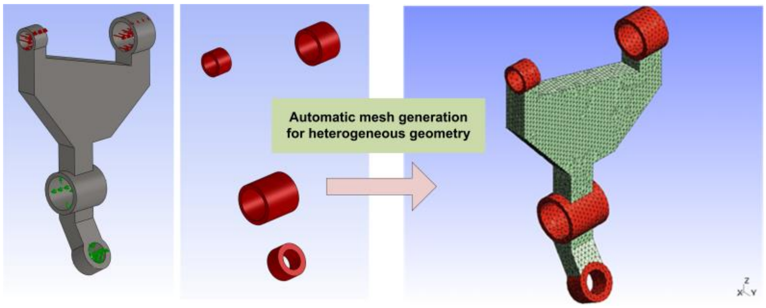

Fig. 1: The initial model and BCs, non-design material and resulting mesh.

Then, the SIMP optimization process is applied. A classical scheme has been adapted from [1] for the context of unstructured tetrahedral meshes. This optimization process results in a density field (see Fig. 2) throughout the initial domain that has to be processed in order to generate an optimal design. We have developed two approaches towards the objective. The first approach is based on deactivating finite elements and applying mesh transformation algorithms [2] that will be presented with details. The second approach is based on smoothing the density field and on computing iso-density surfaces. We will see on practical examples that these two approaches lead to very similar results. We will also see that mesh parameters (especially mesh size) have a strong impact on the final optimization results obtained.

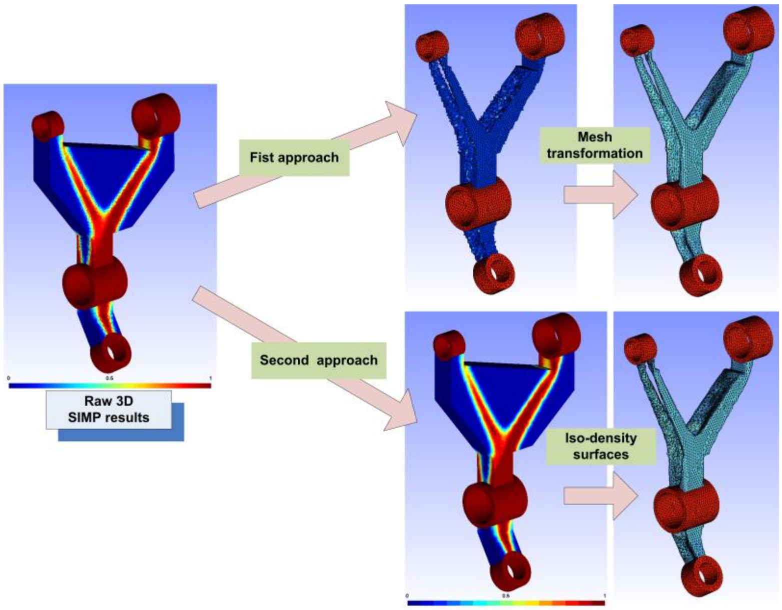

Fig. 2: Two methods for the generation of an optimized shape from SIMP raw results.

Conclusions:

Practical optimization results show that the approach proposed represents a promising step forward and that the TO process can be actually and successfully integrated with CAD. As mentioned in the introduction, the work presented here is based on the SIMP method with FEA. The detailed presentation will show that the integration of other optimization methods can easily be foreseen, which is an immediate extension of this work. However, the practical use of TOM on 3D parts also shows that many challenges remain in the context of fully integrating TOM in the CAD process. The fact that topology optimization results are influenced by many parameters, such as mesh sizing for example, is one of the important problems that remain to be studied thoroughly. Among all these

Proceedings of CAD'14, Hong Kong, June 23-26, 2014, 164-166

challenges, the most important one remains that TOM should not only provide designers with optimized models. It should indeed provide designers with optimized models that are actually practical and that can be manufactured at a reasonable cost. This objective is still, at this point, extremely ambitious and clearly remains a long-term perspective.

Acknowledgements:
This study was carried out as part of a project supported by research funding from the Québec Nature and Technology Research Fund and by the Natural Sciences and Engineering Research Council of Canada (NSERC).

References:

[1] Bendsoe, M. P.; Sigmund, O.: Topology optimization - Theory,Methods and Applications, 2nd ed, Springer, Berlin, 2003.

[2] Cuillière, J.-C.; François, V.; Drouet, J.-M.: Automatic mesh generation and transformation for topology optimization methods, Computer-Aided Design, (45)12, 2013, 1489-1506. http://dx.doi.org/10.1016/j.cad.2013.07.004

[3] Cuillière, J. C.; Francois, V.; Drouet, J. M.: Towards the Integration of Topology Optimization into the CAD Process, Computer-Aided Design and Applications, (11)2, 2014, 120-140. http://dx.doi.org/10.1080/16864360.2014.846067

[4] Frey, P. J.;George, P.-L.: Mesh generation : Application to finite elements, 2008.