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Sensitivity in shape optimization of complex 3D geometries using level sets and non-conforming finite elements

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ABSTRACT

For the last 20 years shape optimization has been stocking to penetrate industrial and real-life applications, whereas topology optimization was experiencing a fast growing soar and extensions to various applications. By the way there is still a great interest in shape optimization because of the intrinsic capability of shape description to facilitate considering complex problems involving local stress and manufacturing constraints for instance.

The level set description proposed by Osher and Sethian (1988) opened new perspectives to handle variable boundaries as in shape optimization. The implicit description of the geometrical entities allows for a more friendly and flexible manipulation of the geometry and overcome some restrictions related to the explicit approach of the geometry used in CAD systems: for example it is possible to reduce the topological complexity by removing or merging geometric entities (i.e. holes can merge or disappear) without degenerating the model, which was major restriction of shape optimization.

A few years ago, the level set method was nicely complemented by the XFEM (eXtended Finite Element Method) proposed by Moes et al (1999). This approach greatly reduces the difficulty of considering time-variable boundaries and complex geometries by using non-conforming meshes. This is definitively an advantage to circumvent the so-called velocity field to carry out shape sensitivity and mesh relocation difficulties, especially with thin walled structures or 3D designs.

The present research is continuing along and extending works by Duysinx et al (2006) and Van Miegroet and Duysinx (2007) to consider shape optimization based on a parametric level set description and XFEM. The work that is carried out in a common research project EFCONICO sponsored by the Walloon Region of Belgium aims at extending preliminary results 3 D structure and complex geometries, increasing the reliability of the method, enhancing the performances using advanced mesh generators as Gmsh, etc.

In particular the paper presents new theoretical developments and their numerical implementation in sensitivity analysis with respect to parametric design variable of level sets. The developments are illustrated with numerical applications dealing with complex shape applications involving 3D geometries and the boundary conditions along design variable boundaries.

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