A Framework for Aerodynamic Shape Optimization in Automotive Applications

A. Scardigli*†, R. Arpa† and H. Telib†

* Department of Mathematical Sciences (DISMA)
Politecnico di Torino
Corso Duca degli Abruzzi 24, 10129 Torino, Italy
e-mail: angela.scardigli@polito.it - web page: http://www.disma.polito.it

† OPTIMAD Engineering Srl
Via Giacinto Collegno 18, 10143 Torino, Italy
e-mail: {haysam.telib,rocco.arpa}@optimad.it - web page: http://www.optimad.it

ABSTRACT

When dealing with shape optimization of industrial geometries using evolutionary algorithms, two crucial aspects need to be addressed: the parametrization of complex geometries subject to constraints and the definition of surrogate models.

Industrial components have to fulfill a wide range of geometrical constraints, dictated for instance by manufacturing or operational requirements. Moreover, parts are often deformed locally and thus some continuity constraints between the deformable and the fixed regions must be prescribed. Classical parameterization techniques, such as the Free-Form Deformation (FFD) [1], are usually designed to manipulate the geometrical object globally rather than locally: bounding the displacements of the control points allows to achieve the desired continuity on the boundaries of the deformed part, as well as to limit the deformation, but this approach is neither intuitive nor efficient for shapes and constraints of arbitrary complexity. In order to overcome this issue, we propose an extension of the FFD, based on level-set methods. The main idea is to efficiently compute the approximate geodesic distance from the constraints through heat kernels [2] and to use this information to locally weigh the deformation field. This approach permits to handle a broad class of constraints, and can be applied straightforwardly to other parametrization methods.

We demonstrate our results for a real-life automotive application, i.e. the aerodynamic shape optimization of a car model subject to physical and geometrical constraints. Since we are interested in the global optimum, a multi-fidelity global optimization is performed. The strategy employs three different levels in order to speed-up computations and consists of two steps, both exploiting an Efficient Global Optimization algorithm [3]. In the first phase, we train a low-fidelity model and we use it in order to reduce the extension of the parametric space, whereas in the second one, the optimum is found using a few high-fidelity evaluations.

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