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Gradient-based optimization of parameterized CAD geometries

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Abstract

During the development of a new product, designers aim to meet requirements all while taking into account conflicting constraints. Thanks to HPC, numerical optimization methods are more and more used to determine the optimal shape in a faster manner at a lower cost.

Among these methods, both design of experiments and surrogate modeling methods allow to work directly on CAD parameters with the exception that the design space, i.e. the number of parameters, should be confined enough in order to be explored within a reasonable computational time. Other methods are based on the gradients provided by adjoint solvers, that is to say on the sensitivity of a cost function with respect to the displacement boundaries. The sensitivity is used to know how to change the shape at any node of the mesh to obtain better results. They naturally get over the number of degrees of freedom but they are computed with respect to the coordinates of the vertices of the surface mesh. However, since manufacturing constraints are difficult to express mathematically, they are not taken into account during the mesh morphing. This drawback can be avoid by using a CAD model that implicitly includes these manufacturing constraints.

To take advantage of both approaches, we propose an innovative method to extend these gradients to CAD parameters. An harmonic projection is used to compute the sensitivity of the mesh with respect to each CAD parameter. It projects a 3D geometry on a 2D parametric domain so as to compare the initial geometry and the perturbed geometry (generated by a change in the value of the CAD parameter). Thus, one computation provides both the desired result (like a pressure drop or an eigenmode) and the sensitivity of each CAD parameter. So, our approach is no more limited by the number of CAD parameters and can easily be integrated into the industrial development process. Academic test cases have proved the efficiency and accuracy of our method.