Acoustic Shape Optimization without Mesh Update

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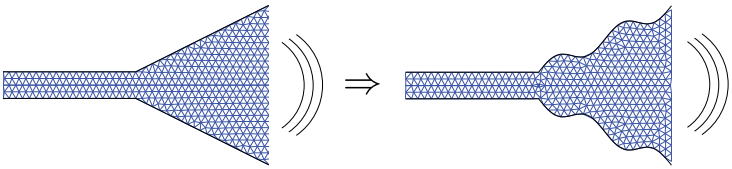
Shape optimization of an acoustic horn is considered, where a part of the outer boundary is updated iteratively to maximize its radiation efficiency. Traditionally when using the finite element method (FEM) to determine the properties of a given design, a body fitted mesh is used. However, this requires a mesh update at each design iteration, which can be costly and is not always robust. In this project, a fictitious domain approach with an unfitted mesh is used, to eliminate the need for a mesh update.

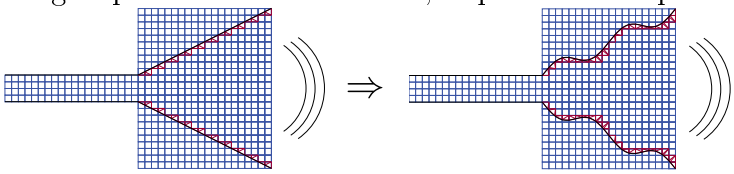
The governing Helmholtz equation is discretized on a rectangular, structured, unfitted mesh. The boundary of the horn is given by the zero-level contour of a level set function, and allowed to cut through the elements. The level set method has been used in a variety of shape optimization problems, and it is convenient to use in the implementation. The gradient of the objective function with respect to the level set is computed with an adjoint approach, which efficiently handles a large number of design variables.

A crucial component in the method is stabilization: developed in the context of the CutFEM approach, stabilization is needed to make the condition number of the system matrix bounded independent of the way the boundary cuts the mesh.

Although presently the project focuses on 2D acoustics, the procedure is also applicable to 3D acoustics and electromagnetics; in fact, the advantage of not re-meshing at every optimization step is more significant in 3D, since meshing is costlier in three than in two dimensions.



Design update with fitted mesh, requires mesh update.



Design update with unfitted mesh, no mesh update needed.