Introduction

The purpose of our research is the development of an automated approach to shape optimization for use with three-dimensional, complex, surface triangulations. Our approach is designed to enable parametric shape optimization of geometries for which a Computer-Aided Design (CAD) or user-defined parameterization is unavailable. In doing so it also eliminates communication and security issues associated with CAD engines operating outside the high performance computing environment.

In order to develop this method, we require two pieces of machinery:
1) A method for automatically creating low-order parameterizations of triangulated surface meshes
2) A mesh deformation engine driven by these parameters

Our design framework combines a Cartesian Euler solver (CART3D) with a BFGS gradient-based optimizer. This gives us flexibility to pursue surface mesh based methods for deformation as cartesian volume meshes with cut cells are very inexpensive to reproduce. However, with an expensive objective function, we’d prefer our optimizer to take as large of steps as possible through the design space. This means we require a robust deformation engine that won’t fail when requests are made for large shape modifications.

This poster exhibits the surface deformation method we have chosen. Initially developed for computer graphics applications, it uses a nonlinear global variational energy minimization technique that mimics the behavior of thin plates.

Identification of an appropriate set of design variables can be one of the most challenging aspects of an aerodynamic shape optimization problem. The parameterization of any complex geometry is typically a labor intensive task. When geometries are generated in a parametric CAD package, this task is somewhat alleviated, since design variables can be embedded in the model. However, this implies that the designer must anticipate all possible design variables at the time of model creation. Hence, there is a deeper problem with respect to the quality of optimization results. If a geometry is heavily composed of free-form surfaces, ideal parameters may not be identified.

We generate surface parameterizations, composed of faces, edges, and points, based on local curvature estimates. This parameterization is linked to design variables that specify translations and rotations of these primitives. During the design process, the optimizer modifies elements of the parameterization and a deformed surface is defined by solving a nonlinear variational energy minimization problem. The new surface is determined using the PriMo method of Botsch et. al. This method is based on a volumetric layer of rigid prisms extruded from the initial surface geometry. An energy functional is defined as the summation of integrated non-linear elastic energies between each pair of neighboring prism faces. These prisms naturally resist stretching and bending due to the integration of the elastic energy over a volumetric face, thereby emulating thin shells and plates.

Deformations are prescribed by transforming a subset of the prisms away from the initial minimum energy configuration. Updated prism positions and orientations are determined by solving a global shape matching problem. The modified surface is derived by translating unconstrained vertices based on the new locations of their incident prisms.

Future Work

We are continuing to investigate better methods of parameterization as well as methods to accelerate the solution process. Although currently using a sparse Cholesky solver for our linear system solution, we are working on an agglomeration multigrid solver. This work will be presented in Vancouver in September at the AIAA Multidisciplinary Analysis and Optimization conference. By then we will have our design framework.

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Bibliography


Further Information

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