GENERATION AND VALIDATION OF CURVED MESHES FOR UNSTRUCTURED HIGH-ORDER METHODS

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In the last two decades, unstructured high-order methods have attracted a remarkable attention from the community of computational methods. For problems with smooth solutions, high-order methods have the potential to deliver higher accuracy with a lower computational cost than low-order methods [1, 2]. However, their application has been hampered by technical issues such as the difficulty of generating valid 3D curved meshes.

The main goal of this work is to propose a robust procedure to validate and generate curved and high-order meshes. The resulting meshes are composed by valid and high-quality elements with the boundary nodes on the surfaces of a CAD model. To this end, we use an a posteriori approach [3]. First, a linear mesh that prescribes the geometrical features desired for the high-order mesh is generated, see Figure 1(b). Second, the linear mesh is converted to a high-order mesh by increasing the interpolation degree. Third, a valid high-order surface mesh is generated. Specifically, the distortion of the surface mesh is minimized by moving the nodes on the CAD surfaces [4, 5]. Following, we curve the faces of the boundary elements to match the surface mesh, see Figure 1(c). In this step, non-valid (folded) and low-quality (distorted) elements can appear close to the curved boundaries. Finally, see Figure 1(d), the tetrahedral mesh is untangled and smoothed to obtain a mesh composed by valid and high-quality elements [6].

To implement the detailed procedure, two main ingredients are required. First, we propose a mesh quality measure to validate nodal high-order triangle and tetrahedral elements of any interpolation degree. The proposed measure is obtained as the extension of any Jacobian based distortion measure for linear elements. Second, we propose a robust smoothing and untangle method that converts an initial linear mesh (ideal mesh) to the desired curved and high-order mesh. The proposed method is based on a regularized and non-linear minimization of the mesh distortion. This minimization is formulated both for surface and 3D high-order meshes. The main advantage is that the minimization repairs
Figure 1: Tetrahedral meshes of interpolation degree 4 colored according to the shape quality measure on a Falcon aircraft: (a) overview of the final mesh, (b) initial straight-sided mesh, (c) initial curved mesh, and (d) final smoothed mesh.

non-valid configurations (untangles), since it uses an element-wise regularization of the mesh distortion.

Finally, we present several examples to illustrate the advantages and the application of the proposed technique. The examples show that the method can: untangle meshes composed by a large number of inverted elements; deal with convex features and large deformations; maintain the size prescribed on the linear mesh and preserve straight edges where possible; generate high-order boundary layer meshes; and be applied to generate valid and high-quality high-order tetrahedral meshes from CAD models.

REFERENCES


