A sphere relaxation based approach for three-dimensional mesh deformation

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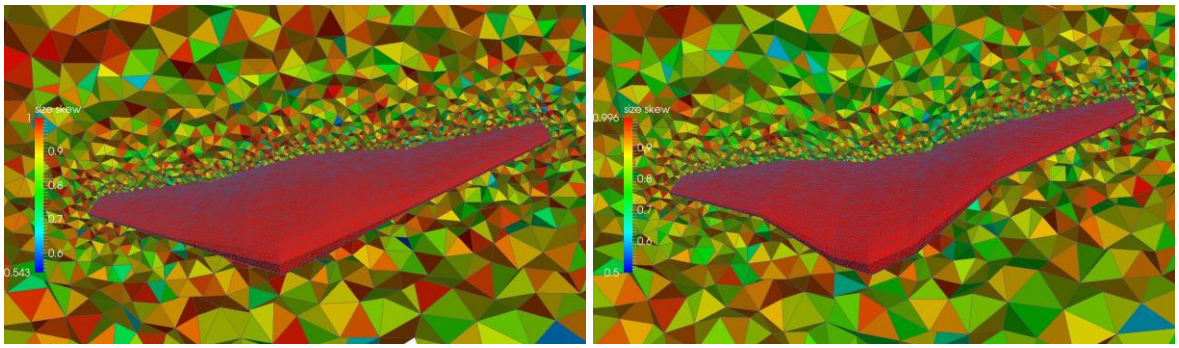
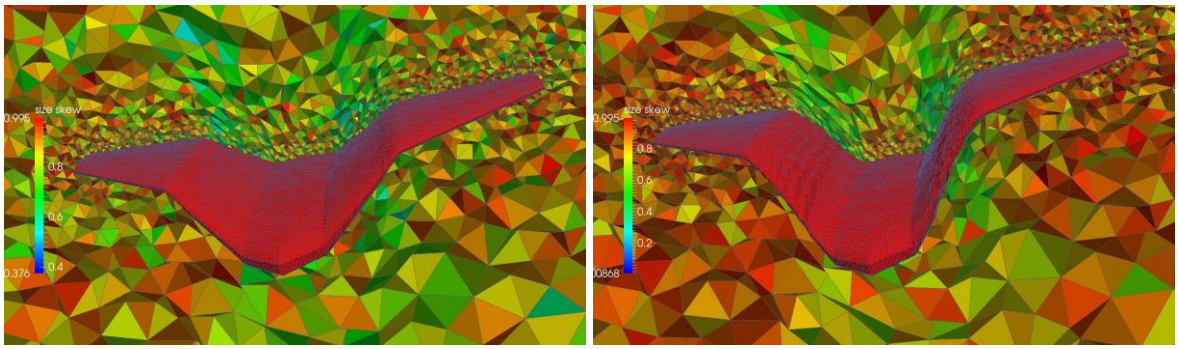
Abstract

Dynamic mesh is crucial to numerical simulations in engineering, e.g., fluid-structure interaction, aeroelastic computation and aerodynamic shape optimization, which usually involve moving or deforming boundaries. A popular method to generate dynamic meshes is the mesh deformation which adapts the computational mesh to the new deformed domain without changing the grid connectivity. In our previous work [X. Zhou, S.X. Li, J. Comp. Phys., 235 (2013) 199-235], we developed the disk relaxation based mesh deformation method for two-dimensional mesh deformation. In this paper, the idea of the disk relaxation is extended to the sphere relaxation for three-dimensional meshes with large deformations. The proposed mesh deformation method is based on the sphere relaxation algorithm with pre-displacement and post-smoothing (SRA). First, the SRA moves nodes in the computational mesh roughly according to the layer indices of the nodes. Second, a modified sphere relaxation algorithm is conducted to adjust the nodes locally and transfer boundary deformations into the computational domain, which also improved the mesh quality. Finally, a mesh smoothing technique is applied to avoid the negative volume of the tetrahedral elements, and to further improve the mesh quality. 3D examples including the wing rotation, the bending beam and the morphing aircraft are presented in this work to demonstrate the deformation ability of the SRA. The results demonstrate that the sphere relaxation based approach has several important properties. First, the boundary deformation has been transferred smoothly and uniformly to maintain the high quality of the boundary mesh, even for the complex boundaries in irregular deformations. Second, the deformed mesh achieves high mesh quality in the entire computational mesh, and even better than that of the original one. Third, the SRA method avoids the occurrence of negative volume elements successfully in large deformations. Moreover, the SRA method is comparable with the newly developed IDW (Inverse Distance Weighting) and RBF (Radial Basis Function) methods, and achieves better minimum mesh quality. Finally, the method is universally applicable for various boundaries and movements, and no global equations have to be solved.

Keywords: Mesh deformation, Dynamic mesh, Sphere relaxation, Mesh smoothing



(a) The boundary mesh in the initial stage **(b) The 4th deformation step, folded 20 °**



(c) The 8th deformation step, folded 40 º **(d) The 13th deformation step, folded 65 º**

Figure.1 Size-skew metric and detailed views of deformed boundary meshes in: the initial stage (a), the 4th, 8th deformation step (b, c) and final deformation (d) for the morphing aircraft example