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ADJOINT-BASED SHAPE OPTIMIZATION AT ISOCONNECTIVITY THROUGH ROBUST MESH DEFORMATION

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In adjoint based shape optimization problems, after the sensitivities have been computed, there are two ways of applying the necessary changes to the computational domain. The first one is re-meshing based on the new shape, while the second one is adapting the existing mesh (by moving the nodes) to fit the new shape. Re-meshing may be expensive and introduces inconsistencies in the process, as the sensitivities have been computed at isoconnectivity. Morphing also has challenges, namely maintaining the mesh quality (avoiding distorted and negative cells) while deforming it. In this article, we present a new approach for morphing, the Rigid Motion Mesh Morpher.

Various mesh morphing techniques have been developed in recent years, each one having its merits and shortcomings. The Spring Analogy [1] is simple but exhibits limited robustness. Laplacian smoothing [2] is suitable for translation but does not account for rotation. The Linear Elasticity approach is more robust [3] but can be obstructed by mesh anisotropy and is difficult to implement for general meshes, since finite elements are usually employed in the solution of the equations. Finally, the Radial Basis Functions [4] are promising but either have prohibitive computational cost (as the matrices involved are full thus restricting the mesh size), or could be lightweight at the cost of added complexity in their implementation.

The Rigid Motion Mesh Morpher approach aims at overcoming those limitations by introducing a seemingly contradictory concept. The concept of deforming the mesh by moving groups of nodes (stencils) in an as-rigid-as-possible way (deformation versus rigid motion). In other words, applying a macroscopic total mesh deformation which, if viewed in a microscopic per-stencil level, resembles a rigid motion for its components. The method has greater flexibility and is essentially mesh-less, since it does not require any inertial quantities related to the mesh.

Firstly, the set of boundary nodes (nodes defining the shape) of the mesh is identified. The prescribed motion of these nodes (their velocities) will be known. Then, all nodes are grouped into stencils, each one having a rotation velocity and a translation velocity. Those, plus the velocities of all internal nodes, form the set of unknowns. The as-close-to-rigid-as-possible stencils' motion is ensured by trying to minimize a quantity representing the difference of the actual deformation from a perfectly rigid motion (a translation plus a rotation). It will be shown that this quantity is related to some anisotropic deformation energy. Next, the resulting system of equations is solved, having the prescribed motion of the boundary nodes as boundary conditions.

The results of this work, assessment of the method's robustness, as well as comparison with existing methods will be presented in the article.

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