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A 2D TOPOLOGY-ADAPTIVE MESH DEFORMATION FRAMEWORK FOR EXTREMELY LARGE BOUNDARY DEFORMATIONS

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There are numerous applications for which the geometric domain deforms as a function of time. Applications of such applications include fluid flows, fluid-structure interaction, plasticity, crack propagation, medical devices, and computer graphics. Whenever such deformations occur, the mesh must be updated in response to the deforming domain in order to remain a valid approximation to the domain geometry. There are two main strategies for updating the mesh: remeshing and mesh warping. Mesh warping refers to moving the mesh from the source domain to the target domain typically via interpolation. Mesh warping is preferred over remeshing whenever possible since frequent remeshing can lead to a loss of data resolution and accumulation of round-off errors leading to inaccuracies. In addition, mesh warping is more efficient than remeshing.

We propose a 2D topology-adaptive mesh deformation framework [1] for performing anisotropic mesh deformations in the case when the boundary deformation is extremely large. Our goal is to produce high quality meshes with no inverted elements on domains which undergo extremely large boundary deformations. To the greatest extent possible, the meshes should have similar element shape, which is accomplished via mesh warping. However, topological changes are performed as necessary in order to improve mesh quality.

Our mesh deformation framework is based upon the previous work of Kim, Miller, and Shontz [2] and Kim, Panitanarak, and Shontz [3]; the framework consists of four steps. The first is to perform anisotropic finite element-based mesh warping (anisotropic FEMWARP) [2] to estimate the interior vertex positions in the deformed mesh while the mesh topology is held fixed. Anisotropic FEMWARP corresponds to solving an anisotropic Poisson boundary value problem based on an appropriate choice of partial differential equation (PDE) coefficients specified in [2].

The second step of the mesh deformation framework is to perform multiobjective mesh optimization [3] in order to eliminate inverted elements and improve element shape. The untangling beta and the target matrix paradigm metrics are used to formulate a multi-objective mesh optimization problem which is solved via the exponential sum method [3]. The Fletcher-Reeves nonlinear conjugate gradient method was used to solve the multiobjective mesh optimization problem.

Edge swaps are then performed in step 3 to further improve the mesh quality. Edge swaps are performed when the Delaunay flipping criterion is met. A constraint as to the number of times that a particular mesh edge can be flipped was also added.

The fourth and final step of the framework is to perform a final mesh quality improvemnt pass in order to improve the mesh quality. The inverse mean ratio metric was used to formulate the optimization problem which was then solved via the Fletcher Reeves nonlinear conjugate gradient method.

The first and third steps of the framework were implemented in C/C++, whereas the second and fourth steps were implemented in Mesquite [4] (which is also implemented in C/C++).

Our numerical results show that our framework can be used to generate high quality meshes with no inverted elements for extremely large boundary deformations. In particular, the addition of topological changes to our hybrid mesh deformation algorithm [2] proved to be an extremely efficient way of improving the mesh quality.

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