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A Hybrid Dynamic Mesh Generation Method for Multi-Block Structured Grid

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Abstract. In this paper, a hybrid dynamic mesh generation method for multi-block structured grid is presented based on inverse distance weighting (IDW) interpolation and transfinite interpolation (TFI). The major advantage of the algorithm is that it maintains the effectiveness of TFI, while possessing the ability to deal with multi-block structured grid from the IDW method. In this approach, dynamic mesh generation is made in two steps. At first, all domain vertexes with known deformation are selected as sample points and IDW interpolation is applied to get the grid deformation on domain edges. Then, an arc-length-based TFI is employed to efficiently calculate the grid deformation on block faces and inside each block. The present approach can be well applied to both two-dimensional (2D) and three-dimensional (3D) problems. The proposed method has been well-validated by several test cases. Numerical results show that dynamic meshes with high quality can be generated in an accurate and efficient manner.

AMS subject classifications: 65Z05

Key words: Multi-block structured grid, mesh deformation, inverse distance weighting, transfinite interpolation.

1 Introduction

Unsteady flow calculations for problems with deformable boundaries, such as those in aeroelastic simulations, require a fast and robust method for regeneration of the computational grid in each time step. For generation of a single-block dynamic mesh, transfinite interpolation [1–5] (TFI) method with an algebraic interpolation is frequently used. Its efficiency is still very high when the grid size is large. However, TFI is very difficult to be applied for a complex geometry when a multi-block structured grid is used. This

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is because mesh points on block edges are irregularly distributed when the mesh is deformed. Therefore, the main problem is the computation of the displacement of edges in a multi-block grid.

Point-by-point methods do not rely on connectivity information as they determine the displacement of each mesh point based on its relative position with respect to the domain boundary. Inverse distance weighting (IDW) interpolation [6–8] is an explicit interpolation technique, which computes the interpolation function as a weighted average of the known boundary node displacements. In contrast to radial basis function (RBF) interpolation [9–11], it does not require solving a system of equations for deforming the volume mesh. The IDW interpolation is found to be faster than RBF [12]. However, in terms of computational effort, it is still expensive, especially in the case where the number of interior and boundary nodes is large. For example, a mesh with approximately 3 million nodes, of which 130,000 are boundary nodes, has a deformation time of 2 hours in serial mode [13]. Luke et al. [14] used a tree-code optimization to increase the efficiency of IDW for large scale meshes. However, this method is fairly complicated and there are several input parameters for the users to tune according to different geometries. Moreover, for IDW interpolation, the distance-decay effect can be influenced by a power parameter c [15]. Large values of c result in an interpolation that is influenced mainly by the closest points. On the other hand, lower values of c result in smooth interpolations where the solution at a point is influenced by more distant points. Witteveen [16] proposed to use different values for the power parameter c for rotation and translation and spatially non-uniform power parameter distributions based on data density have been used in adaptive IDW [17].

In order to solve aforementioned problems, a novel mesh deformation method for multi-block structured grid based on inverse distance weighting interpolation and transfinite interpolation is presented in this paper. In this approach, only the domain vertexes with known displacements are selected as sample points so as to improve the efficiency while the quality of mesh deformation is only affected very little and IDW interpolation is merely utilized to generate the dynamic mesh on domain edges, decreasing the impact of the power parameter on the dynamic mesh quality. Then, an arc-length-based TFI is adopted to generate structured mesh on block faces and within each block. The major advantage of the proposed method is that it maintains the effectiveness of TFI, while possessing the ability to handle multi-block structured grid from the IDW method. As compared with the traditional IDW method, the hybrid method can greatly improve the efficiency of grid generation and the generated mesh usually has good quality. Furthermore, the users don't need to spend much time on adjusting affected parameters according to different geometries. This is because the only affected parameter, power parameter, has little influence on the mesh quality.

The present hybrid method is firstly applied to the dynamic mesh generation for two two-dimensional (2D) and one three-dimensional (3D) problems with different complexity. Then numerical simulation of a 2D unsteady flow is conducted. The results demonstrate that dynamic meshes for all test cases can be generated in an accurate and efficient