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# Feature moving operation of hexahedral mesh

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**Abstract**

In the product design process, the finite element mesh regeneration is an inevitable step, but it is time consuming. The mesh editing is a kind of an effective mesh regeneration technique. In this paper, a method for widely moving features of hexahedral mesh is proposed to satisfy application requirement. After the feature moving operation is applied to CAD model, the mesh deformation based on the mean value coordinates is carried out in the corresponding deformed region of the hex mesh to decrease the possible inverted elements caused by a wide range deformation. Then, the parameters of generating the density field are extracted from the initial hexahedral mesh, and used to calculate the local target density field by considering the geometric and topological information on the deformed region. Finally, based on difference between current density field and target density field of deformed region, the local refining and coarsening operations are devised and conducted to make the deformed region compatible with the target density field. Experimental results for the mechanical parts verify the effectiveness of proposed method.



*Keywords:* hex mesh; mesh deformation; feature moving; adaptive meshing.

## 1. Introduction

Mesh editing refers to the method for generation of deformed mesh model by modifying the initial mesh after the CAD model is modified. In current product design, the design model needs to be constantly modified in order to meet the requirements of analysis. Therefore, we constantly need to generate a new mesh model according to the modified geometric model. The trial-and-error process is time consuming and it requires a large number of manual operations, so it greatly increases the cost of product design. An effective solution is mesh editing which reuses the initial mesh model to improve the efficiency.

There are many studies on 3D mesh editing. The mesh deformation [1–3] is an effective method to solve the mesh editing tasks. This method is efficient and maintains the affine invariance. However, this method only changes the position of points, and keeps the topology unchanged. Therefore, many twisted or even inverted elements could appear in mesh deformation. Maehama et al. [4] proposed a quality improvement method for deformed tetrahedral mesh based on Optimal Delaunay Triangulation(ODT) smoothing. In their method, element shape qualities are improved from the mesh boundary to the inside of the mesh, and original mesh properties are recovered in deformed mesh.

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Zhu et al. [5] proposed a direct editing method for hexahedral mesh after the CAD model is manually modified. The method automatically optimizes the quality of associated hexahedral mesh model through dual operations. Sheffer et al. [6] proposed a method for re-meshing CAD models after parameter modifications to maintain the required sizing and quality for tetrahedral and hexahedral meshes. For deformed tetrahedral mesh, authors used an adaptive method based on the ball filling method. On the other hand, for deformed hexahedral mesh, the density of mesh was adjusted by dual operation. Borden et al. [7] proposed the Mesh Cutting algorithm to cut a simple mesh model with the given geometric model as a reference to construct the complex negative features. However, it is difficult to deal with a wide range feature moving using the existing hexahedral mesh editing methods, which results in generation of poor-quality elements and may not meet the required mesh density. In addition, in the actual design process, such a large change in model is inevitable, so this paper presents a method for wide range feature moving of hexahedral mesh.

During the mesh editing process, in order to ensure the quality and size of edited mesh model, we need to recalculate the target density field [8]. The commonly used method for, which defines size functions using a background overlay grid, was proposed by Zhu et al. [9]. Moreover, this method defines the size function based on curvature and proximity of geometric entities in model. Afterwards, Zhu et al. [10] extended the method of size field generation to consider the pre-meshed geometric entities. Quadros et al. [11] proposed a skeleton-based computational method to generate a mesh sizing function. The method proposed in [11] adequately analyzes the geometric complexity of model to calculate the local thickness and uses the octree as a background mesh to save memory and to improve query processing.

The adaptive adjustment of mesh model is a key step of mesh editing which tends to achieve the target density. The refinement template [12,13] is often used to refine a given region of structured hexahedral mesh, but local refinement domain determination and mesh size gradient control cause problems. In order to solve these problems, Borden et al. [14] and Tchon et al. [15] developed a pillowing-based hexahedral refinement method that can be applied to unstructured mesh. Through iteratively pillowing operations, the required density field is met. The hexahedral mesh coarsening can be achieved by sheet extraction operation, but if we extract the entire sheet, that will influence the entire mesh extensively. Shepherd et al. [16] developed a localized sheet generation method in order to extract sheet in a local domain.

A method capable for widely moving features of hexahedral mesh is presented in this paper. Its objective is to generate a high quality hex mesh automatically and efficiently after certain features of the original hex mesh are widely moved due to requirement. In order to achieve this goal, a mesh deformation based on mean value coordinates is firstly conducted in the deformed region, which is the region affected by feature moving. Then, the target density field of deformed region is calculated according to the geometric and topological information on the initial hex mesh. Finally, an adaptive local adjustment of hex mesh is performed to make the deformed region meet the target density requirement.

## 2. Algorithm Overview

In this paper, we present a method of moving a feature on a plane for hexahedral mesh. The input of the algorithm consists of hexahedral mesh model, geometric model, specified feature, the features moving direction and distance. The output of the algorithm is the hexahedral mesh, which is locally regenerated after feature moving.

In order to enable the algorithm to handle the case of wide range feature moving, three critical problems need to be addressed: 1. Reducetion of inverted elements during deformation of deformed region; 2. Reasonable calculation of target density field of deformed region; 3. Local adjustment of mesh density of deformed region to meet the requirement. With the aim to solve the first problem, we use the mean value coordinates to achieve mesh deformation by reasonable construction of control mesh of the deformed region and to avoid the inverted elements. In order to solve the second problem, we use the parameters of generating the size field extracted from original mesh and local geometric and topological information to calculate the target density field of deformed region. Lastly, in order to solve the third problem, those regions that need to be refined or coarsened are accurately determined by comparing the current density field with the target density field, and they are adjusted by well devised local refining and coarsening operations.

As it is illustrated in Fig. 1,the proposed method mainly consists of three following steps: