Development of Mesh Modification System for

Finite Element Simulations Using CAVE Environments

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1 Introduction

The three dimensional finite element simulations are becoming more powerful and popular tool for various CAE (Computational Aided Engineering) problems in accordance with the development of hard- and software of computers. However, the following problem is pointed out in pre-process for practical computations as: it is difficult to check and modify the quality of mesh for the complicated spatial domain, since the mesh normally express on the 2D screen or display.

This paper presents an interactive mesh modification system based on the virtual reality technology for large scale three dimensional finite element simulations in order to overcome the problem.

The present authors have been presented a prototype system for the mesh modification [1]. Users can check the details of three dimensional mesh structures and can modify the shape of mesh idealization in VR space interactively by using the controller. However, as the node relocation method was only employed for the mesh modification method, the improvement of mesh quality was not sufficient. In order to improve the mesh quality sufficiently, the mesh refinement method is introduced as a new mesh modification method in this paper.

2 CAVE Environments

The present systems are designed for the use of virtual reality system based on IPT (Immersive Projection Technology) such as CAVE [2]. The stereoscopic view is realized in VR space by creating the images that corresponds to binocular retinal images. Fig. 1 shows the exterior view of the VR system "Holostage" of Chuo University, which consists of a PC cluster (one master-PC and four-slave-PC), three projectors, three large screens and a position tracking system. The stereoscopic image from the arbitrary viewpoint of observer is displayed in VR space by the position tracking system.

Fig.1 CAVE system

3 Mesh Modification System

Users can investigates the details of three dimensional mesh structures and to improve the mesh quality interactively in VR space by the present system. For the finite element mesh, the four nodes linear tetrahedral element is employed. The present systems are developed by the VR programming languages, Open GL and CAVE library.

3.1 Flow Chart

FIG. 2 shows the flow chart of the present system. First, the mesh quality is computed, and then the mesh quality is improved by the mesh modification by both mesh relocation and mesh refinement methods. Users can select the modification method from the menu which is displayed in the VR space. Users can change the nodal position of the bad quality element in the node relocation method, and can refine the bad quality element in the mesh refinement method. The modification method by mesh refinement is added as a new modification method to the conventional system [1].
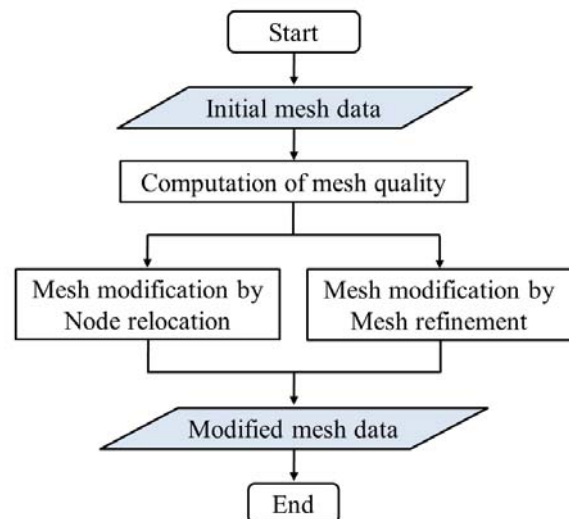

Fig.2 Flow Chart

3.2 Input data and mesh quality

The mesh data is prepared for the input data for pre-processing system. The four nodes tetrahedral element is employed for the finite element. The Delaunay triangulation method [3] is employed for the mesh generator.

The mesh quality Q_m can be evaluated by the following equation [4].

$$Q_m = \frac{\left(\frac{1}{6} \sum_{i=1}^{6} L_i^2 \right)^{\frac{3}{2}}}{8.4796V} \qquad (1)$$

where L_i denotes the length of the edge of the element, V is the volume of the element. The mesh quality is to be 1 if the element is to be a regular tetrahedron and the value is to be big value if the element becomes a bent element. In this system, the elements which exceed the setting value for mesh quality are displayed by the red color in VR space.

3.3 Modification by mesh refinement method

In the modification by mesh refinement, the elements which exceed the setting value for mesh quality are refined. Users can specify the element by using the controller. If users move the tip of beam generated from the controller to the inside of the element and click the button, then the element can be specified. In order to investigate the judgment that the element includes the tip of beam or not, the mapping method using a generalized coordinate system is employed. Fig. 3 shows two patterns of mesh refinement methods. The new node is generated at the centroid of the element and the element is subdivided into four smaller elements in case (a). The new nodes are generated on the edge of the element and the element is subdivided into eight smaller elements in case (b). In case (b), the effect of mesh refinement is influenced to the neighbouring elements.
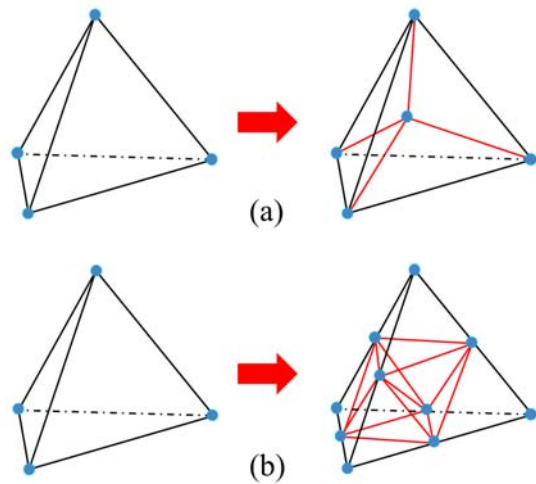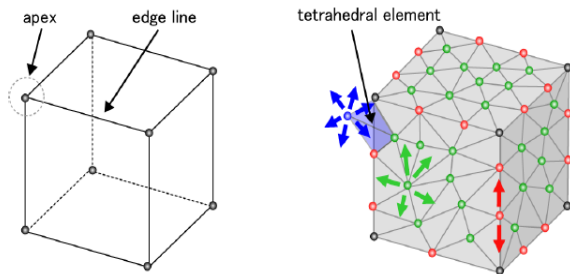

Fig. 3 Mesh refinement methods

Fig. 4 Node movement condition

3.4 Modification by node relocation method

The modification method by node relocation is also available in order to improve the mesh quality. However, the restriction condition for the mesh movement is required to not violate the geometrical shape by the node relocation. In order to avoid this problem, the node movement condition must be introduced for the nodes on the boundary. The condition is prepared by the geographical information, which is obtained by the mesh data. Fig. 4 shows the example for the mesh around a cubic structure. The nodes at the apex (gray nodes in Fig. 4) are assumed to be fixed point. The nodes on the edge-line of the structure (red nodes) can move on the edge-line only. The nodes on the surface of the structure (green nodes) can move on the surface of the boundary only. The nodes in the computational domain (blue nodes) can move to any direction. In this system, if the element violates the geometrical shape by the node relocation, the element is displayed by the green color in VR space.

4 Application Example

The present method is applied to the three dimensional finite element analysis of over-dentures using dental implants. Fig. 5 shows the scene the user modifies the mesh idealization manually using the controller. The mesh quality is improved and the high quality computation is realized by the application of the present system. More detail discussion will be shown in the full paper.

Fig. 5 Mesh modification using controller in VR space

5 Conclusion

The interactive mesh modification systems based on the virtual reality technology for three dimensional finite element simulations have been developed. Users can improve the numerical accuracy and stability by using the mesh modification system based on node relocation and mesh refinement. From this, it can be concluded that the present system provides a useful tool to realize the high quality computing for three dimensional finite element simulations.

References

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