한국 CAD/CAM학회 논문집
제10권 제3호 2005년 6월 pp. 162-167

학술논문

CAE Solid Element Mesh Generation from 3D Laser Scanned Surface Point Coordinates

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ABSTRACT

A 3D solid element mesh generation algorithm was newly developed. 3D surface points of global rectangular coordinates were supplied by a 3D laser scanner. The algorithm is strait forward and simple but it generates hexahedral solid elements. Then, the surface rectangular elements were generated from the solid elements. The key of the algorithm is elimination of unnecessary elements and 3D boundary surface fitting using given 3D surface point data.

Key words : 3D, Laser Scan, CAE, Sold Element, Mesh Generation, Surface Smoothing

1. Introduction

Computational reverse engineering may be defined as an applied technique for getting a structural model (CAD) from the physical shape of an object[1,2]. We need structural models as well as functional modeling particularly in optimized structural design for functional devices. The target of computational reverse engineering is to get proper structural models from measured physical shape information using any particular algorithm[3,4]. The method of getting physical shape data can be diverse; contacting or non-contacting methods such as optical interference, computerized tomography, magnetic resonance imaging, ultrasonic scanning, laser scanning etc[5]. The more we get shape information, the more precise modeling is come out. Once we get the 3D shape data in grids or in volume, structural models may be automatically generated by different numerical approaches[6-8]. Regional approaches are based on surface edges or surface grids[9,10]. In other approach triangular polygons are locally generated around input point data and then expanded to whole surface area[11]. Surface meshes are followed by volume meshes.

CAE application requires minimum number of elements or nodes with proper aspects of ratio. CAD only modeling does not concern the size or the dimension of elements. Therefore it is a common rule to remodel or regenerate structural meshes when CAD models are used for CAE simulation[12]. This paper suggests and proves a new method for solid element mesh generation[13]. The method is strait forward and very simple.

2. 3D volume sculpture

All the measured surface point data were provided by a 3D laser scanner in high resolution. The surface points are in rectangular coordinates and the number of points were 200,000~300,000. The shape of the object may be any arbitrary form. The overall procedure of the present algorithm is shown in Fig. 1. Initially 3D volume grids are generated. The number of divisions in x-, y-, z- axes may be arranged according to the size of each local volume element. The whole volume elements are initialized as rectangular 3D grids. Outward elements are eliminated if they do not include surface scanned points. After elimination, externally exposed elements adaptively change its shape in the accordance with the scanned points[14-16].

2.1 3D Volume grid initialization

The dimension of each local volume element is the

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- 논문투고일: 2003. 12. 01
- 심사완료일: 2004. 11. 11

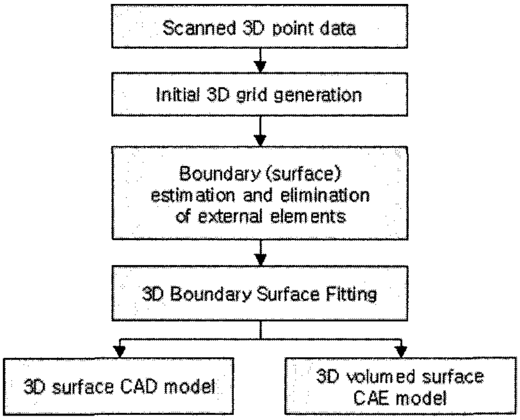

Fig. 1. Procedure of the proposed algorithm.

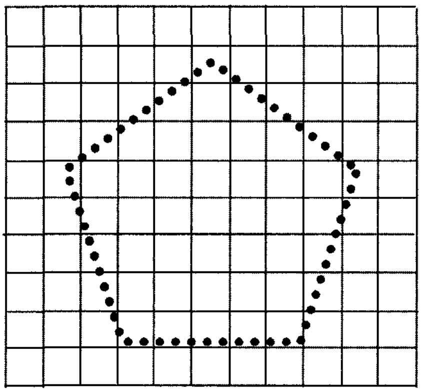

Fig. 2. Initial volume grids: 11×10.

same in x, y, z rectangular coordinates. The user decides the degree of the volume resolution for his CAE application purpose. The finer the volume resolution is, the more accurate the result is. But the longer the calculation time is. For convenience, two more elements are added in each axis as shown in Fig. 2. Figure 2 shows the 2 dimensional area grids where two more element grids are added in the +x and −x axes as well as +y and −y axes. The actual numbers of the area grids are 9 in x (horizontal) axis and 8 in y (vertical) axis respectively.

2.2 Element elimination

The most outward elements are confronted with external bounds which are defined by the scanned points. The procedure of the present algorithm is like marble sculpture. We chisel marble into a statue. The chiseled feature shows the outward appearance of the marble. The fragment of the sculpture is each volume

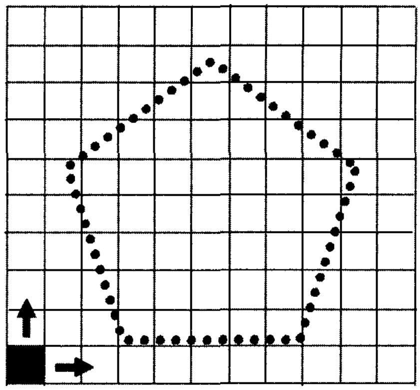

Fig. 3. Boundary search and unnecessary element elimination.

grid. Figure 3 shows the starting point of element elimination. It is always from a corner of the volume grids. The criterion of the element elimination is the number of scanned points inside and/or onto the outward elements. If the bounded element does not enclose enough number of scanned points, then the element is removed. This procedure ensures the elimination of the unnecessary boundary elements like a noise rejection filtering.

Figure 4 shows the remained area grids after the elimination[14]. It should be noticed that the inner elements which are inside the object model are remained even though they do not include any scanned points within them. It is done by searching externally bounded elements from outside into inside in xyz global coordinates. This ensures that the mesh generation is carried out for both solid volume elements as well as plane surface elements.

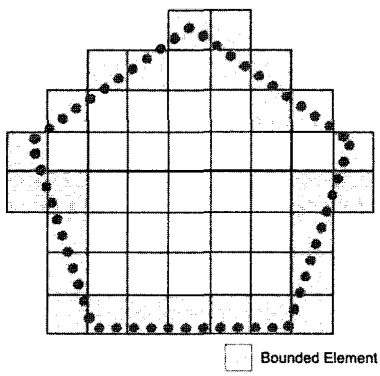

Fig. 4. Remained grid elements after the element elimination.

2.3 Three dimensional boundary surface fitting

The remaining volume grids have sharply rectangular feature because we initially supplied only rectangular solid brick elements. Each volume grid represents a solid brick element which has 8 corner nodes. The next step is locally moving the corner nodes in the accordance with input scanned points around the corner nodes. This procedure can be defined as three dimensional boundary surface fitting[14]. The volume elements inside the object model are remained without nodal movement. Therefore 3D boundary surface fitting is done only on the corner nodes exposed to the outside environment.

There should be some number of adjacent scanned points around the corner node of consideration. So we have to decide which scanned point is the most suitable position onto which the corner node is moved. We selected some number of possible candidate scanned points which have short distances from the corner node. Then the averaged position of the selected scanned points is the place where we move the corner node (Fig. 5). More than two elements may share the same covalent corner node. Therefore the 3D boundary surface fitting is done on the corner node basis[15].

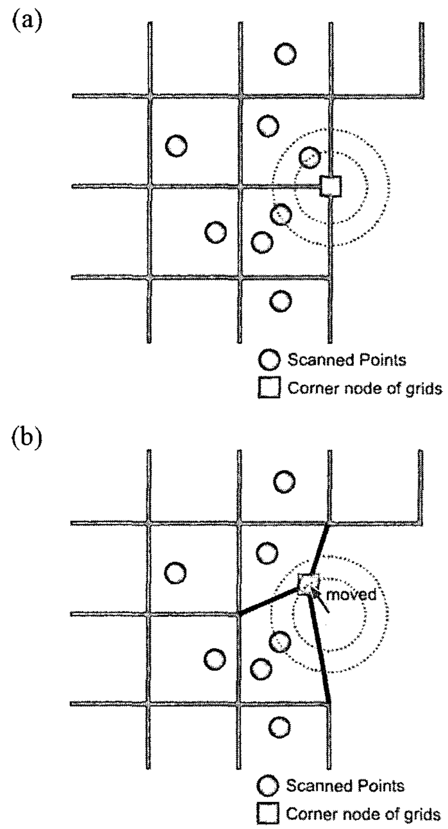

Fig. 5. 3D boundary surface fitting: (a) selected adjacent scanned points closed at a corner node (b) a possible candidate position of the corner node.

There is also one more important consideration. The present algorithm also considers the proper aspect of ratio of each solid volume element. The inner elements are all right in the aspect of ratio. But the outer bounded elements can have bad aspects of ratio if the movement of the corner node is simply done to move the averaged position of the scanned points. We in parallel calculate the aspect of ratio of each boundary element while the 3D boundary surface fitting is carried out. The maximum value of the aspect of ratio may be variable depending on the accuracy of CAE simulation. The default maximum value of the aspect of ratio is set up as 5:1 for solid hexahedral elements. Fig. 6 explains about the aspect of ratio.

Fig. 6. The aspect of ratio is the ratio between the lengths of dimensions such as B:A or B:C. The aspect of ratio should be less than 5:1 for proper CAE calculation results[12].

2.4 Mesh Generation for Robot dog model

In this paper the present algorithm was applied to convert 3D scanned points of a robot dog to hexagonal solid elements. Fig. 7(a) shows 3D scanned 240,000 points of the robot dog. These data were scanned by ScanWare 3.0; 3D image scanner of SCANBULL company.

We find each maximum and minimum value of the set of these cloudy points in x, y, z coordinates. The maximum length between maximum and minimum values is divided into 55 grids as one side of regular hexahedron elements. When the length of one side is L, the number of elements would be (Maximum − Minimum) ÷ L in x, y, z coordinates.

Therefore, we could form the set of initial grid ele-

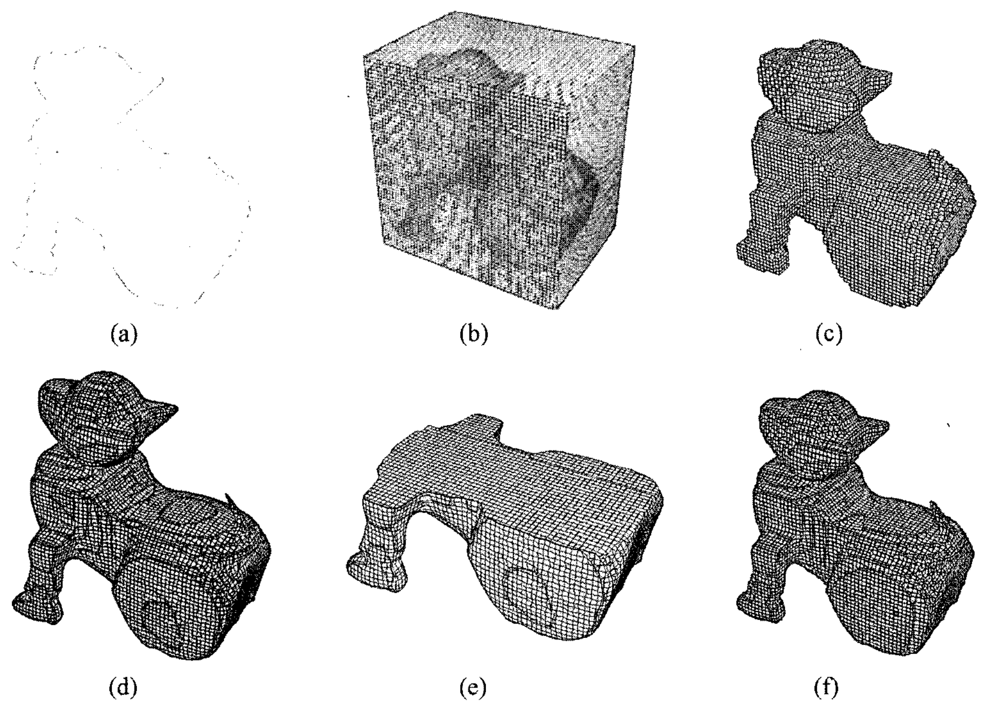

Fig. 7. 3D structural mesh generation of a 3D laser scanned robot dog: (a) laser scanned points are figured in 3 dimensions, (b) Initial solid brick element grids, (c) remained grid elements after unnecessary bounded element elimination, (d) 3D boundary surface fitted CAE mesh model without the aspect of ratio consideration (e) 3D cross section view of (d), (f) 3D boundary surface fitted CAE mesh model with the aspect of ratio consideration.

ments like the rectangular hexahedron form of Fig. 7(b).

3. Results

The algorithm was programmed using both VC++ 6.0 and Visual Fortran 6.5. The three dimensional graphics was programmed using OpenGL library.

Figure 7 shows the procedure of the 3D structural mesh generation of a 3D laser scanned robot dog. Figure 8 shows mesh generation models of the spine and the rail with several holes. Fig. 7(a) shows about 240,000 laser scanned points figured in 3 dimensional x-y-z coordinates. Fig. 7(b) shows initial solid brick element grids. The sizes of the volume grids are 53, 38, 55 in x, y, z coordinates respectively. Fig. 7(c) shows remained grid elements after unnecessary bounded element elimination. Fig. 7(d) shows the CAE mesh model of the robot dog after 3D boundary surface fitted without the aspect of ratio consideration. Fig. 7(e) shows solid elements of cross section of Fig. 7(d). The inner elements are fixed to original

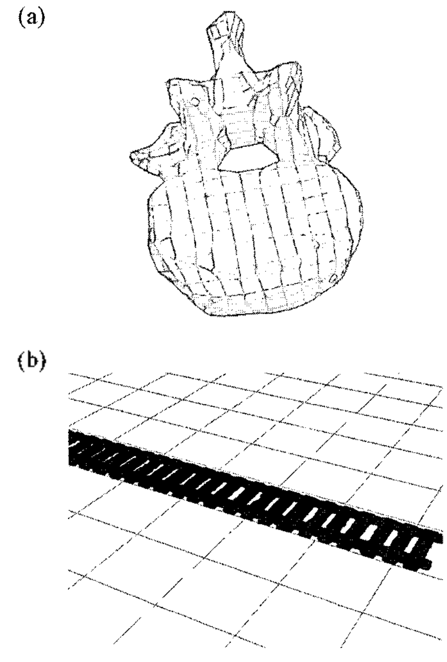

Fig. 8. 3D structural mesh generation of a 3D laser scanned points with hole: (a) The spine, (b) The rail.

positions. Finally Fig. 7(f) shows the meshed hexahedral model of the robot dog after 3D boundary surface fitted but with the aspect of ratio consideration. The total number of the 20-nodes hexahedral elements is 9848 and the total number of the nodes is 70845. It takes 187 minutes to get the result with Pentium 4 2.4 GHz PC.

4. Conclusions

The procedure of the present algorithm is like marble sculpture. We chisel marble into a statue. The chiseled feature shows the outward appearance of the marble. The fragment of the sculpture is each volume element. After unnecessary bounded elements are eliminated, the externally exposed surface nodes are fitted or moved to averaged positions of the adjacent scanned points. Also the aspect of ratio is in parallel considered during the 3D boundary surface fitting procedure. So the finally generated 3D solid hexahedral meshes can be directly used for CAE simulations such as finite element method and boundary element method. The present 3D mesh generation algorithm has a strong feature for an arbitrarily shaped object with several holes opened through the object.

The present algorism indicates that the number of nodes and elements could be increased by the uniform arrangement of inside elements in the model.

In the future, we would try the best fitted arrangement of elements and decrease the number of nodes by different elements' size.

Acknowledgment

The study was supported by research fund from the ministry of commerce, industry and energy (MOCIE Korea) standardization technology development project (standardization study on digital hearing aid: project number 10016821) in 2004.

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