Algorithm for Automatic Merger of Spine-Implant FE Models

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Abstract. Authors propose algorithms and methods to intersect and merge spine and implant finite element models. In our task environment, spine and implant models are already composed of complex mesh structures rather than maintaining only geometry. Therefore those who perform the simulation with given mesh models must spend a lot of time in manual overlapping. Additionally, if we use overlapping function of existing CAD tools then analysis result is remarkably changed because of shape modification. In this study, we use interference searching, traversal and triangulation algorithms to develop the automatic overlapping function that has reduced execution time and not appeared shape modification. Developed function automatically perform the process that composed of interference position searching, interference part re-creation and implementing shape that inserted implant in spine model, in the single or multi-layered spine model. In this study, we use three layer spine model and cylinder implant model for automatic overlapping test. Test result is that automatic overlapping is performed within seconds. In This result, the time of overlapping is more remarkably reduced than manual overlapping that take about some hours to some days.

Keywords. spine, implant, FEM, element intersection, algorithm, automatic merger

1 Development of the intersection area detecting algorithm among finite element

1.1 detecting the intersection area

First, we get a plane equation from cross product of each point of triangle element then calculate the intersection point using topology of two points. An angle with each point is calculated from intersection point and scalar product of three points. If the

total sum is 2π then we decides that intersection point is exist in inside of triangle element [1].

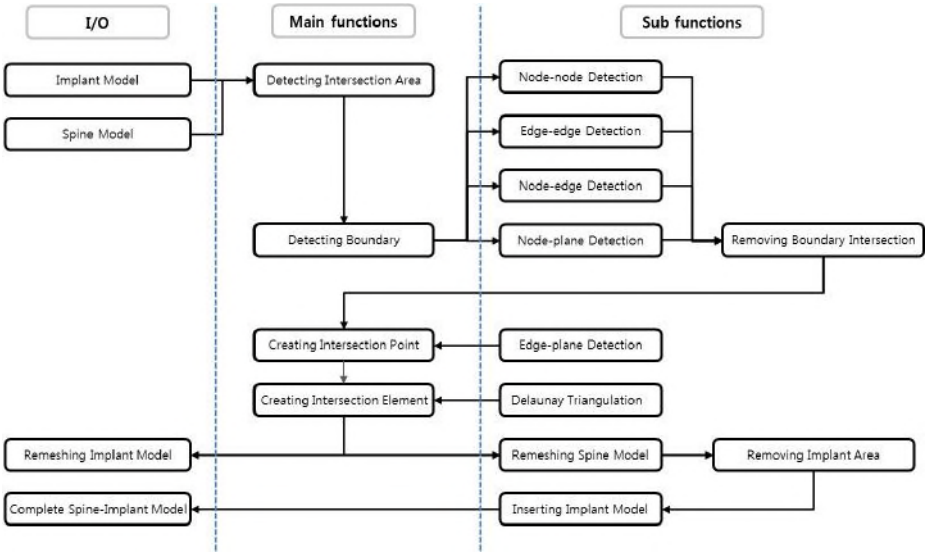
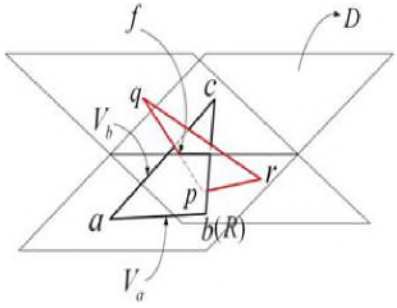


Fig. 1. Overall Procedure of Automatic Merger of Spine and Implant FEM Models

1.2 Detection of Intersection element in boundary position

In the process that calculates the intersection point among adjacency element, if the intersection point exists in the boundary position then not intended intersection point may be generated because of generation of floating point error. Therefore, error is prevented using modification of element in this case [2].



$$D = -(C_x x_b + C_y y_b + C_z z_b) \quad (1)$$

$$p(x_p, y_p, z_p)t = q(x_c, y_c, z_c)(1-t) \quad (2)$$

$$t = \frac{((C_x x_c + C_y y_c + C_z z_c) + D)}{(C_x(x_p - x_c) + C_y(y_p - y_c) + C_z(z_p - z_c))} \quad (3)$$

$$f(x, y, z) = p(x_p, y_p, z_p)t + q(x_c, y_c, z_c)(1-t) \quad (4)$$
$$(where \quad p \equiv x_p, y_p, z_p \quad q \equiv x_c, y_c, z_c)$$

Fig. 2. Searching Intersection Points of Plane and Edge

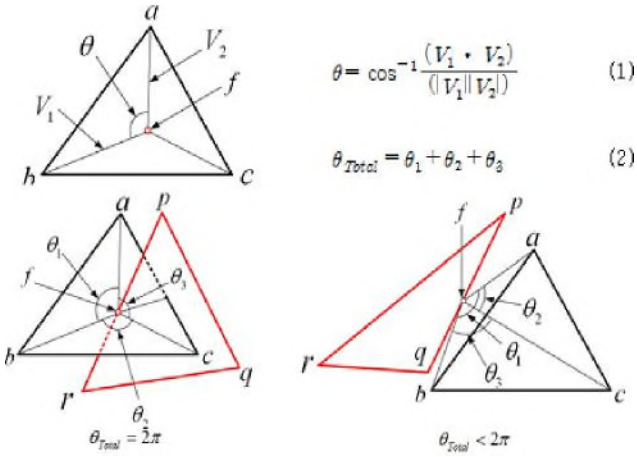


Fig. 3. Recognition of Location of Intersection Points

Element modification is performed in advance when exist intersection element in the boundary position of nodes and edges like figure 2 and 3.

1.3 Creation of intersection point

After remove the intersection of closed range, valid intersection point is generated through re-searching the intersection area. The met surface elements of the spine models is automatically nested at same time.

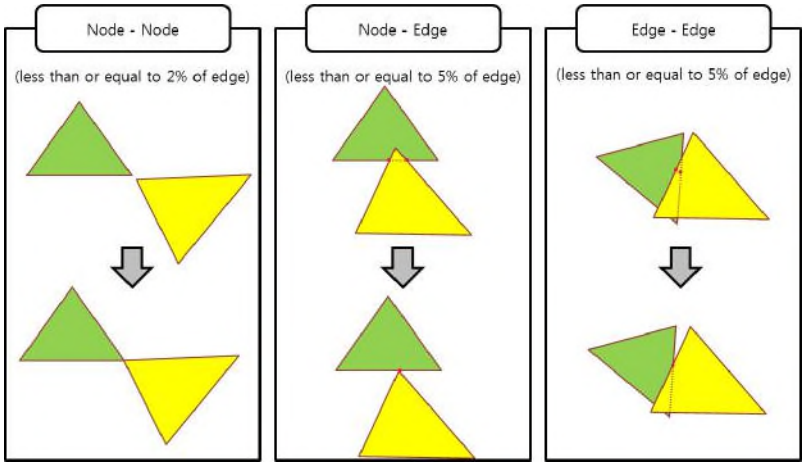


Fig. 4. Creating Intersection Points According to Node-Edge Relations

2 Development of the intersection point creation and the existed intersection area delete algorithm

2.1 Triangulation of intersection point created area using Delaunay triangulation

New mesh that maintains the shape of original model is generated automatically using Delaunay triangulation in searched intersection area. Delaunay triangulation is triangle generation method that considers the distance among nodes without overlapping.

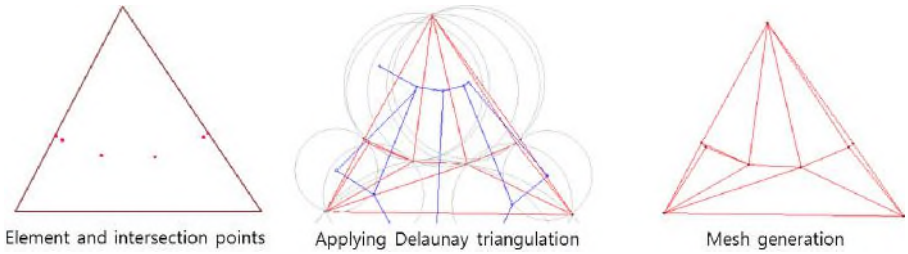


Fig. 5. Example of Delaunay Triangulation

2.2 Spine elements remesh of the overlapping part

It can be an unfit shape for finite element analysis (FEA) that generated triangle using Delaunay triangulation. Therefore triangle element that generated in spine element is re-organized using remesh function. When this is performed, minimum and maximum value is entered that calculate minimum and maximum value of the component of spine element. In this phase, remesh is performed with the hard-edges arrange of remesh area for node alignment. For prevent the urgent generation of remesh, it is implemented that performing remesh added adjacency element and intersection generated element. [3]

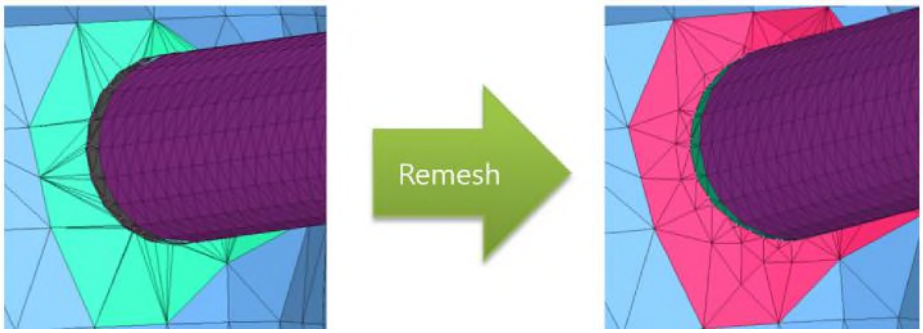


Fig. 6. Remeshing Spine Elements around Implant to Regulate Triangles

2.3 Deletion of the intersection area

Element of the existed intersection area delete function is implemented to insert the re-organized element after that triangulation and remesh is finished.

3 Development of inserted area element creation algorithm

After surface mesh in intersection area of finite element model is reorganized, two finite element models are overlapped that creating the inserted part in the inside of other inserted element model. For search the inserted part, the searching module is implemented using que in a STL (Standard Template Library). Searching speed increase using DFS(depth first search).

Fig. 7. Masking the Surface Mesh of Spine Model Copying Implant

Spine elements of area that implant is passed are deleted through that search the overlapping part. After search the implant inserted part in spine, automatic overlapping task of implant and spine is finished.

Multiple models should be identical overlapping result of contacted surface after automatic overlapping is finished. Therefore, function that searches the contacted surface in the process of overlapping calculation is developed. Surface that contacted in the automatic overlapping process copy the overlapping calculation result on opposite surface. This prevents the error that is generated by overlapping calculation. Multiple model overlapping is capable to perform about multiple spine models about one implant model.

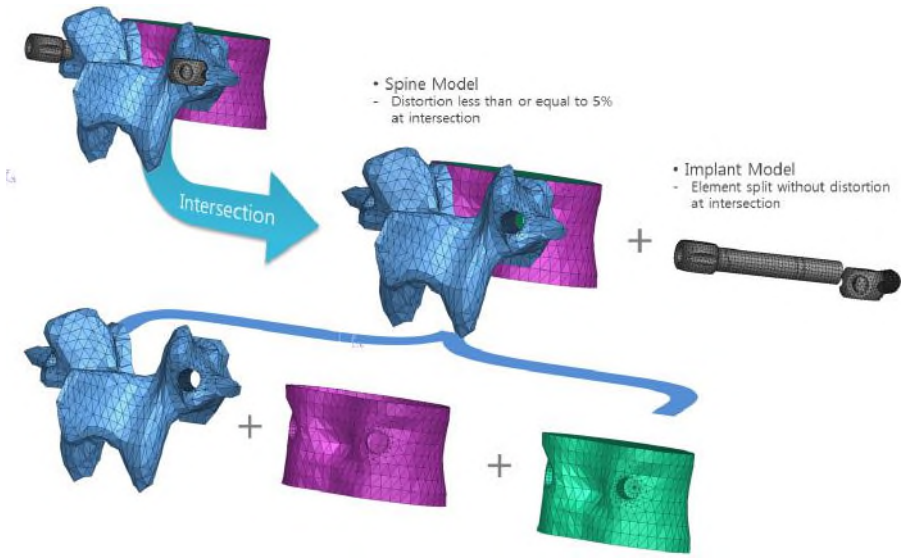


Fig. 8. Result of Automatic Intersection and Merger of Spine and Implant FEM Models

Reference

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