Simplification of Hexahedral Mesh

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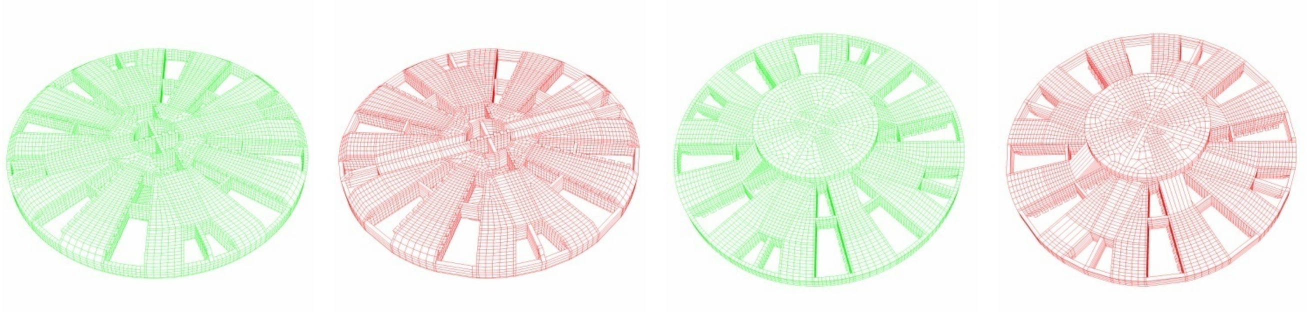

(a) (b) (c) (d)

Figure 1: (a) (b) Input cell set for a hexahedral mesh model, (c) (d) output simplified model.

1 Introduction

Mesh simplification is an important and difficult problem in pretreatment and post-processing of finite element analysis (FEA). Simplification of tetrahedral mesh has been studied deeply in the past two decades. However, although hexahedral mesh is widely used in FEA, there is almost no related work about its simplification method.

Shepherd, Staten and their partners has proposed a new method to structure new hexahedral cells through inserting conforming interfaces among the non-conforming interfaces into the original model[Shepherd and Johnson, 2008][Staten, Shepherd and Shimada, 2008]. Contrary to the algorithm mentioned above, we can imagine that if we could extract the conforming interfaces form the original model and remove them, the model would be simplified. Based on the idea, a simplification method defined over hexahedral meshes is presented in this work.

2 Our Approach

The overall strategy is making all the vertices in a conforming interface merged with the neighbor vertices on the same side of the conforming interface.

Before simplification, as some complicated model could not be subdivided to a pure hexahedral mesh model, we must perform pretreatment for the original model. If there is small number of other-type mesh cells, just take them away from the original model, treat them individually and take the remaining space as cavity of the original model. Besides, if there are adjacent-hexahedral-cell couples which do not shall the same quadrilateral chip, just take the interface between the two hexahedral cells as a part of the surface of the original model.

Given a pure hexahedral mesh model, we first build the adjacent relationship between one node with the nodes around it. In order to store the relationship, we create a list called "six adjacent-node list". There are two kinds of different node in the list: some of them can be merged with the list's owner when removing a conforming interface from the original model without changing the model's topological structure while others not. The former must come up with one another node, so we call them node couples and the other nodes are named by "extra adjacent nodes". The number of node couples that a node possesses is defined as "degree" and it figures out the biggest number of conforming interfaces which pass through the node.

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The next step is extracting conforming interfaces from the original model by seeking the nodes in the same conforming interface with the six adjacent-node lists. A very interesting finding is that the nodes in a conforming interface's list can be traversed with a leftmost tree.

Finally, we erase the nodes in the same conforming interface and merge the coupled cells on both sides of the conforming interface. As a result, the conforming interface is removed. It's worth noting that no vertex in non-conforming interfaces can be merged with the vertices in conforming interfaces so as to maintain the shape of the model.

In order to prove that our algorithm is able to work well, two examples are given and one of them is very simple but the other one is quite complex. Two factors is found that would limit the performance of the algorithm. For one thing, most part of the time is consumed in constructing the adjacent relations of nodes. For another thing, if the preprocessing algorithm could not work, simplification could not work as well.

If we consider the hexahedral mesh as a cylinder with a quadrilateral-grid cross-section and make the quadrilateral-grid cross-section simplified by edge-collapse[Daniels, Silva, Shepherd and Cohen, 2008], we can see that the main difference between our algorithm and the idea based on edge-collapse is that there is no non-conforming interface could be removed or added to the original mode in our algorithm.

References

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