

Small Feature Suppression and Preservation for Finite Element Analysis in Biomedical Application

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Abstract. The employment of finite element analysis (FEA) in the biomedical practice provides a number of benefits. FEA helps to guide physical therapy, assist the development of more efficient implants and improve understanding of the bone re-modelling processes. However, most of biomedical application may post huge challenge if it is required to be developed in CAE environment. Thus, reverse engineering and CAD technology play a central role in today's multidisciplinary simulation environments. Most notably CAD models now contain many details which are irrelevant to simulation disciplines. CAD systems contain feature trees which record the features creation but not specific to its use in biomedical applications. Many features of little significance to an analysis only emerge during the construction of the model. The ability to selectively suppress and reinstate features while maintaining an audit trail of changes is required to facilitate the control of the idealisation process. This work explores CAD model for biomedical applications to examine its small features that are useful or needed in the FEA so that CAD model simplification operations can be designed as continuous transformations. Irrelevant features can then be suppressed and subsequently reinstated, within defined limitations, independently from the order in which they were suppressed

Keywords: Feature Suppression, Feature Preservation, FEA, Biomedical Application

1. Introduction

Seamless integration for CAD application and CAE application is a challenge to many researchers in solid modelling[1]. Difficulty to achieve the interoperability for CAD and CAE application include inefficacy of robust intelligent geometric reasoning and editing tools to automate the CAD models simplification, insufficient flexibility in generating analysis model at different level of details without repetition of model simplification steps and large amount of cost and processing time is needed in the conversion. Given growing demand in multiphysics and multidisciplinary CAE system, it is clear that seamless integration is needed to smooth the process and ease the pressure in configuration analysis models, without tedious hierarchical modelling investigation. Several works have been conducted to automate the model simplification process prior simulation. Topology simplification techniques[2], soft geometric editing approach[3], vertex and edge collapsed based technique[4], feature identification[5, 6] all are complicated but provide insightful information on solving problem. Interest in modelling multiphysics-biomedical application with numerical solution rises during recent years. Typical problems analysis are found in the related areas, linked finite element model to prosthetic devices, cell and tissue scaffold, bone mechanics, cardiovascular system modelling, eye surgery, and drug delivery system [7]. The complex model can be constructed from MRI image and save in IGES(Initial Graphics Exchange Specification) since it is the only exchange format compatible with the licensed software available[8] or use Mimic software to generate IGES

file[9]. Then it is exported to CAE system to have a proper analysis in finite element module. With a medium like IGES, the model characteristic can be preserved.

Functional unit in IGES are entities, which can be categorized as geometry entities and non geometry entities. Geometry entities represent the definitive of physical shape like points and curves while non geometry entities provide a perspective view on which plane it draw and provide annotation and dimension appropriate to the drawing. Each IGES has 5 sections, Start, Global, Directory Entry, Parameter Data, and Terminate. From IGES version 4.0[10], each entity occurrence consists of a directory entry and a parameter data entry. The directory entry provides an index and includes descriptive attributes about the data. The parameter data provides the specific entity definition. The directory data are organized in fixed fields and are consistent for all entities to provide simple access to frequently used descriptive data. The parameter data are entity-specific and are variable in length and format. The directory data and parameter data for all entities in the file are organized into separate sections, with pointers providing bi-directional links between the directory entry and parameter data for each entity.

The design philosophy behind the IGES is discussed in [11]. Every boundary model consists of a set of topological entities together with geometric surfaces, curves, and points that serve to fix the geometric shape. In IGES, all are represented into ASCII text, to provide a full description of model and facilities the data transfer in computational modelling field. The data representation can thus be utilized for wireframe models, surface models, and solid models together with the possibility for representing schematic models[11]. In Fig. 1, the shell represents a set of faces constituting one bounding topological surface of an object while face is a portion of the surface of the object. Loop represents a boundary of a face that consists of an ordered, closed, connected, non-self-intersecting cycle of edges and vertices. Edge is the topological equivalent of a geometric curve and vertex represent the topological equivalent of a geometric point which also references a point.[11]

In this paper we presented two models which demonstrate the level in which the IGES file preserve the data and finite element analysis is applied to the model in ANSYS to identify the preservation of small features in the model.

2. PROPOSED METHODOLOGY

A biomechanical model is sketched out in 3Dmax, software designed to link the graphic designer and engineer. Without same function like Photoshop, a human organ can be conducted in the faster time due to its friendly user designed interface. Once it is modeled, the file is saved in .IGES file. Another methods is get the MRI file and use software like Mimic to convert the MRI images into IGES file so it can be further use. In our paper, we choose the first one. Latest IGES 5.3 format remain the original ideal to keep model data into the geometry entities and non geometric entity[12]. Solidworks supports IGES ver. 5.3 and the file format has entities like 100(Circular Arc), and others. In the interface processing, the basic surface of a model must be a face. With proper setting in the file exported, like 144 trimmed surface, 126 sub curves and composite curve entity 102, the data should be able to be preserved in IGES format. This information is important for whatever generating system and receiving system. Redundant data is minimized and misplacement of curve entities is avoided in maximum effort.

A .3ds model [13] is imported to 3dmax, a product trial provided by Autodesk Inc. By converting the model in editable patch surface, it gives user freedom manipulating an object as a patch object. The object's geometry is converted into a collection of separate Bezier patches. Each patch consists of three or four vertices connected by edges, defining a surface. Next the model is converted into NURBS as in Fig. 5 and Fig. 6. The term NURBS stands for Non-Uniform Rational B-Splines[14]. Model is required to be converted into NURBS model so that Galerkin Method can be applied on it. Similar approach is conducted in skeletal muscle modeling[15].

The feature can be suppressed and reinstated easily through a suppress option in the Solidworks as shown in Fig. 1 and Fig.2, small features are suppressed and reinstated on a solid rectangular.

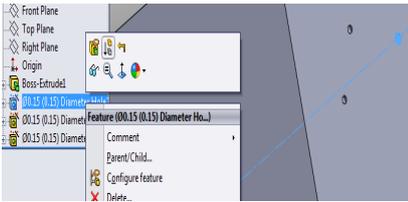


Fig. 1 Holes before suppress in Solidworks

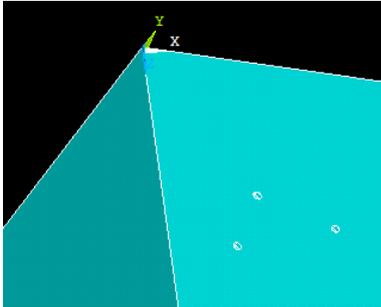


Fig. 3 Holes preserved in ANSYS

Suppress option

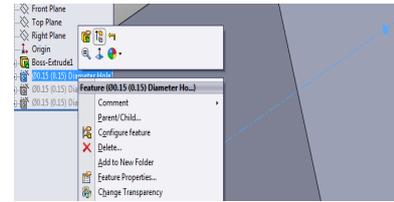


Fig. 2 Holes after suppress

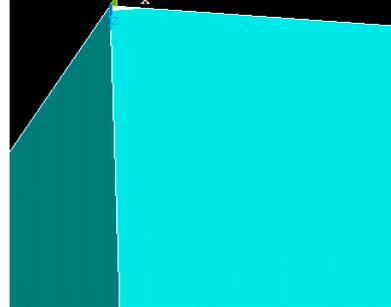


Fig. 4 no hole appears.

Both suppress and reinstated features can be tested in the ANSYS to evaluate the differences (Fig. 3 and Fig. 4) while the mesh process can be run in ANSYS. Solid model after added in the small feature in Solidworks is exported in IGES format. By setting the file exported format to ANSYS, it can be imported in ANSYS, FEA software. FEA is applied to the model to test the reliability of feature preservation. Common weighted residual methods are being applied in FEA software, for ANSYS, it uses Galerkin method to do the finite element analysis. To test for 3D stress and strain analysis in ANSYS, shell structure Elastic 4 node 63 is selected. The bone is considered as a linear-elastic, isotropic and homogeneous. Material properties of the hand bone and foot bone follow properties of cortical bones which is taken from the literature[16], Young modulus of elasticity $E=17000\text{Mpa}$, Poisson ratio 0.26. Model with small features can be further analyzed in ANSYS to demonstrate the data preservation with complete meshing of model in ANSYS.

3. Results And Discussion

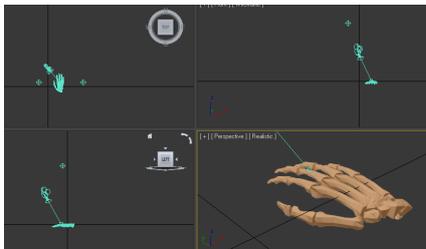


Fig.5 Metacarpals in 3dMax

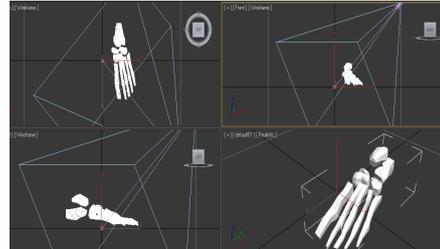


Fig. 6 Metatarsals in 3dMax

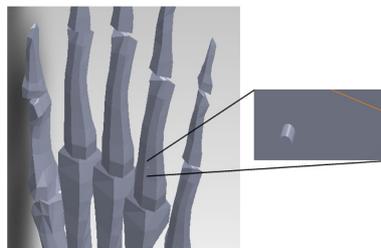


Fig. 7 Metacarpals with extrusion

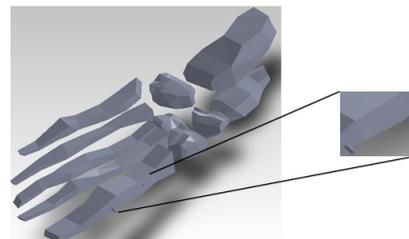


Fig. 8 Metatarsals with extrusion and holes

A 4mm circle with 5mm extruded is added into metacarpals model in Fig. 7 and saved in IGES file format in Solidworks for importing into ANSYS. A 2mm circle with 5mm extruded and same dimension cut is added into the metatarsals as indicated in Fig. 8 before imported into ANSYS. The FEA is demonstrated from Fig. 9 to Fig. 13.

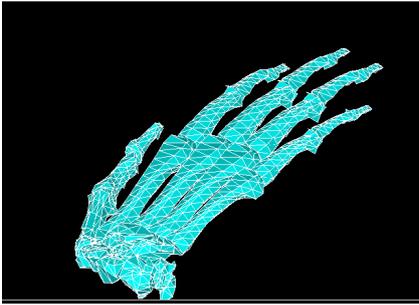


Fig. 9 Metacarpals in ANSYS

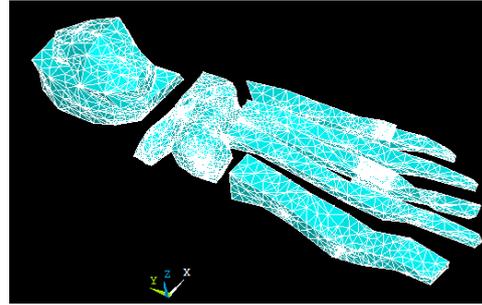


Fig. 10 Metatarsals in ANSYS

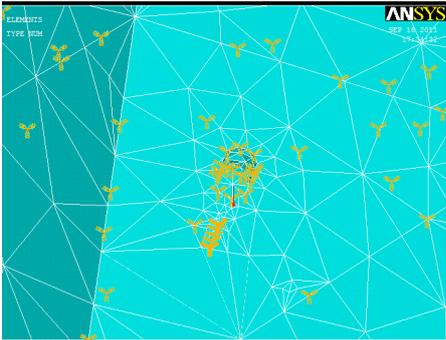


Fig. 11a Metacarpals extrusion with -1000N pointed downwards

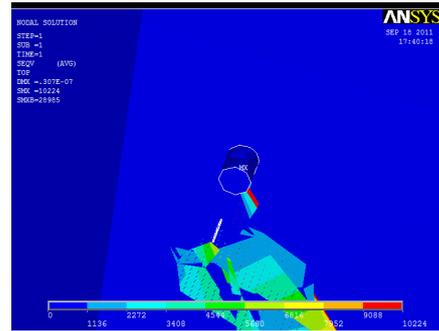


Fig. 11b Contour plot on Von Mises stresses

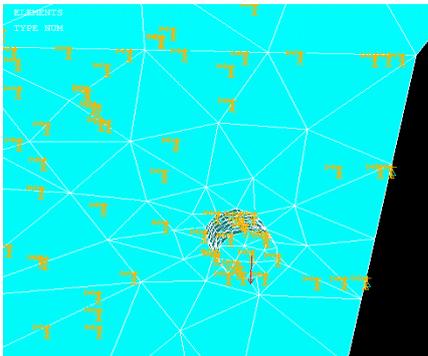


Fig. 12a Extrusion with -1000 N point downward

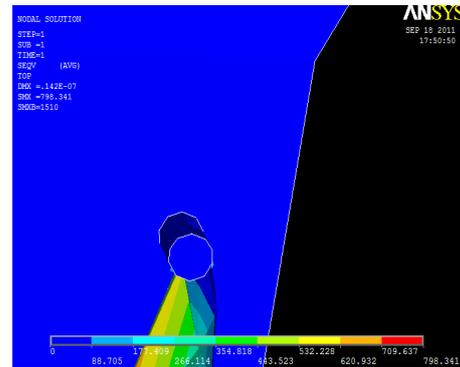


Fig. 12b Contour plot of Von Mises stress

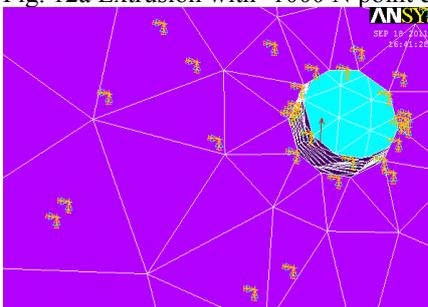


Fig. 13a 1000N pointed upward is applied

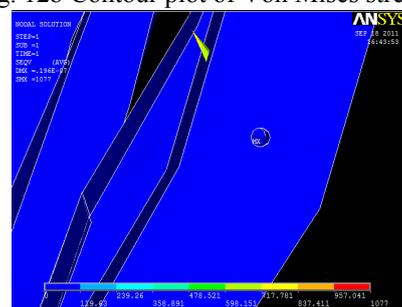


Fig. 13b Contour plot of Von Mises stress

Table 1 Maximum Von Mises Stress and Displacement when the degree of freedom is zero

Part	Figure	Maximum Von Mises Stress	Maximum Displacement
Metacarpals extrusion	7	10224	0.307e-7
Metatarsals extrusion	8	798.341	0.142e-7
Metatarsals hole	9	1077	0.197e-7

The small feature is transferred from 3dmax to Solidworks through IGES format. Furthermore it can be imported into ANSYS for FEA. All the experiment shows the consistency of geometry with von mises stress and displacement listed out.

4. Conclusion

In conclusion, seamless integration between CAD and CAE system in biomedical application through IGES file format with proper definition of model geometry. CAE modelling provides better meshing and explicit more towards real application on stress and displacement analysis while CAD provides an easy way for 3D modelling. IGES provide a low cost bridge for both CAD and CAE system. The experiment demonstrative the usefulness of IGES and can be further used in the rapid prototyping machine with. It certainly improves transferring technique and can be used in the 3D biomedical application modelling.

5. Acknowledgement

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6. References

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