

# Feature Preservation Considerations for Metacarpals and Heart Related Modeling

Xin Wang, ChingSeong Tan, KokYong Lee, and Hin Yong Wong

**Abstract**—Typical biomedical model transformed from CT scan and MRI images involved features suppression during the conversion to CAE (Computer Aided Engineering) model. However, most of biomedical application may post significant impact if minor features are suppressed or neglected during the conversion process. Thus, reverse engineering and CAD (Computer Aided Design) 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 CAE 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.

**Index Terms**—Feature suppression, feature preservation, FEA, biomedical application

## I. INTRODUCTION

Seamless integration for CAD application and CAE application is a challenge to many researchers in solid modeling [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 multi-physics 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 multi-physics 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

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X. Wang was with the Universiti Tunku Abdul Rahman, 53300, Kuala Lumpur, Malaysia. She is now with School of Enigneering, Monash University Sunway Campus (e-mail:emwangxin@gmail.com).

C. S. Tan and H. Y. Wong aer with Multimedia University, Jalan Multimedia, 63100 Cyberjaya, Selangor, Malaysia (e-mail : cstan@mmu.edu.my, hywong@mmu.edu.my).

K. Y. Lee was with the Universiti Tunku Abdul Rahman, 53300, Kuala Lumpur, Malaysia. He is now in the industry (e-mail:kokyong.lee@gmail.com).

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 to 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.

## II. 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 format. Another method is to get the MRI file and use software like Mimic to convert the MRI images into IGES file so it can be further used for CAE purposes. 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]. The 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.

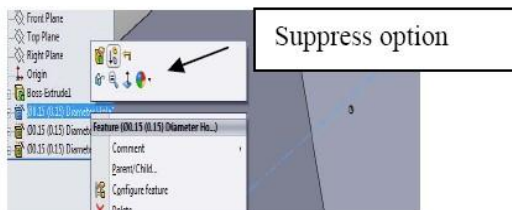


Fig. 1. Holes before suppress in Solidworks.

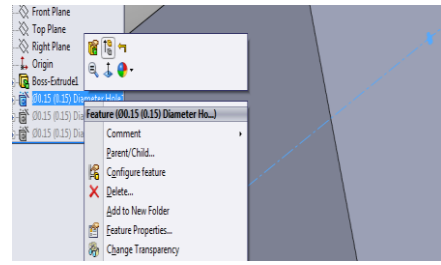


Fig. 2. Holes after suppress

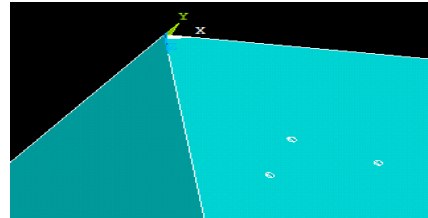


Fig. 3. Holes preserved in ANSYS

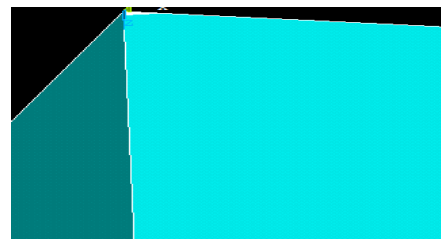


Fig. 4. No hole appears.

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.

## III. RESULTS AND DISCUSSION

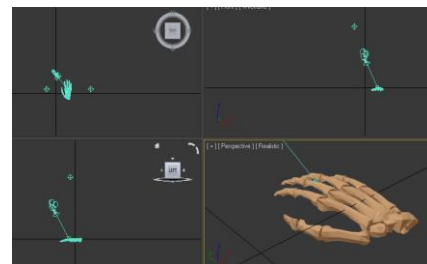


Fig. 5. Metacarpals in 3dmax

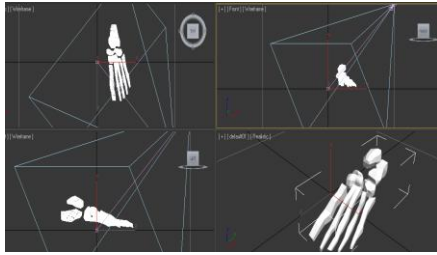


Fig. 6. Metatarsals in 3dsmax.

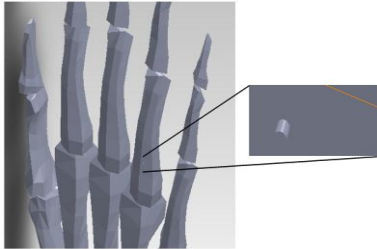


Fig. 7. Metatarsals with extrusion.

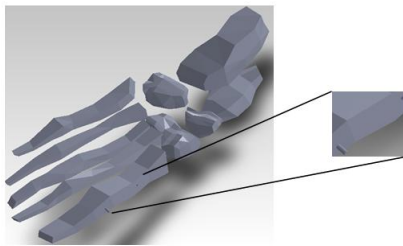


Fig. 8. Metatarsals with extrusion and holes.

A 4mm circle with 5mm extruded is added into metatarsals 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.

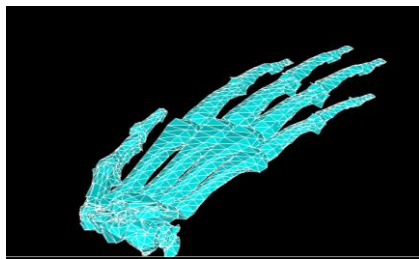


Fig. 9. Metatarsals in ANSYS.

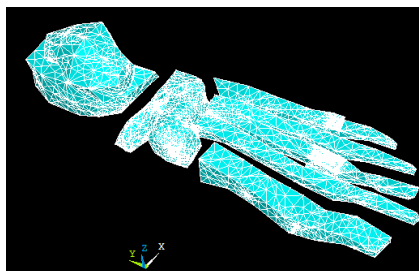


Fig. 10. Metatarsals in ANSYS/



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

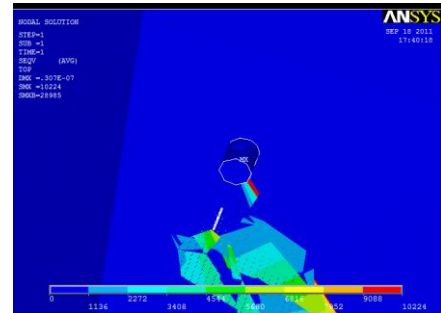


Fig. 11b. Contour plot on von mises stresses.

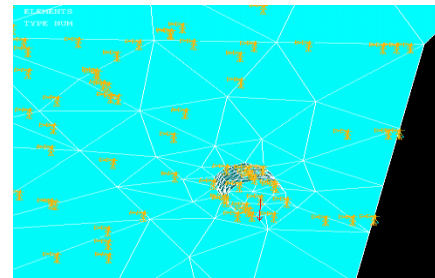


Fig. 12a. Extrusion with -1000 N point downward.

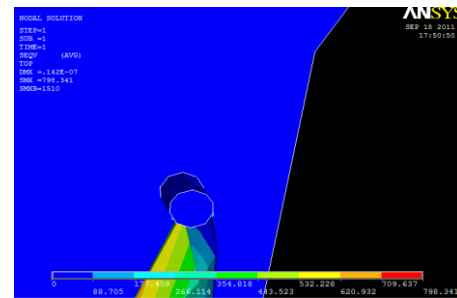


Fig. 12b. Contour plot of von mises stress.

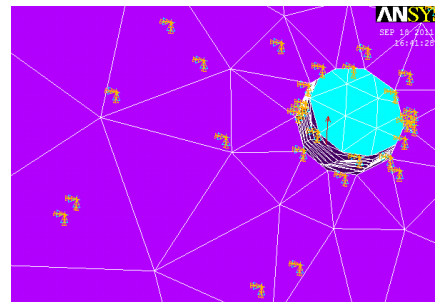


Fig. 13a. 1000N pointed upward is applied.

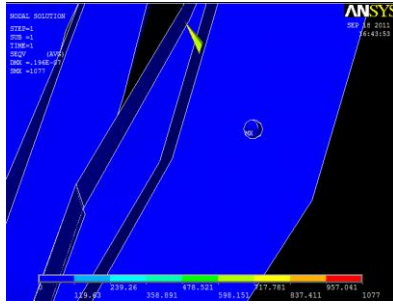


Fig. 13b. Contour plot of von mises stress.

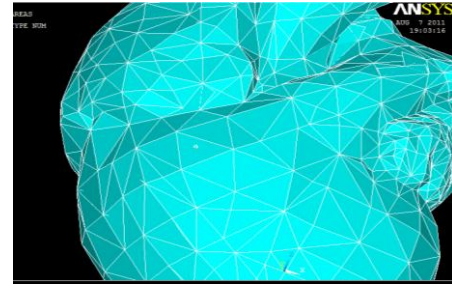


Fig. 16. Small extrusion in the heart model in ANSYS.

TABLE I: 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

After an experiment on how the feature can be preserved in ANSYS by importing the model from Solidworks, a complicated model like heart model can be constructed in 3dmax and further import to Solidworks to produce a complete solid model with whole features and imported into ANSYS for finite element analysis.

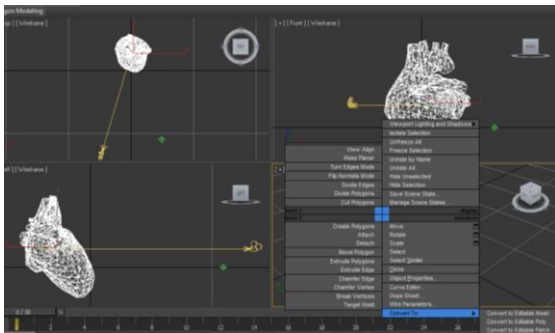


Fig. 14. GUI of 3dmax and heart model is imported.

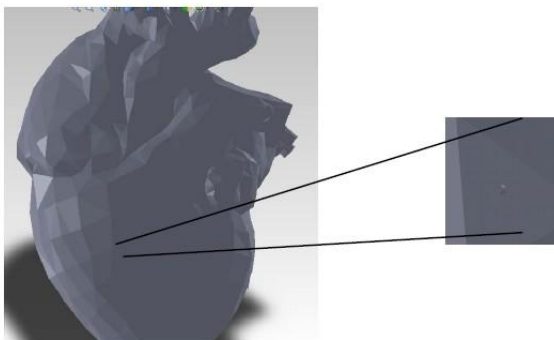


Fig. 15. A small extrusion is added on the model in solidworks.

A circle with 1mm diameter extruded 1mm in  $x$  direction is added into heart model and saved in IGES file format for importing into ANSYS.

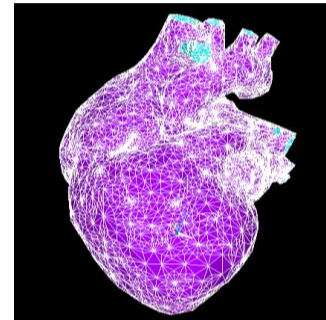


Fig. 17. Triangular surfaces meshing in ANSYS.

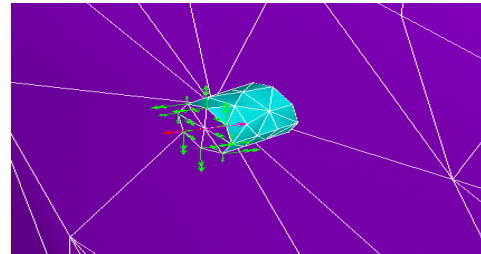


Fig. 16. X direction 1000 force is applied on the centre of extrusion.

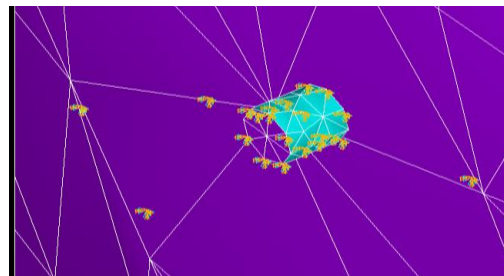


Fig. 17. Degree of freedom set to zero on lines of whole model.

The finite element analysis results as indicated in Fig. 20.

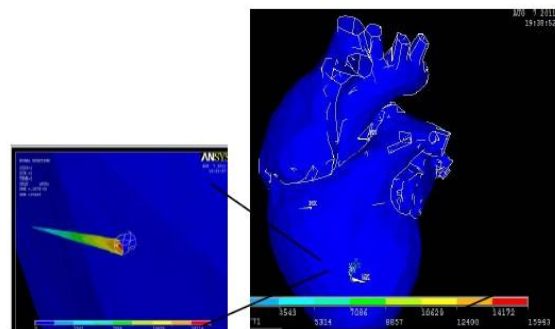


Fig. 20. Contour plot of small extrusion on the heart model.

The small extrusion finite element model has maximum displacement of  $0.167e-8$  and maximum stress 15943. The heart model in IGES can be opened in 3dmax further modification as illustrated in Fig. 21.

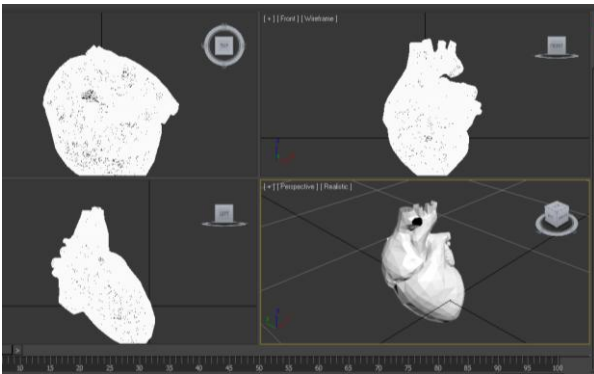


Fig. 21. Heart model with IGES format in 3dmax.

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 as equivalent to the typical conversion process that suppress the feature itself.

#### IV. CONCLUSION

We propose enhanced 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. It certainly improves transferring technique and can be used in the 3D biomedical application modelling.

#### ACKNOWLEDGMENT

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**Xin Wang** received her Ph.D. degree in 2007 from Nanyang Technological University (NTU), Singapore. She was research fellow at the Robotics Research Center, NTU from 2007 to 2009. She was Assistant Professor at Faculty of Engineering & Science, Universiti Tunku Abdul Rahman, Malaysia from May 2009 to March 2012. She is currently a Senior Lecturer at Monash University Sunway Campus. Her research interests include finite element analysis, non-destructive testing and measurement, and machine vision.



**ChingSeong Tan** received his Ph.D degree from Nanyang Technological University, Singapore. He was also drilling services engineer in Schlumberger Ltd, Research Engineer ASTAR, Senior Lecturer Multimedia University, Assistant Professor UTAR. In 2011, he joined Multimedia University where he is currently an associate professor in the Faculty of Engineering. His research interests include machine vision, optical measurement and failure analysis.



**KokYong Lee** received his Ph.D degree from Queen's University Belfast, UK. He was Research Assistant in a EU Framework 5 project. Before joining Autodesk Ltd, UK as engineer in 2005. Then in 2008 joined UTAR as Assistant Professor. He is now working in industry.



**Hin-Yong Wong** received the B.Eng. (1st class honours.) in Electronics , M.Sc Eng.(with distinction) and PhD from the University of Sussex, University of Leeds and University of Glasgow respectively all from the UK. Among some of the awards he received are the Tetley and Lupton Scholarship(U.K) , University of Glasgow Postgraduate Research Scholarship, Oversea Research(ORS) Award (U.K.), IET Young Malaysia Engineer Award, and was a SPIE visiting lecturer. He joined the Multimedia University (MMU), as a Lecturer since its inception in 1999. He is now an Associate Professor and the Dean of Faculty of Engineering. He is a Professional Engineer & Chartered Engineer registered with the Board of Engineer Malaysia and Engineering Council UK respectively. His current research interests include organic electronic devices, nanolithography technology, optoelectronic devices, photonics integrated circuits, thin film , solar technology & optical measurement.