THREE DIMENSIONAL MODELING ANALYSIS OF CRANIOFACIAL HARD TISSUE USING VARIOUS 3D MODELING SOFTWARE

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KEYWORDS: Craniofacial Hard Tissue, CT Scan, 3D Modeling Software, Statistical Analysis

ABSTRACT

The aim of the research is to determine the most accurate, reliable and low cost 3D modeling software for 3D modeling of craniofacial hard tissue data (skull). The software namely RapidForm2004, 3D Doctor and 3D Slicer were used to generate the 3D model of the skull from Computed Tomography (CT) scan raw data. The similar CT scan dataset was also process using high quality MIMICS software, where the 3D model of the skull was selected to be a "gold standard". The accuracy analysis involved with the deviation analysis between the 3D model generated by the test software and the gold standard. For reliability analysis, the 3D modeling process (in each software) was repeated five times and the RMS value of the deviation with the gold standard was calculated.

1.0 Introduction

In medical imaging field, the most accurate, reliable and low cost 3D modeling software for 3D modeling of skull is very important and needed for surgeon. Such a model can be used in plastic surgery and its related disciplines, forensic medicine, anthropology, orthodontics, psychology, surgical simulation, face recognition and in many other applications (El-Hussuna, 2003). This research was using RapidForm2004, 3D Doctor and 3D Slicer software to generate 3D model for craniofacial hard tissue. The 3D models from Mimics (gold standard) come from Standard & Industrial Research Industrial Malaysia (SIRIM). Using RapidForm2004, the software converts data from any 3D scanning device (such as laser, white-light, moire, CT/MRI, touch probe or any other) into high quality polygon mesh, accurate freeform NURBS surface, or geometrically perfect solid models (Halim et al, 2005). Besides, 3D Doctor is an advanced 3D modeling, image processing and measurement software for MRI, CT, PET, microscopy, scientific, and industrial imaging applications. This software creates 3D surface models and volume rendering from 2D cross-section images in real time (Able Software Corp, 2003). User must have a license from software developer before using RapidForm2004 and 3D Doctor software. 3D Slicer is freely available, open-source software for visualization, registration, segmentation, and quantification of medical data. The software uniquely integrates several facets of image-guided medicine into a single environment. It

provides capabilities for automatic registration (aligning data sets), semi-automatic segmentation (extracting structures such as vessels and tumors from the data), generation of 3D surface models (for viewing the segmented structures), 3D visualization, and quantitative analysis (measuring distances, angles, surface areas, and volumes) of various medical scans. User can download this software through the internet. Materialise's Interactive Medical Image Control System (Mimics) is an interactive tool for the visualization and segmentation of CT images as well as MRI images and 3D rendering of objects. Mimics is a fully integrated, user-friendly 3D image processing and editing software based on scanner data. The software imports scanner data in a wide variety of formats and offers extended visualization and segmentation functions. This software used as the gold standard model because of their textured image is quite good compare to the other software but the software is more expensive.

2.0 Method

Figure 1 is showing the methodology for this research. Firstly, data and 3D model acquisition was done to get the CT scan raw data and 3D model from Mimics software. Then the software namely RapidForm2004, 3D Doctor and 3D Slicer were used to generate the 3D model of skull from Computed Tomography (CT) scan raw data. For reliability analysis, the 3D modeling process was repeated five times for each software. After that, each of the 3D skull model will be imported and registered

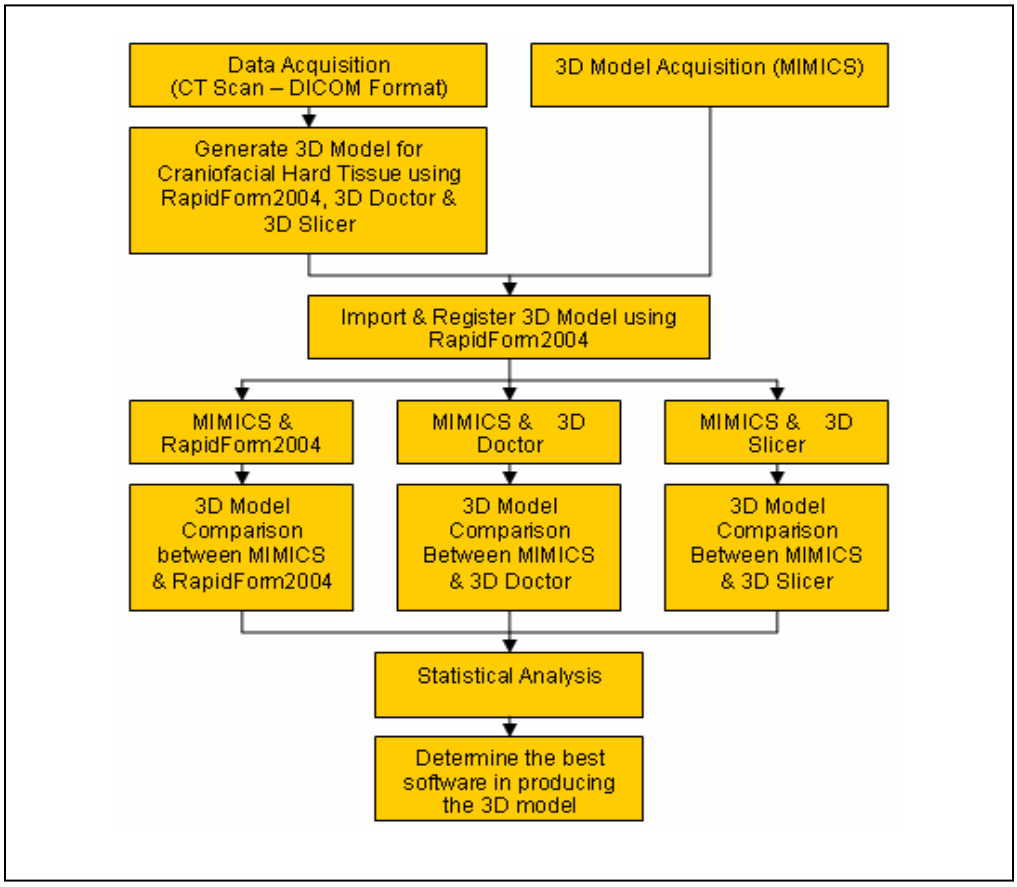

Figure 1: Research Methodology

with Mimics model using RapidForm2004 software. Then, the comparison of the 3D skull will be done for each 3D software between Mimics and RapidForm2004, Mimics and 3D Doctor and Mimics and 3D Slicer. Finally, statistical analysis will be done to get the value of average distance, standard deviation, root mean square (RMS) and variance for the comparison of 3D skull model.

2.1 Image Processing to Generate 3D Model for Craniofacial Hard Tissue

3D model for skull will be generated using three software i.e RapidForm2004, 3D Doctor and 3D Slicer. Figure 2 show the process to generate the 3D skull model. The image pixels (grayscale and color) come from CT scan raw data in Digital Imaging and Communications in Medicine (DICOM) format will be classified into separate colour groups based on their colour and textured information using a clustering algorithm. Then, image segmentation will be done to determine the part which is needed for the 3D model of the skull. Segmentation is the process that separates an image into its important features (primitives) so that each of them can be addressed separately (Karangelis et al, 2002). The segmentation process to generate the 3D skull model for craniofacial will be done using threshold technique. Then, image contouring will be done before the 3D model was generated. After all the process was done, the 3D skull model will be showed and editing process will be done for post processing.

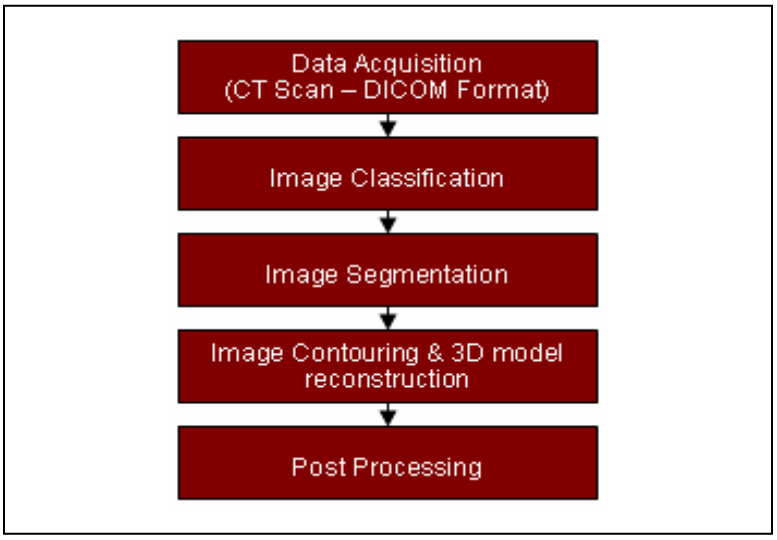

Figure 2: Process to Generate 3D Model for Skull

2.2 Model Comparison

The skull comparison for each software with Mimics is to determine the most accurate, reliable and low cost 3D modeling software for 3D modeling of craniofacial hard tissue data (skull). The accuracy analysis involved with the deviation analysis between the 3D model generated by the test software and the gold standard. For

reliability analysis, the 3D modeling process was repeated five times for each software and the RMS value of the deviation with the gold standard was calculated. Figure 3 show the step to compare 3D skull model for each software with MIMICS using RapidForm2004 software.

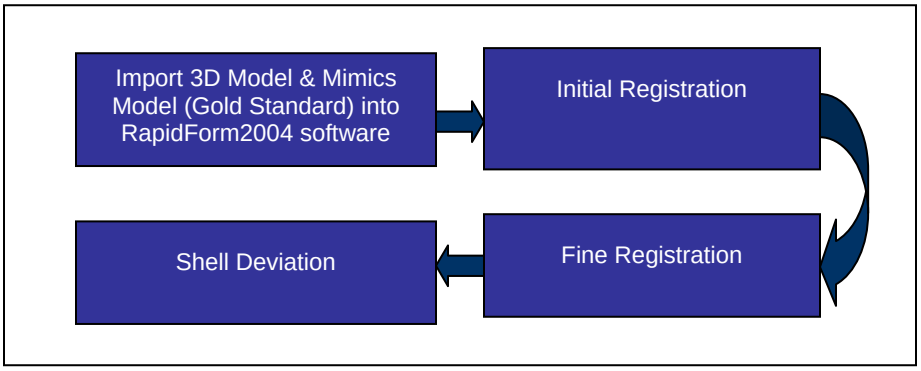

Figure 3: Model Comparison

Firstly, 3D model for skull i.e 3D Slicer's model and 3D model from Mimics software will be imported into RapidForm2004 software. All the 3D models will be registered with each other using initial registration and fine registration. The registration process between 3D slicer's model and Mimics's model was using Iterative Closest Point (ICP) algorithm. ICP algorithm attempts to register a pair of range images by defining a metric describing the amount of error in a candidate registration. Finally, shell deviation will be done to get the value of average distance, standard deviation, RMS and variance. This process was repeated five times for each software for reliability analysis. Using that value, statistical analysis for this research can be done.

3.0 Results and Analysis

This research was come out with some result after the comparison was done. Figure 4 show the 3D skull models that was generated with 3D softwares i.e RapidForm2004, 3D Doctor, 3D Slicer and Mimics.

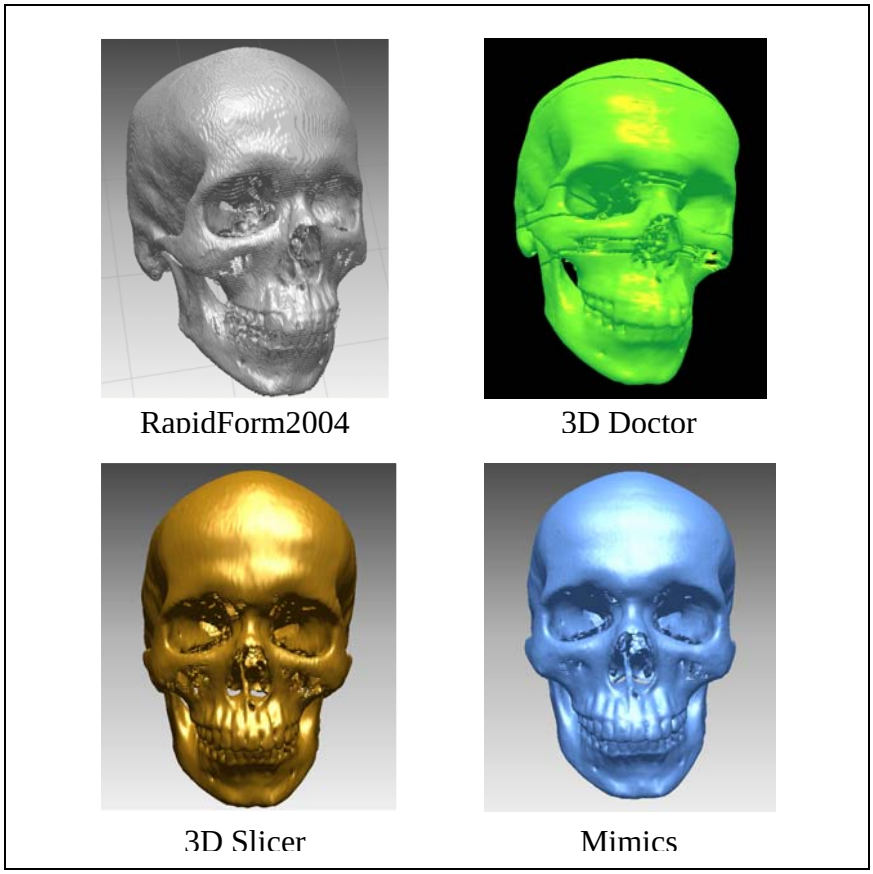

Figure 4: 3D Model for each Software

After the 3D models was processed using RapidForm2004, 3D Doctor and 3D Slicer software, the comparison with Mimics model will be done using RapidForm2004 software for each model. Figure 5 show the sample of shell deviation's result for Mimics and 3D Doctor's model.

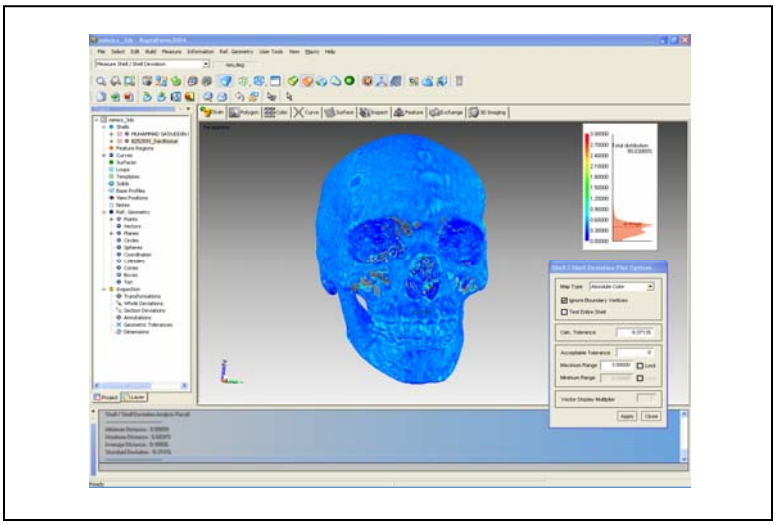

Figure 5: Shell deviation process

In Figure 5, the graph show a few colour i.e blue, green, yellow and red which is referring to the error of the skull model while registering process was done. The blue colour in the skull meaning that there are a few errors after registering between two skull model and the red colour refer to error which is bigger than the blue colour.

Table 1 and Table 2 show all the result for the comparison of skull such as average distance, standard deviation, root mean square (RMS) and variance. From this analysis, the result show that 3D slicer is the best software that most accurate, reliable and low cost 3D modeling software for 3D modeling of craniofacial hard tissue data (skull).

Model 1	Model 2	Average Distance	Std Dev	RMS	Variance
MIMICS	RapidForm1	1.41697	1.2801		1.63866
MIMICS	RapidForm2	1.41376	1.27325		1.62117
MIMICS	RapidForm3	1.42027	1.27716		1.63114
MIMICS	RapidForm4	1.41708	1.28011		1.63868
MIMICS	RapidForm5	1.41682	1.26947		1.61155
Average		1.41698	1.276018	1.276025	1.62824
MIMICS	3DSlicer1	0.40845	0.47373		0.22442
MIMICS	3DSlicer2	0.40848	0.47389		0.22457
MIMICS	3DSlicer3	0.40792	0.47137		0.22219
MIMICS	3DSlicer4	0.40833	0.47346		0.22416
MIMICS	3DSlicer5	0.40804	0.47194		0.22273
Average		0.408244	0.472878	0.472879	0.22361
MIMICS	3DDoctor1	0.55324	0.77917		0.60711
MIMICS	3DDoctor2	0.56364	0.80532		0.64854
MIMICS	3DDoctor3	0.56355	0.80497		0.64798
MIMICS	3DDoctor4	0.56223	0.80871		0.65401
MIMICS	3DDoctor5	0.56266	0.81021		0.65644
Average		0.561064	0.801676	0.801757	0.64282

Table 1: Comparison between 3D Model (RapidForm2004, 3D Slicer, 3D Doctor) with Mimics

	3D Slicer - RapidForm	3D Slicer - 3D Doctor
Model 1	-1.00852	-0.14479
Model 2	-1.00528	-0.15516
Model 3	-1.01235	-0.15563
Model 4	-1.00875	-0.15390
Model 5	-1.00878	-0.15462
Average	-1.00874	-0.15282
Standard Deviation	0.00250	0.00453
RMS	1.00874	0.15287
Variance	0.00001	0.00002

Table 2: Comparison Between 3D Slicer - RapidForm2004 and 3D Slicer - 3D Doctor

4.0 Conclusion

This study focused on comparison of three software with Mimics to determine the most accurate, reliable and low cost 3D modeling software for 3D modeling of skull. The results obtained 3D model for each software, average

distance, standard deviation, RMS and variance. The 3D modeling and analysis results were presented in the suitable forms. From this analysis, the result show that 3D slicer is the best software that most accurate, reliable and low cost 3D modeling software for 3D modeling of craniofacial hard tissue data (skull).

Acknowledgment

This research is part of a prioritised research (PR) IRPA Vot 74537 sponsored by Ministry of Science, Technology & Innovation (MOSTI), Malaysia. The PR involves Universiti Teknologi Malaysia (UTM), Standard & Industrial Research Industrial Malaysia (SIRIM), and Universiti Sains Malaysia (USM).

References

Halim Setan, Mohd Sharuddin Ibrahim & Zulkepli Majid (2005). Precise Measurement and 3D Modeling for Medical and Industrial Application: Verification Test, FIG Working Week 2005 and GSDI-8, Egypt.

Grigorios Karangelis, Dr.Stelios Zimeras (2002). A 3D Segmentation Method of the Spinal Cord Applied on CT Data. Computer Graphik Topics in 2002 Issue 1 2002 Vol.14
http://www.inigraphics.net/press/topics/2002/issue1/1_02a12.pdf

Alaa El-Hussuna (2003). Statistical Variation of Three Dimensional Face Models. IT-University of Copenhagen: Tesis Ijazah Sarjana.

Kolar, J. C. & Salter, E. M. (1997). Craniofacial Anthropometry ; Practical Measurement of the Head and Face for Clinical, Surgical and Research Use. Springfield, USA: Charles C. Thomas Publisher Ltd.

Able Software Corp, (2003). User Manual : 3D Doctor For Windows 9X/NT/2000/XP. Lexington, USA