

# Comparison of Image Generation And Processing Techniques For 3D Reconstruction of The Human Skull

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*Abstract* - The purpose of our study was to compare the accuracy of an unconventional, non-invasive and relatively inexpensive Microscribe (3D digitizer) with a standard widely used and expensive CT-Scan and/or MRI for 3D reconstruction of a human skull, which will be used for biomechanics studies. Two models of the human skull were developed (reconstructed), one using the 3D coordinates generated by the Microscribe 3D digitizing unit and another one using the CT-Scans (2D cross-sections) obtained from a GE scanner. Both models were then subjected to stress analysis using a Finite Element Analysis program.

Additionally, a few image processing software – OSIRIS [ 1], SCION IMAGE [2], EFILM [3], 3D DOCTOR [4] and OPTIMAS [5]- were compared in order to find the best software that could function as an interface between medical and engineering software and in the same time to have a 3D reconstruction algorithm.

## I. INTRODUCTION

Although in the last few years, the use of the non-invasive medical techniques for diagnosis and treatment has experienced a huge development, mainly due to advancement in technology, for research and education these methods are still elaborate, expensive and not readily accessible.

Using the hand-held digitizer, the Microscribe, X, Y and Z coordinates of a human skull were generated to create the first computer model. The 3D coordinates were brought as splines in to 3D Studio Max, a 3D modeling software, and U-lofted to form a solid NURBS model.

The second model was designed using the two-dimensional slice data from a CT scanner as input for the three dimensional reconstruction of the skull. The final solid model was designed using a mechanical design software by lofting all the contour cross sections.

## II. METHODOLOGY

### A. First Model – Direct Method

The Microscribe captures the physical properties of a three-dimensional object and translates them into a 3D model. This kind of device is used to collect data directly from the surface of the study object. The stylus tip is moved over the

contour of the object following its surface until the entire surface is digitized [6]. Usually, points are drawn on the object's surface in order to facilitate the digitizing process. 3D Studio Max takes this "raw" data and produces complex 3D models using various modeling techniques. In 3D Studio Max objects can be modelled using *polygons*, *patches* or *nurbs* [7]. For making the first skull model I used *Spline-based modeling*, namely DRAW SPLINE option. This method allows the user to begin a new spline or to do multiple splines by adding splines to those already created. I used this command to digitize my model because it is quick, easy to use, and produces the most accurate result. The final skull model was obtained in three steps. In the first stage, half of the skull was digitized following every point previously traced on the skull' surface. The digitizing process was more difficult as splines became more complicated, having more points and more complex shapes [8]. This is why I decided to use a symmetry method and obtain the skull from two identical halves. This is how the first object was obtained - MicroscribeSpline object (Fig.1).

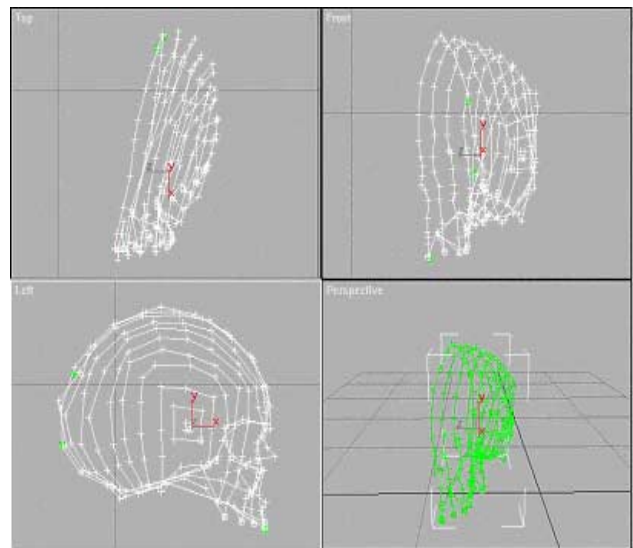


Fig. 1. MicroscribeSpline object

The MicroscribeSpline object can be converted to NURBS object by first drawing a NURBS point curve and then attaching the MicroscribeSpline object to the NURBS curve.

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The MicroscribeSplines may be transformed into NURBS curves object only if the splines types are changed to Curve and the vertices are Smooth or Bezier.

In the second stage, the splines were transformed in NURBS curves and the second object was called NURBS Curves object (Fig.2).

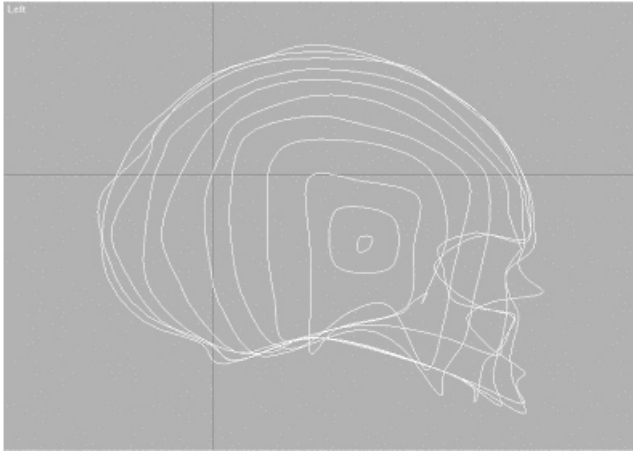


Fig. 2. NURBS Curves object

Finally, in the third stage, the NURBS curves were transformed in NURBS surfaces using the NURBS surface command, U-LOFT, and the final model, NURBS surface object, was obtained (Fig.3).

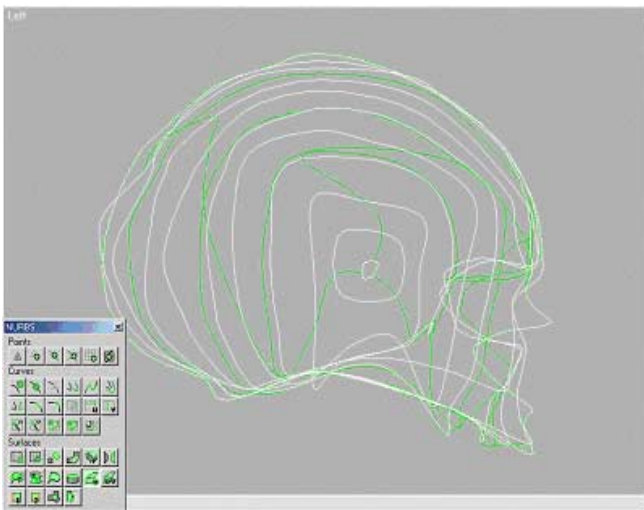


Fig. 3. NURBS surface object

The final solid skull model designed in 3D Studio Max from 3D coordinates recorded by a Microscribe can be seen in figure 4.

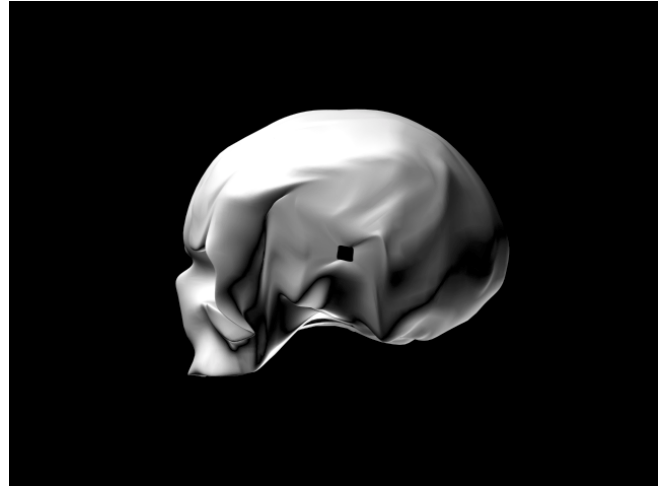


Fig.4 Solid skull model

The solid model was then exported to FEA software for analysis. (Fig.5)

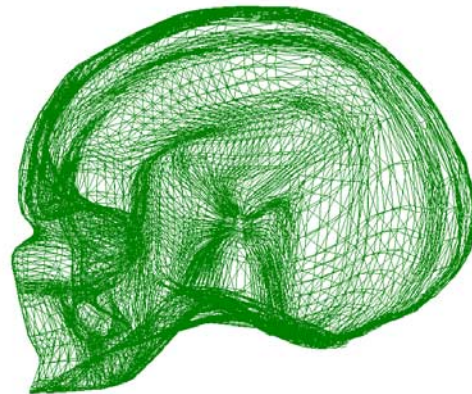


Fig. 5. FEA Solid Model

#### B. Second model – Indirect Method

For designing the second skull model, an indirect 3D imaging method was used, that is gathering a sequence of 2D images and then combining them (x, y) instead of actually collecting a three-dimensional set of information all at once (x, y, z) as in the direct method used for designing the first model [9].

The CT scans were made at the O’Bleness Memorial Hospital, in Athens, OH using a GE Helical Hi Speed – FX/i scanner. The images were captured and analyzed using the Image Works Workstation. Beside film and image analysis and manipulation, the Image Works Workstation supports also 3D reconstruction from 2D slices. A 3D skull model reconstructed by the Image Works Workstation can be seen in figure 6.



Fig. 6. CT skull

The CT cross-sections were captured as DICOM files using the E-film software and exported as TIFF images. The TIFF images were brought into OPTIMAS, an image analysis software, which extracted the X, Y coordinates of each cross section using the POINT MORPHOMETRY option. A visual basic program was developed to convert the extracted coordinates to closed curves under Unigraphics Solid Edge software. To obtain the final model, the external boundaries of each cross section were lofted using the LOFT PROTRUSION command (Fig. 7)

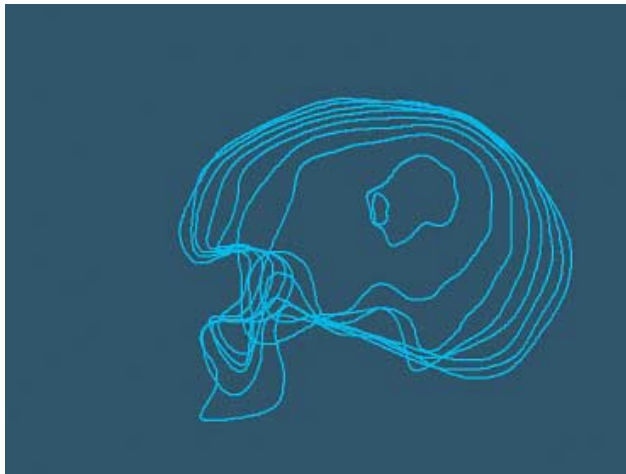


Fig. 7. Curves in Solid Edge

In order to find the best result, an additional indirect approach was developed in parallel, using Adobe STREAMLINE, an image processing software. It extracted the boundaries of each cross section and exported them as DXF files, compatible with the Solid Edge software.

Both models were then subjected to stress analysis using a Finite Element Analysis program, Algor software. Figure 8 presents the first model analyzed in Algor.

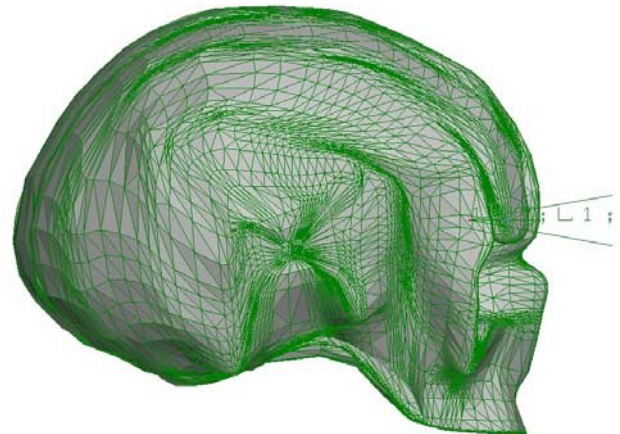


Fig. 8 FEA analysis for the first skull model.

The analysis results obtained from the two scanning techniques will be discussed and presented, including the pros and cons of using the more accurate and expensive CT-scans versus the inexpensive hand-held scanner, the Microscribe, and their effects on finite element models. During this study, different image processing software such as OSIRIS, SCION IMAGE, EFILM, 3D DOCTOR and OPTIMAS were investigated in order to find the best interface to capture, reconstruct and model body data.

### III. RESULTS

The models were subjected to stress analysis by applying a nodal force on the middle of the frontal bone of every skull model. The analysis is still in progress but the final results are expected to be similar even if the two models are so different - designed by different methods, using different software tools. Another important part of this project was to determine, from an engineering point of view, the features, availability, cost and user-friendliness of various medical images processing software available today, regarding the 3D volume reconstruction from 2D slices. A comparison was drawn and some of the results are presented in Table I. Opinions presented as "features" in table I are those of an inexperienced user, mainly based on personal experience with each software. In finding the best software to do the reconstruction, two major criteria were followed. The best software will not create a contour, projection or rendering but a real 3D reconstruction. The second criterion was the ability to export this reconstructed volume in an engineering software for analysis. The only software that seems to fulfill both criteria was 3D Doctor. Unfortunately, the trial version we have used doesn't have those options available therefore one could only guess that the results are satisfactory.

TABLE I  
Comparison between various images processing software.

	Features	Import / Export	3D / Reconstruction	3D Command	Cost
OSIRIS	- Easy to use; - Robust, stable software.	Papyrus 2,3 Dicom, Tiff	Creates a contour volume	<i>"Multiple ROI Volume"</i>	Free
SCION IMAGE	- Professional look; - Multiple possibilities to process and analyze an image.	Dicom, Tiff, Lut, Roi, Txt	Makes a projection	<i>"Project"</i>	Free
EFILM	- Medical image and information system; - Image retrieval; - Multiplanar options; - 3D cursor	Dicom, Tiff, Jpeg, Bmp	-	-	Free
3D DOCTOR trial	- Reconstruction, DXF, 3D Studio export (not available in demo); - 3D rendering;	Dicom, Tiff, Jpeg, Bmp, Suf, Vol, Lst, Hdr	Makes a 3D image	<i>"Volume rendering"</i>	Free
OPTIMAS	-Excellent measurement functions; -Automatic data output.	Tiff, Bmp, Fits, Jpeg, Photo CD Targa, Gif, Pcx,	-	-	Aprox. \$7000

#### IV. DISCUSSION

The two models were designed primarily for finding a simple and nonexpensive method of 3D reconstruction and for comparing the accuracy of two very different methods.

The first model, obtained by collecting real three-dimensional coordinates, was designed using an unusual, unconventional technique and this is considered maybe even more important than its FEA analysis results. Making the model combines working with a relatively inexpensive 3D digitizer and processing the results in a 3D modeling software. The whole process takes very little time and the cost involved is insignificant.

On the other hand, the second model obtained using the indirect method required collecting data from a CT scan, which is very expensive, and using many software to reconstruct the model. Besides this, many other problems arose when the model had to be transferred in a FEA software. For example, the DXF files, obtained using STREAMLINE software, were not "seen", accepted by different FEA software. Also, it is extremely difficult to reconstruct the model from many cross sections in an engineering software, because the perimeters have different dimensions and intricate shapes, the coordinates must be chosen to be approximately the same for all the sections and so on.

The medical image software analyzed in this paper are designed for medical use. Each one of them have at least

one command that make them unique and extremely useful in various medical fields but the most important aspect in my opinion is that they facilitate the access to medical files and ease the possibility of sharing information.

For our purpose however, none of the free available medical image software could be use because, as can be seen from table I, none of them makes 3D reconstruction. That is why, designing this model could be even more expensive because involves either spending a lot of time trying to find the best software to do the reconstruction or spending a lot of money to buy such software.

#### V. REFERENCES

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