A MODELING METHODOLOGY OF IMAGE SEGMENTATION FOR CREATING HUMAN PROSTHESIS IN THE CAD SYSTEM

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Abstract. *The union of discoveries of the most varied areas results in great jumps as, for example, the junction of Radiology to Computer science can be cited, resulting in a basic technology to the diagnosis for image. With the incorporation of the computerized tomographic scan, and follow with the three-dimensional processing (3D) of images, it was created the possibility of virtual visualization. Considering the great technological development in the medicine and engineering, the objective of the work is the Conception of Models of Human Prosthesis by CAD/CAM or transference of data generated from the same ones, to offer it has supported the geometric modeling or construction of a three-dimensional model in an environment CAD (Computer Aided Design), or either, a specific environment to project and to analyze the best forms of manufacture, using tomographic images. Of this form, it facilitates to the analyses and more sensible research with relation to the viability of the construction of models, bio-models or prosthesis. This work of research presents the conception of a methodology for conversion of tomographic images in models 3D in the CAD. Notices that the union of the areas as much is basic for the success of this methodology that in the present time can be perceived the junction of some areas, as Engineering assisting the Medicine, Computer science in Engineering, the Physics in Engineering.*

Keywords: *CAD/CAM, Prosthesis Modeling, Conversion of images, Geometric Modeling, Tomographic scans.*

1. INTRODUCTION

In the last two centuries there was a quick technological development and consequently a lots of important discoveries appeared in several areas of knowledge. One of them occurred in 1895, when the German physicist Wilhem Konrad Rontgen had found out the X Ray, which allowed the indirect access to the human body, resulting in a fundamental technology to the diagnostics by image. Another was the incorporation of the computerized tomography (CT) in the 70's, and followed by the three dimensional processing of image (3D). These developments had created the possibilities for the human body visualization, in perspective, in a graphic monitor. In this way, the analysis of the radiologist and the surgeon was facilitated, being unnecessary the mental and subjective reconstruction of the various two dimensional tomography sections. There are patient that have congenital or acquired deformities, whose treatment is a constant challenge to the surgeon team, including, in the most of the cases, multiples and complexes surgeries, that can have high costs and with the results, in some cases, not satisfactory. Therefore, the Health Care Organizations and the Health professionals started to search and to develop studies about new ways of to make the diagnosis and to treat the deformities.

In Brazil, it is estimate that 12% of the people are physical disable. It is about 19 million of people. There are several reasons for their deformities but the main reasons are: car accident, accident at the work, radical sports, bad formation with genetics origin, and the pathological and degenerative illness (D'URSO, 1998).

In the product development area, the CAD systems (Computer Aided Design) was consolidated as powerful and indispensable tool to the technological improvement in the conception and development of the products, in the industries in a general way. Other important aspect was the manufacturing processes evolution and in the radical change in the geometry form of the products. This was possible only through the integration of the Computer Aided Design (CAD) that offers support to the Computer Aided Manufacturing (Canciglieri and Young, 2003).

This scenery showed the opportunity to unite the knowledge of the Medicine, Engineering and Information Technology to create new conception ways for prosthesis and bio models to increase and make easier for the medicine in the surgeries planning.

The current way of prosthesis production, in the most of the cases, are handmade and this has a direct influence in the quality and in the operational costs, since that normally the prosthesis are geometrically irregular obligating the surgeon to make adjusts during the surgery process. These adjustments increase substantially the surgery time and costs and, also, can cause, in certain cases, traumas to the patient that can be psychological or terrible sequelae.

From this, it is the fundamental importance to develop a Methodology that can be able to conceive and manufacture prosthesis which can be used as support base to the CAD/CAM design systems. Therefore, the aim of this research is to presents a modeling methodology of image segmentation for creating human prosthesis in the UNIGRAPHICS CAD System. It shows, also, a case study applied to this methodology through de modeling of the top of a human skull.

2. METHODOLOGY TO DESIGN/CONCEPTION AND MANUFACTURING OF PROSTHESIS

The methodology to the conception of prosthesis through de CAD systems must start with the conversion of the computerized tomography sections from tomography file (DICOM format) in two dimensional poly lines figure that will generate the geometrical three dimension models in the CAD system. To achieve good results the image of tomography file must be segmented in order to generate a 3D models and this geometry will be used by the CAM module to realize the virtual machining. The figure 1 emphasizes how the image segmentation for creating a human prosthesis profile will be made from the whole methodology defined by Canciglieri, *et al.* (2006). This methodology is divided in two main function: i) the acquiring and conversion of the tomography image and the creation of the geometrical model in CAD; and ii) the virtual machining of the model.
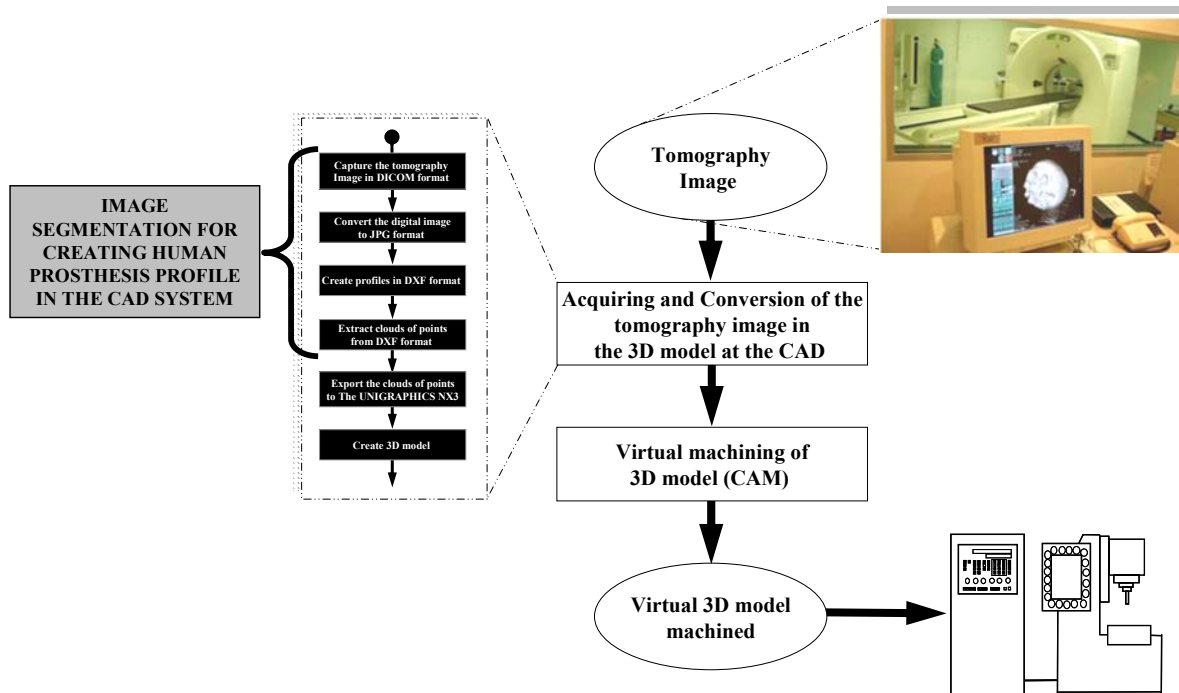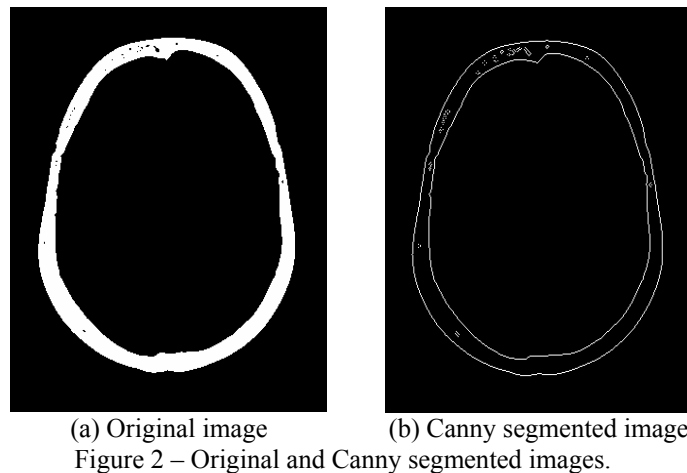
Figure 1 − Conception and manufacturing of prosthesis models (based on Canciglieri, *et al.* 2006).
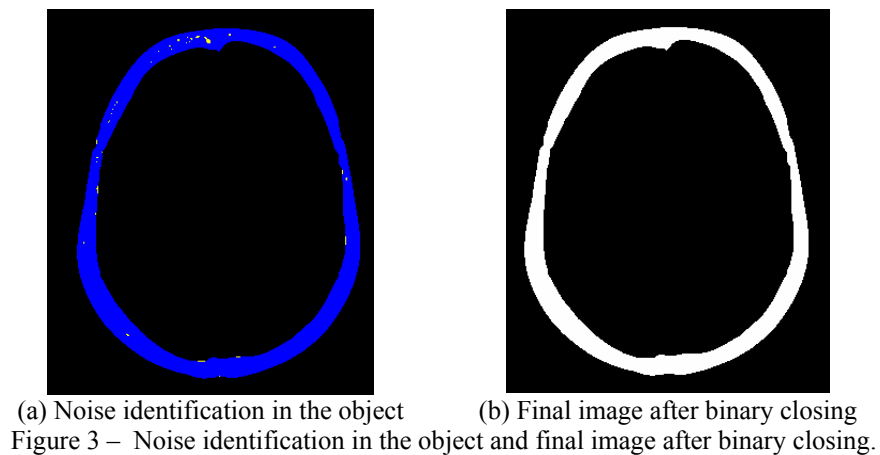
3. IMAGE SEGMENTATION

The image segmentation procedure is useful to subdivide the image into its constituent parts, by detection of points, lines and edges. The objective in this work is to extract the borders of a skull silhouette shown in figure 2.a. The edge is a discontinuity formed by a transition between intensity level of background and the object in the foreground. In a special case to segmented bones from computed tomography, some applications uses global or local thresholding approaches (COMER, 1999; KOHLER, 1981; BERNSEN, 1986; OTSU, 1979) because it assumed the homogeneity of the pixels in the objects being segmented. The theory of edge extraction is based on some different techniques. Its presented in (YAO, 2005) some used methods in bone segmentation, as region growing, region compaction, watershed segmentation and active contour models or multi-agent approaches (MAHDJOUB, 2006) among others. The use of each one depends of the problem kind. Although (YAO, 2005) refers that edge filters produces nonclosed contours or false edges, the edge identification in this application, was sufficient solved by the more conventional gradient based algorithms. The gradient definition is given in (GONZALEZ, 2002). The first-order derivative of image is zero in the regions with constant values of black or white, but is not zero when calculated on a discontinuity. The first-order derivatives are based on 2D gradient. Some gradients operators as Roberts, Prewitt, and Sobel (LIM, 1990; PARKER, 1997) or Canny (CANNY,1986) that works with a Gaussian process, are frequently used to edge detection.

The figure 2.b presents the initial segmented image result after Canny method of edge identification. It can be seen some information detected, between internal an external borders. Bones have different shapes in the inner structures which cause the variation of the intensity in a wide range (YAO, 2005), and it is not desirable for this application, because this will go to make it difficult the extraction of border points. Then, before edge segmentation it is necessary to extract the useless points. A morphologic process called binary closing (dilation followed by erosion) can be used in this case to extract the noise information, and its expression is given by (GONZALEZ, 2002) as follow:

$$A \bullet B = (A \oplus B)\Theta B \tag{1}$$

(a) Original image   (b) Canny segmented image
Figure 2 – Original and Canny segmented images.

The binary closing permits to fill the holes that appearing into the border region. The image result after this process is presented in figure 3. The figure 3.a shows the noise identification and figure 3.b presents the final result.

(a) Noise identification in the object   (b) Final image after binary closing
Figure 3 – Noise identification in the object and final image after binary closing.

The contour segmentation can be doing on the filtered image using the same Canny process. The resultant image is presented in the figure 4 that shows two edges identified. The center of contour's pixels is also showed.
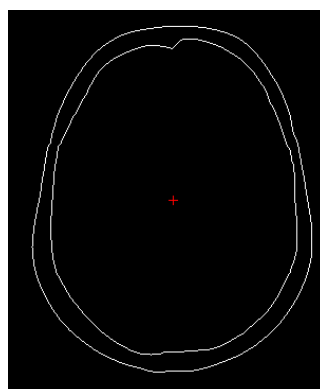

Figure 4 – Final edge segmentation and center of pixels region.

4. IMAGE BORDERS EXTRACTION

The skull slice image generated after the Canny edge segmentation, presents two single pixels borders. An outer border identified as B_E and an inner border identified as B_I. The both B_E and B_I are matrices that contains the 2D pixel positions, as follow:

$$\mathbf{B_E} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix} \qquad \mathbf{B_I} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix} \qquad (2)$$

Where x_k and y_k are the coordinates of each edge pixel, with $k = 1,2,...n$. The n is the total perimeter's points for each border, and it can assume different values, because the length of the contours is not the same. The important question is to know which points will compose each matrix in equation 2. An edge-tracing algorithm can be used to form a closed contour, to obtain the x_k and y_k coordinates or its representation for computational routines. The closed contour is a finite point's sequence, and its identification can be hard because the gray level smoothing in original image. In (YAO, 2005) it is presented a method for edge tracing that is based in the normal direction calculations concept, and in (MAHAMUD, 2003) is proposed a segmentation method based on saliency measure to solve multiple saliences' problem. But, in this work, the TC image does not present these problems because the edge identification it is doing on the binary image, and there are not gray level information nor contour problem identification as shown previously in figure 4.

It was used an edge-tracing process based on an algorithm to follow points in the closed border. It was different of a chain code process (GONZALEZ, 2002) or snakes (XU, 1998), because the mean idea is not the contour representation's, but the real pixel position on the skull edge. The algorithm is based on neighbor pixels directions. In each edge point found, the algorithm mark the point as located and continues looking for the next neighbor pixel. The figure 5 shows the masks with the directions was tracing.
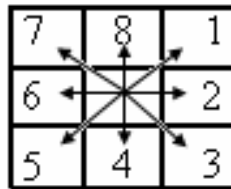

Figure 5 – Direction analysis mask.

The process starts on the direction 1, and when the first pixel was found, the algorithm analyzes the next pixels in each direction, $d = 1,...,8$. If the pixel edge was found in position d, it was marked (change binary code 1 to 0) and it can not found more. The direction $d=1$, is always in the diagonal, because the algorithm begins the search in this direction (It is the edge direction). The algorithm finish when the point located is the same of the initial point. In figure 6 shows the results of this procedure.

(a) Identification of external border   (b) Identification of internal edge after external border previously removed
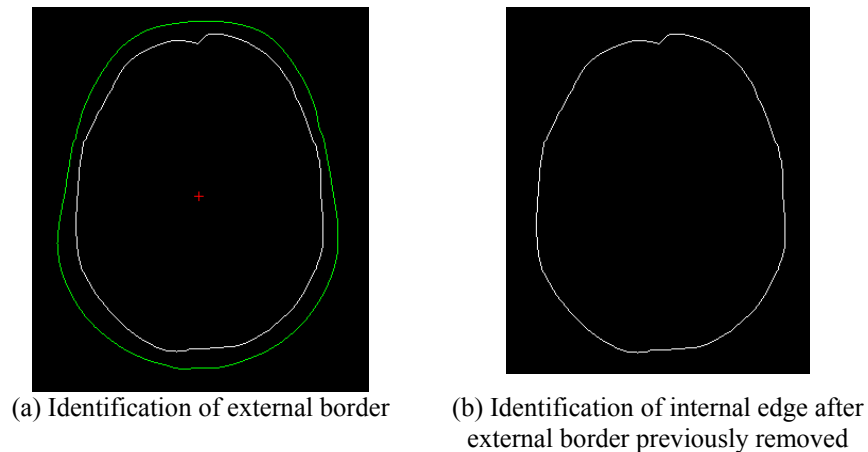
Figure 6 – Identification borders (external and internal).

In Figure 6.a, it is presented the external border identification. The first point is located on the diagonal line of image that intercepts the edge. Form this point, all edge points are located and marked in image. The points are saved in a B_E matrix (equation 2). After only the internal edge exists. The same procedure is used to form the B_I matrix. The figure 7, shows the matrices points plot. This slice contains the (x,y) Cartesian coordinates of each point on the edge.
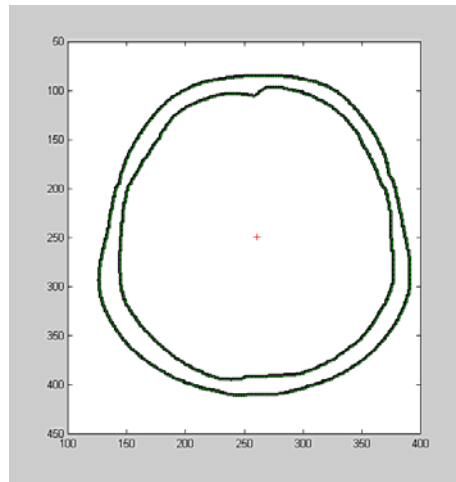
Figure 7 – Edge points plot.

5. A METHODOLOGY APPLICATION – A CASE STUDY

In order to test the methodology, the authors have limited the tomographics cuts from cut number 110 until number 149, that is, the initial height in the "Z" axis correspond 110 millimetres. The methodology steps application for imaging segmentation to create human prosthesis in a CAD system are: i) skull preparation; ii) tomography images in the DICOM format acquisition; iii) Converting from DICOM images format to JPG format; iv) generating profiles in the DXF format; v) generating of cloud of points; vi) export the cloud of points to a CAD system; vii) modelling 3D model in the CAD system.

a) Skull preparation: The skull was fixed to acrylic support, guaranteeing in this way, that the skull always use the same references between tomography cuts. The support is transparent to avoid influence in the tomography image. The skull and support were depicted in figure 8a;

b) Tomography images in the DICOM format acquisition: The obtainment of DICOM images were made through of DicomWorks 1.3.5 freeware software (DICOMWORKS, 2004), as it is illustrated in figure 8b;

c) Converting from DICOM images format to JPG format: This conversion was made through the same freeware software DicomWorks 1.3.5 and an example of this cut is showed in figure 8c;

d) Generating profiles in the DXF format: Now, through the Vextractor 2.95 software the profiles created in JPG format were converted to the DXF format. In this step an analysis is made to solve and take out the imperfections (small open areas), privileging only the borders, as in the figure 8d;

e) Generating of cloud of points: A computer routine in Visual Lisp was created in order to obtain the co-ordinates (starting and final) of the profiles for the preparation of the image and the cloud of points acquisition. The algorithm developed for the co-ordinates acquisition divides the DXF image into two borders: external and internal. To the data transference A DATA file was used, as illustrated in figure 8e. This file has the whole cloud of points (Cartesian Mapping) of the borders based in the reference axes;

f) Exporting the cloud of points to a CAD system: The acquisition routine of the cloud organizes the DATA file according to a standard format, required by the Unigraphics NX3 system, where the three dimensional model will be automatically build. The file formatting requires the division of the cloud of points into three distinct columns. The first correspond to the Cartesian axis x, the second to the y axis and the last one to the z axis;

g) Modelling 3D model in the CAD system: From this files of points, parallel planes can be constructed in the Uigraphics NX3, inserting curves by poles. This application is showed in the figure 8f. To transform the present curves in parallel planes it was used the Through Curves command, but firstly some adjusts had to be made in the curves, in order to correct the conversion mistakes.
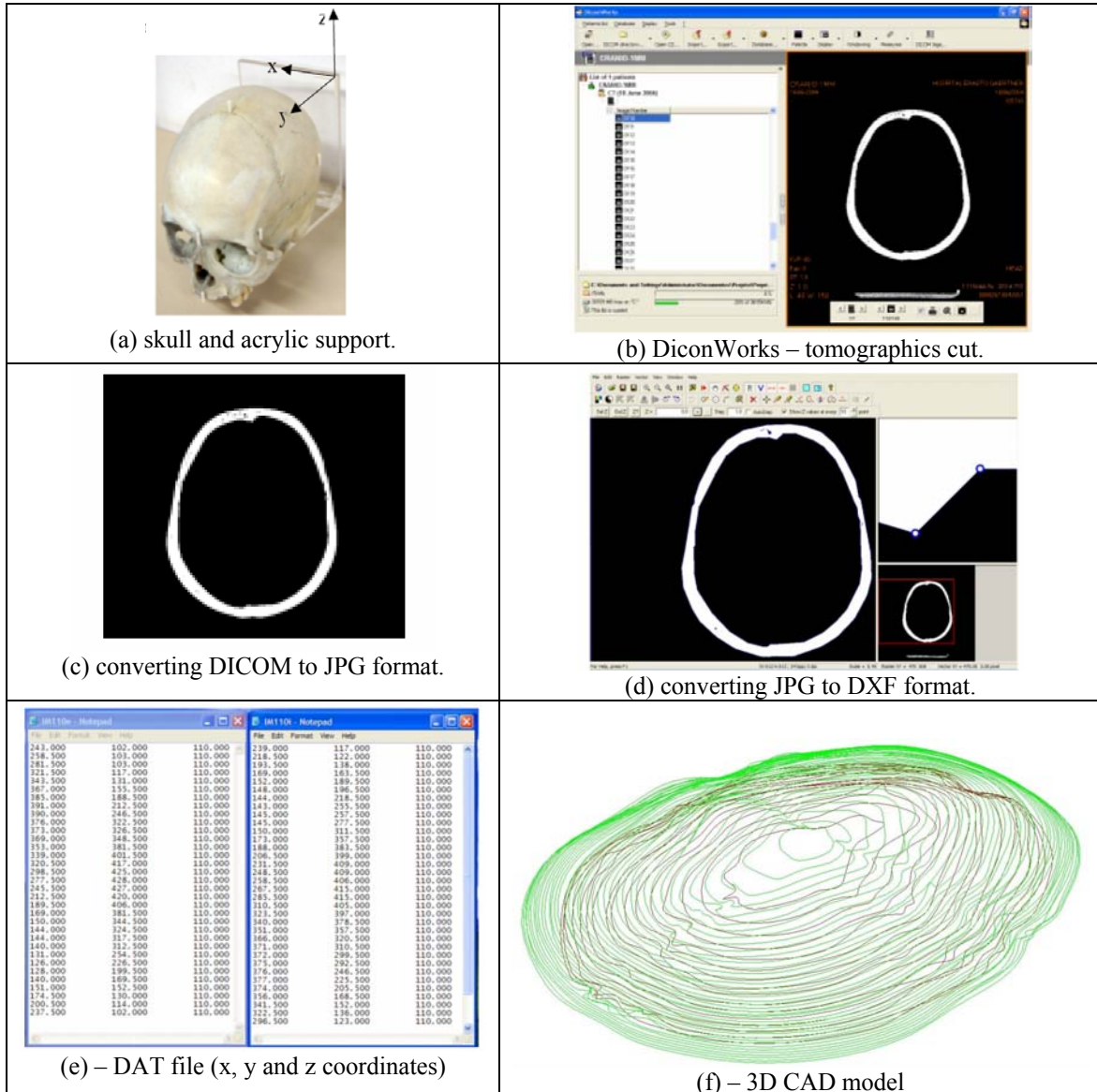
(a) skull and acrylic support.	(b) DiconWorks – tomographics cut.
(c) converting DICOM to JPG format.	(d) converting JPG to DXF format.
(e) – DAT file (x, y and z coordinates)	(f) – 3D CAD model

Figure 8 – Image Segmentation for creating human prosthesis in the CAD System

6. DISCUSSION AND CONCLUSION

The methodology developed in this research can be discussed focusing on aspects for the conversion from the tomography to the three dimensional CAD. In the conversion from the tomography to the three dimensional model was presented an exploratory study that needs new experimentations in order to quantify the dimensional deviation found in each border to evaluate the several techniques used in the image conversion, moreover the necessity to increase the translation of the borders in the way to avoid the resulting intersections that make more difficult the three dimensional reconstruction process in the CAD. In the future the research will regard to the virtual machining, the complexity of the human bones geometry to be used can present some difficulties, therefore, new approaches as the milling process in 5 axes that should be refined in the acquirement of the whole prosthesis model machining process.

The research showed that through the proposed methodology it is possible convert the tomography images of the DICOM pattern in to a geometry in the CAD. It was developed using the graphic environment of the UNIGRAPHICS NX3 software. The generation of the "splines" or "poly lines" from the conversion need to be adjusted to avoid mistakes in the three dimensional modelling. Through the function "through curves" it was possible generate the solids automatically. These solids and the Bolean operations allowed the final geometry in the CAD.

Inside the Unigraphics environment NX3 will be possible to realize virtually the machining since it has the integrated CAD and CAM systems.

Through this methodology new researches are recommended: i) a more accurate study about the conversion from images to the CAD profiles (splines); ii) a study to optimize the time and method of the model machining; and iii) in order to expand the proposed methodology , and its validation, a model with relative complexity should be used.

7. ACKNOWLEDGEMENTS

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9. RESPONSIBILITY NOTICE

The authors, Osíris Canciglieri Junior, Marcelo Rudek and Tiago Francesconi are the only responsible for the printed material included in this paper.