

AUTOMATIC RECONSTRUCTION OF 3D CAD MODELS FROM TOMOGRAPHIC SLICES VIA RAPID PROTOTYPING TECHNOLOGY

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ABSTRACT

This paper presents few notes about the reconstruction of a 3D model of fibula bone using tomographic slices from CT scanner. CT images are reassembled to illustrate a 3D presentation of an anatomic structure by using a 3D reconstruction software, Mimics. Mimics is a software system for interfacing from a medical or technical scanner (mostly a CAT or CT scanner but also MRI) to Rapid Prototyping or CAD systems.

Keywords: fibula bone, 3D reconstruction, rapid prototyping.

1. MEDICAL MODELLING PROCESS

In medical imaging, the two most common systems used in acquiring detailed anatomical information are Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). Other systems used include Ultrasound System, Mammography and X-ray. The key feature of these imaging technologies is their ability to provide detailed information about the anatomical structure and abnormalities. [3]

During the scanning process, the patient is stepped through the measurement plane 1-3 mm at a time. The information from each plane can be put together to provide a volumetric image of the structure as well as the size and location of anatomical structures. The scanned model becomes a virtual volume that resides in a computer, representing the real volumes of the patient's bone. When a series of CT images is reassembled to illustrate a 3D presentation of an anatomic structure, the medical practitioner or prosthetic designer can use this information directly and the overall shape of body structures is more clearly understood or visualized.

However, visualization requires good visualization software and so a number of dedicated software packages have been developed to enhance the visualization of such 3D computer models and enable the surgeon to grasp the particular details of individual cases. Some of these software packages include Analyze biomedical image processing package, Surgicad Template from Surgicad Corp., Intergraph Corp. and Mimics from Materialise Software Company.[3]

2. 3D RECONSTRUCTION OF HUMAN ANKLE

The proposed solution is based on a method which combine the image processing techniques and 3D computer graphics. For these techniques it has been used a 3D reconstruction software (MIMICS) [1]. Mimics is a software suite that performs the segmentation of the anatomy through sophisticated three-dimensional selection and editing tools. Also this software can be used as an interface between CT scan and Rapid Prototyping installation or a CAD software. The method adopted for visualization is the conversion of 2D image slice data, as grey value images. The resolution can vary from 0.2 to 1 mm. The program also generates high-resolution 3D renderings in different colours directly from the slice information, as shown in figure 1. Contrast enhancement can be carried out interactively to improve the model. The segmentation mask can be displayed in a different colour on top of the image. The steps to obtain the human ankle 3D model are:

1. Import of all processor data which are represented by 2D tomographic slice (figure 1). The number of 2D slices are 72 and the height of each one is one millimetre. These 2D slices belong to a person with

a weight of 70 kg. As it can see in the picture below, the bright colour zone appertain to the bone tissue whom it can be attribute a colour mask to be differentiated by the soft tissue [1].

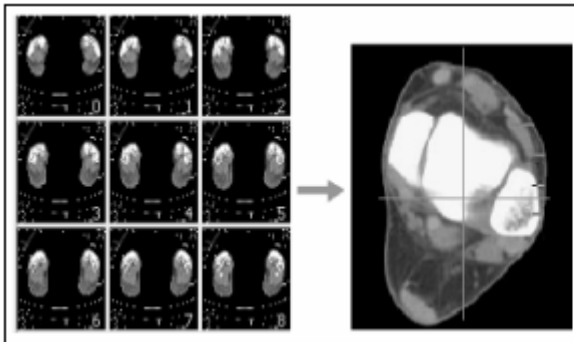


Figure 1. The input source represented by 2D tomographic slices.

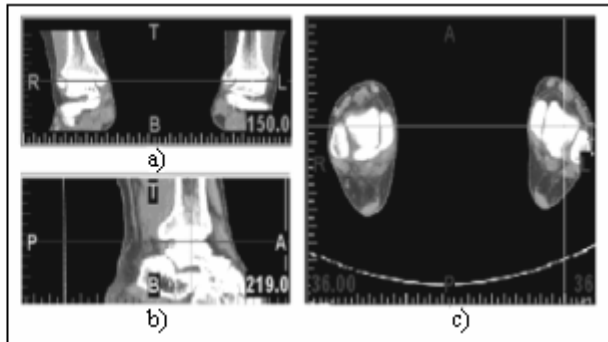


Figure 2. Work planes: a) frontal plane; b) sagittal plane; c) transversal plane.

2. The second step is to establish the work planes. All images are loaded and displayed in three views. The view on the right shows the images as they are exported by the scanner (X-Y-view or axial view) (figure 2.c). The upper left corner is a reslice of these images in the xz-direction (X-Z-view or coronal view) (figure 2.a) and the bottom left is a reslice in the yz-direction (Y-Z-view or sagittal view) (figure 2.b). The different colours of the intersecting lines (dashed lines) refer to the colours of the contour lines of each view so every line refers to the slice in the corresponding view [1].
3. Thresholding means that the segmentation object (visualized by a coloured mask) will contain only those pixels of the image with a value higher than or equal to the threshold value. Sometimes an upper and a lower threshold are needed, the segmentation mask contains all pixels between these two values. A low threshold value makes it possible to select the soft tissue of the scanned patient. With a high threshold, only the very dense parts remain selected. Using both an upper and a lower threshold is needed when the nerve channel needs to be selected. Defining a good threshold value also depends on the purpose of the model. The detection of bone tissue can be obtained by using the optimal grey value, established between minimum value of 2080 and maximum value of 3056 Hounstfield units [1].
4. The 3D representation of the ankle articulation and fibular bone.

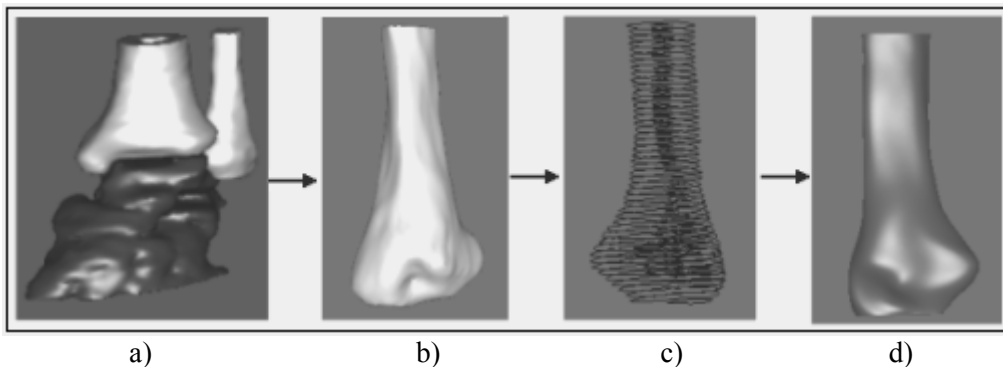


Figure 3. The steps required to obtain the IGES format of the model: a) ankle joint model; b) fibula model; c) model formed from polylines; d) IGES model.

The virtual model of fibula can be exported as IGES file to the CAD software where a fibular implant will be designed. This implant is used to fix the fibular fracture.

The IGES model is described by a surface witch “wraps” and copy with fidelity all the irregular parts of the natural bone and it is taken as reference model for ulterior design of the fibular implant by CAD software (ProEngineering).

To obtain an IGES format of the anatomical part takes three stages:

1. Determination of polylines resulting the outer contour of the bone (figure 3. c),

2. Verification and patching of contours determined by polylines. The analysis can be affected by the influence of artifacts. The artifacts are some erroneous signals received during scanning time and they are produced by the metal implants which are already in the human body.
3. Obtaining of the IGES model (figure 3. d) [1].

3. DESIGN OF MEDICAL IMPLANT

The IGES model of the fibular bone can be exported in the same format to the CAD software (ProEngineering) with a view to design a medical implant. ProEngineering is a software package intended to design, analyze and fabricate by using the computer. The modules which compound the ProEngineering package permit the construction of geometrical models, the definition of complex ensembles, the generation of technical documentation of projects, etc.

The fundamental concept used by the ProEngineering package is the graphical block of construction (feature). The construction of fibular implant starts by defining a base graphical block (base feature). This graphical block is the base for the next steps used to construct the rest of the model. The graphical blocks introduced ulterior depend of base graphical block by references.

The final model of the fibular implant (figure 4) is obtained by using some complex operations like: extrude, sweep, revolve, blend, cut, slot, etc. Another important characteristic of CAD software is the parametrisations of implant. This means that the form and the structure of model can be established and modified every moment. Every modification of these attributes (known as parameters) immediately is reflected in the geometrical model [1].

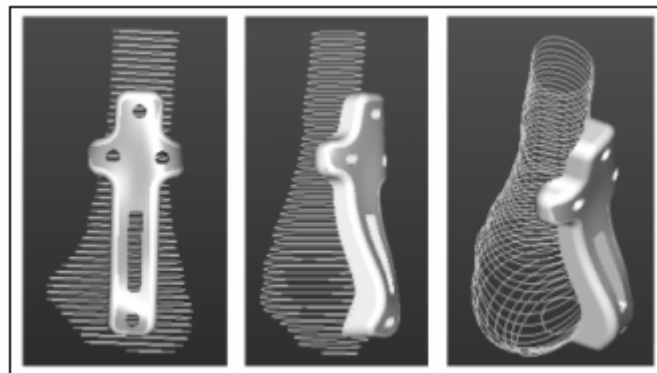


Figure 4. Fibula implant model obtained by using ProEngineering software.

4. RAPID PROTOTYPING TECHNOLOGY USED FOR MEDICAL IMPLANT

Rapid Prototyping (RP) is a relatively new technique that was invented over a decade ago to rapidly produce solid 3-D objects of complex shapes directly from CAD files. RP constructs solid physical models from 3D computer data by the addition of layers of material. These techniques provide ways for making a variety of complex shaped parts which are difficult, costly or sometimes impossible to make by conventional methods of material removal. [2][4][5]

The selection of a particular process will depend on the medical model application. Some of the most commonly available systems are: Fused Deposition Modelling (FDM), Stereolithography, Selective Laser Sintering (SLS), Sanders Prototyping Technology and Z Corporation Fabrication Machine. All these systems employ the same basic five-step process. The steps are:

- create a CAD model of the design,
- convert the CAD model to STL format,
- slice the STL file into thin cross-sectional layers,
- construct the model one layer atop another,
- clean and finish the model.

First, the medical implant to be built is modeled using a Computer-Aided Design (CAD) software package, such as ProEngineering.

The next step is to convert the CAD file into STL format (figure 5) by using again the Mimics package. This format represents a three-dimensional surface as an assembly of planar triangles, “like the facets of a cut jewel”. The file contains the coordinates of the vertices and the direction of the

outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger file size. Since the .stl format is universal, this process is identical for all of the RP build techniques. [4][5]

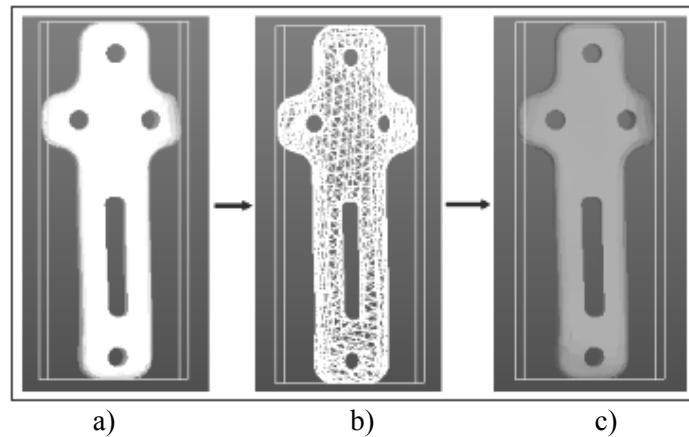


Figure 5. The conversion process of the CAD file into STL format: a) the model made by using ProEngineering software; b) the STL model; c) the final model which has to be made by one of the Rapid Prototyping systems.

In the third step, the pre-processing module of Mimics software prepares the STL file to be built and most allow the user to adjust the size, location and orientation of the model. The software may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin-walled sections.

The fourth step is the actual construction of the implant. Using one of several systems mentioned above, rapid prototyping machines build one layer at a time from polymers, paper, or powdered metal. The final step is post-processing. This involves removing the prototype from the machine and detaching any supports. Depending on the intended use of the model it can act as either a master pattern for the purposes of rubber moulding, or can be sterilized for assistance in operating theatre. [4]

5. CONCLUSIONS

Realistically, Rapid Prototyping (RP) technology can make significant impact in the field of biomedical engineering and surgery. The reliability and the accuracy of an RP model in surgical application allow surgeons to rehearse the re-alignment of bones or fitting of implants on the RP models prior to operating the patient, to evaluate and gain confidence in, the planned approach. Surgical procedures continue to be more effective day by day with reduced risk and expense to both the patient and the hospital.

6. REFERENCES

- [1] C. Radu: Improvements Apported to the Biomechanical Systems Modeling, Second Report of the PhD. Thesis: Improvements Apported to the Prosthetic Elements by Rapid Prototyping, Brasov, April 2005.
- [2] Juster, N.P.: A comparison of Rapid Prototyping Processes, Proceeding of the 6th European Conference of Rapid Prototyping and Manufacturing, Nottingham, Great Britain, 1997.
- [3] K. L. Chelule, Dr. T. Coole and D.G. Cheshire: Fabrication of Medical Models from Scan Data via Rapid Prototyping Techniques, Faculty of Technology, Buckinghamshire University.
- [4] Klosterman, D., R. Chartoff, N. Osborne, G. Graves, A. Lightman, G. Han, A. Bezeredi, S. Rodriguez: Direct Fabrication of Ceramics and CMCs by Rapid Prototyping,, American Ceramic Society Bulletin, Vol. 77, Nr.10, October, 1998.
- [5] Petru B., Mircea A., Cristian C.: Fabricarea Rapidă a Prototipurilor, Editura Tehnică, Romania, București 2000.