3D ENGINEERING APPLICATIONS FOR HUMAN SKELETON TAILORED IMPLANTS BUILD ON SELECTIVE LASER SINTERING SYSTEMS

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Abstract. *MIMICS come from: Materialise Interactive Medical Image Control System (is an image-processing package that interfaces between 2D image data (CT, MRI, Technical scanner,...) and 3D engineering applications. Applications include: anatomical measurements, 3D analysis, Finite Element Analysis (FEA), patient-specific implant or device design, additive manufacturing (also called rapid prototyping or 3D printing) and surgical planning or simulation. By using image segmentation in Mimics, users can select a specific region of interest from the collected medical data and have the results calculated into an accurate 3D surface model. Additional modules are available for Mimics that provide an interface with different applications. This means that Mimics can easily be adapted to the needs of users.*

Keywords: 3D reconstruction, DICOM, STL, 3D analysis

1. INTRODUCTION

The principal request for an 3D image processing software is the segmentation of an image which finally can classifies voxels into objects. Tridimensional image segmentation assure the possibility to create 3D rendering for multiple objects. Also, it can execute quantitative analysis for the: size, density and other parameters of detected objects.

An unprocessed tridimensional data image, whether it is CT, MRI or microscopy image, comes as a 3D array of voxels or pixels. Imaging systems generates images by using 16-bit grayscale setting. A tridimensional image has a large number of pixels and is very compute intensive for processing such as segmentation and pattern recognition. On the other hand, a segmented image provides a much simpler description of objects. Thus, it allows the creation of 3D surface models or display of volume data.

While the raw image can be readily displayed as 2-D slices, 3-D analysis and visualization requires explicitly defined object boundaries, especially when creating 3D surface models. For example, to create a 3-D rendering of a human brain from a MRI image, the brain needs to be identified first within the image and then its boundary marked and used for 3D rendering. The pixel detection process is called image segmentation, which identifies the attributes of pixels and defines the boundaries for pixels that belong to same group. Additionally, measurements and quantitative analysis for parameters such as area, perimeter, volume and length, can be obtained easily when object boundaries are defined.

Because of the importance of identifying objects from an image, there have been extensive research efforts on image segmentation for the past decades. A number of image segmentation methods have been developed using fully automatic or semi-automatic approaches for medical imaging and other applications.

Computed tomography (CT) is an imaging technique. It uses complex x-ray hardware in order to generate cross-sectional images of the human body. A CT image has different pixel intensity for tissues such as: bones, soft tissues and other tissues. The threshold-based "Interactive Segmentation" assures an convenient way to visualize a CT image for tridimensional representations. [1]
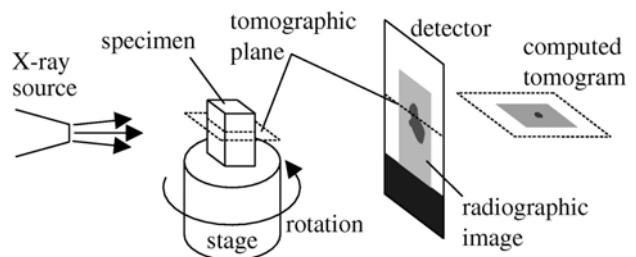

Fig. 1. Simple representation of CT scanner; composition of the the slices on pixels/voxels basis

A tridimensional meshed virtualization can be performed from computed tomography files in three major sequences:

1st. sequence: Open the DICOM file(s). The image could come as many files in directory so you can use the New Stack menu.

2nd. sequence. Use the Interactive Segmentatio in order to regenerate the regions of interests and borders. For reduced soft tissues, there is the option to use manual method instead of auto-generation.

3rd. sequence. Creation of tridimensional meshed objects by rendering them with specific menu. The objects can be saved as STL (standard tesselation library), as well as many other tridimensional CAD formats.
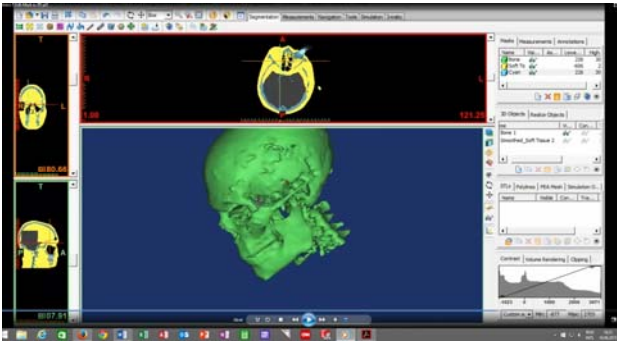
Fig. 2. Image print-screen of 3D software for DICOM based reconstruction

2. IMAGE CLARITY – IMPACT ON SEGMENTATION CT

Exposure to X-rays should be avoided if objects with a high and low density need to be scanned together. This is because the high density objects will tend to obscure those with lower density. Use of stronger radiation level can sometimes solve this artefact phenomenon. However, this is not always possible. For radiation doses for living patients must be kept below dangerous or lethal levels. Note that these obscuring phenomena, also called "metal artefacts" (because they often appear when scanning metallic objects at the same time as organic subjects) do not distort the geometry of the parts that are visible; they merely "hide" information.

CT images are formed by a wide range of pixels of the linear X-ray attenuation coefficient of tissue. The pixel values are arranged on a scale: the linear X-ray attenuation coefficient of air is -1024 and that of water is zero. The scale was named the Hounsfield scale, in honour of Sir Godfrey Hounsfield, one of the pioneers in computerized tomography. Using this scale, fat is around -110, muscle is around 40, trabecular bone have values of 100 to 300 and cortical bone reach values of 2000.
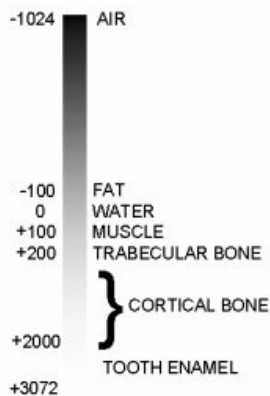

Fig. 3. CT Gray scale

The values for various pixels are graphically shown by a set of gray intensity that range from black to white. MIMICS software cand display the computed tomography DICOM files using 256, 128 or 32 gray levels, differing for display settings. The values for pixels are clearly specified as is seen in Figure 3. You can clearly trace the types of tissues by the variation of the gray intensity. The software can perform this task very accurate and in real-time.

For example, the zero value specifies that water will be shown as mid-gray. The initial gray scale used by MIMICS software gave the possibillity to see the entire range of tissue from air in the maxillary sinus to the cortical bone.

There are a lot of settings in the software paramateres that allow an better imaging for the portion of bodt that will be investigated. If one adapt the gray scale, there can be obtain an better visualization of the small differences in the soft tissue or soft bone tissues, but with the price of pushin the cortical bone to be in white level. Setting up the gray scale could help in many different cases that requires various approaches for better visualization of different types of tissues.

CT is ideally suited to scanning different objects when they can be distinguished via their absorption coefficient (amount of X-ray absorbed by the object). Very simple threshold based tools can then be used to identify them in the CT image.

It is, however, not efficient at distinguishing between different soft tissues. [2]

In terms of image quality, metallic objects will usually not influence the generated image, but magnetic objects (such as some teeth implants) can distort the image.

The magnets may damage electronic components such as pacemakers.

"Loose" metallic objects should not be carried into the room where a MRI scanner is used since the magnets can make them fly across the room. However, and this has to be checked with the technician running the MRI scanner, internal metallic objects such as hip implants do not in general lead to any problems.

MRI is ideal for visually distinguishing soft tissues, but objects MUST contain hydrogen molecules (e.g. water). However it is possible to get around this problem and scan "dry" objects made of plastic, for example, by immersing them in jelly. The negative of the object is then visible in the MRI data.

Fig. 4. MRI scan taken along the neck

Segmentation can be threshold based in some cases. Unfortunately it is quite common for different objects to be easily distinguishable visually, by texture, but not by grey level. In these cases some level of manual segmentation may be required.

MRI images often suffer from signal attenuation and/or noise on the borders of the region of interest. [2]

3. FROM 2D AND RAW DATA TO 3D PARAMETRIC MODELS

Because of the recent trends and developments of the 3D imaging software, specialists became able to create physical models of an patient area of surgery.

For example, to protect patient from further radiation, an model of the spine can be created and used many times for imaging the real bones anatomy.
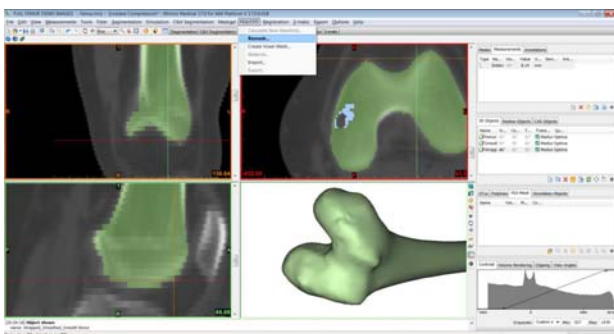

Fig. 5. The image segmentation in order to draw the boundaries of the region of interest of DICOM files

The developments of the 3D imaging technologies in the past years have been focusing on the specific targets: to let the physicians and surgeons to visualize better inside the human body, but also to allow the creation of physical models from DICOM data, CT (Computed Tomography) and MRI (Magnetic Resonance Imaging). A surgeon is capable to perform a "preview surgery following this model prior to ever conduct the real

operation. Thus, a lot of surgeons acknowledge that minutes of operating time can be saved through these techniques that allow better preparation of the surgery.[3]
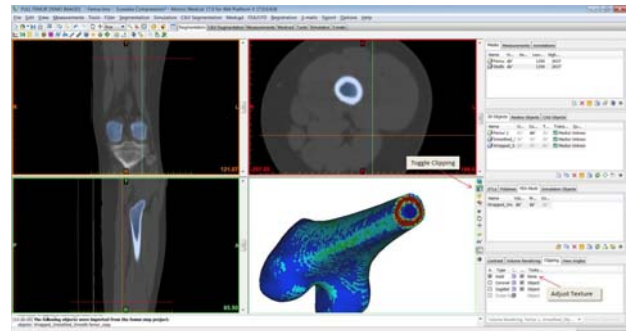

Fig. 6. The algorithm for vector-based surface rendering, assure an 3D model very accurate
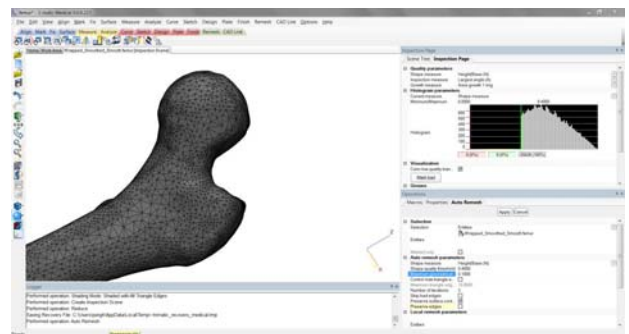
4. THE PHYSICAL MODEL MANUFACTURING

Fig. 7. Parametric model in 3D CAD – 3matic

The CAD models for surgery, are virtual model of parts of the human body that can be used to study the surgery area before the real operation really begin. This is very important in case of patients where functionality of the locomotor apparatus must be established by surgery. There are used a lot of FEA methods in order to calculate required mechanical and physical/biological properties of the implant, the virtual models have been used to verify the surgical procedures, such as: vectors of implantation, required pre-operative treatments and preparations and other procedures.

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