MODELLING OF PROSTHETIC HIP JOINT GENERATED FROM CT SCAN DATA

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ABSTRACT

Total hip arthroplasty is a surgical procedure in which the arthritic or dysfunctional hip joint is replaced entirely by an artificial implant called prosthesis. A device that replaces a natural deceased hip joint is called Prosthesis. Prosthesis is a modular partial hip replacement used for management of intra-capsular neck femur fractures. The aim of this project is to do Modeling and Finite Element Analysis of a prosthetic hip joint generated from CT scan data. A 3D CAD model of original hip femur was generated from the CT scan data of a patient using materialize software MIMICS. Geometry of Prosthetic Hip Femur ware calculated from the original femur using materialize software Magics. Geometry of prosthetic femur was created using CAD software ProE WF5.
Keywords: Arthroplasty, Prosthesis, Finite Element Analysis, Prosthetic Femur, CT Scan.

I. INTRODUCTION

Diagnostic imaging devices such as computer Tomography and Magnetic resonance imaging are able to produce anatomical description of various features such as tissues and organs. These scan image distinguish bone tissue and soft tissue with different intensity in a computer. Doctor uses CT scan or MRI to know the exact cause and the region of the affected portion for the patient. The CT scan images or MRI are stored in the DICOM form which cannot be easily decoded to visualize the actual image without the proper hardware which is normally associated with the scanner. The cost of such system is not affordable by many doctor therefore, medical practitioner faces difficulty in explaining these images to the common people. Medical practitioners also require their skill and experience to understand these images. Therefore it is needed to visualize these images in the proper form so that it can be helpful for the medical practitioner as well as common people to understand the anatomical structure or the abnormalities associated with the patient at important parts of the human body like knee joint, mandible and hip joint.

II. PROBLEM DEFINITION

This project aims to do Modeling of the prosthetic hip joint generated from the CT scan data.

III. RESEARCH METHODOLOGY

The following research methodology is adopted for solving the problem describe earlier

1. Collection of CT scan data
2. Developing the 3D CAD models in Mimics and Converting 3D CAD model in to STL file
3. Determining the geometry of the prosthetic hip from the calculated 3D model using magics software
4. Modeling of prosthetic hip joint in Pro/E WF5

1. Collection of CT scan data

The CT scan of patient is very important step and from where we are get the 2D DICOM images. CT scan data of hip joint was collected from MedAll, MGM, Warangal.

Following parameters of CT/MRI images directly influences the accuracy of the 3-D CAD model

    Slice thickness and slice interval.
    Threshold value
    Resolution
    Gantry tilt

2. Creating 3D cad model

For reconstructing the primary 3D anthropometrical model (bone structure and encapsulated soft tissues), the DICOM images obtained by CT/MRI are converted into 3D CAD Model by using any imaging density segmentation software. viz. MIMICS .

In this project to create 3D CAD anthropometrical models (bone structure and encapsulated soft tissues) MIMICS is used. The 3D visualization, segmentation, 3D rendering of objects of 2D DICOM images obtained by CT/MRI are done by importing 2D DICOM images in MIMICS software which interfaces with all common scanner formats. MIMICS software includes Segmentation, Simulation, Medcad, FEA, Import/Export modules.

MIMICS software can be used for diagnostic, preoperative planning of surgery or surgery rehearsal, reconstruction of custom made implants purposes. A very flexible interface to rapid prototyping processes. The MIMICS software allows the automatic importation of the slice images generated in the CT scan.
The pixel size and the slice distance guarantees the coherent dimensional reproducibility of the models generated during the segmentation process. The steps to be followed in Mimics software for generation of 3D CAD model of hip joint is:

a. Opening the project
b. Organizing images
c. Thresholding
d. Region growing
e. Creating 3D representation
f. Calculation of polylines
g. Patching and Contours

The import modules allows you to convert images from a variety of scanners to the Mimics file format. Importing DICOM (Digital Imaging and Communications in Medicine), the different phases accomplished in the 3D reconstruction using density segmentation techniques with the MIMICS 9.1 software are presented in the below steps.
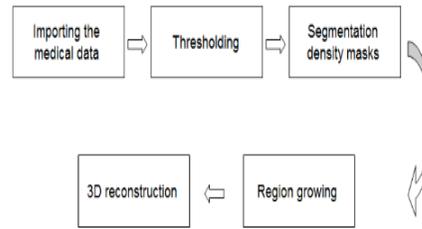

Fig.1: *MIMICS process drawing of building 3D model from CT scan images*

a. Opening the Project and importing DICOM images:
The import module allows importing 2D stacked uncompressed medical images from CT in a variety of formats such as the frequently used .DICOM file format. In this module it is possible to specify the appropriate slices that comprise the considered object.
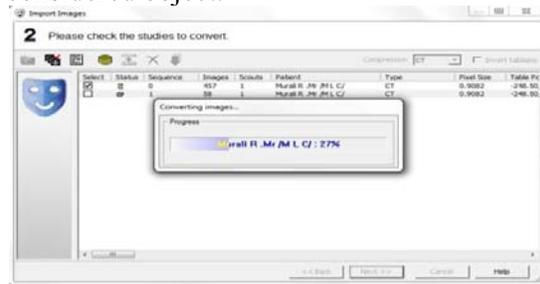

Fig 2: *Conversion of DICOM files to MIMICS file*

b. Organizing images:
It is possible to exclude some images if they are not good or if don't need all of them.

Fig 3: *Organize images*

c. Thresholding:
Thresholding means that the segmentation object (visualized by a colored 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.

Fig 4: *Thresholding window*

d. Region growing:

The region growing tool makes it possible to split the segmentation created by thresholding into several objects and to remove floating pixels.
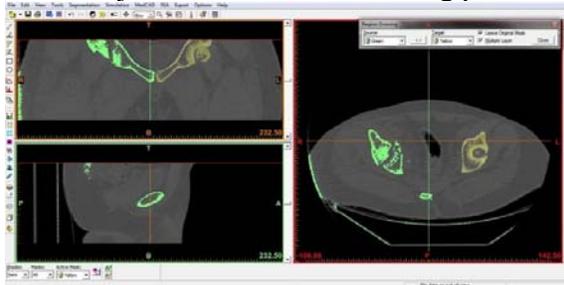

Fig 5: *Region Growing*

e. Creating a 3D representation:

All created masks listed with their respective threshold in Project Management>Masks tab.

A 3D part is calculated by using the following command:

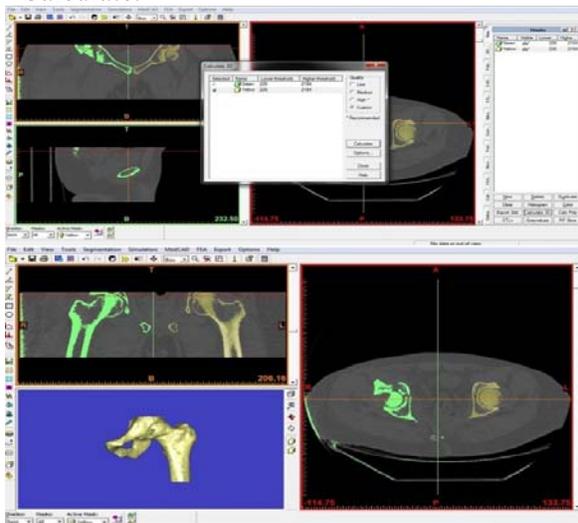Project Management>Mask Tab>Calculate 3D>Select Respective mask (Yellow) >Calculate.

Fig. 6: *Creating a 3D representation*

f. Calculation of the Polylines:

Polylines are calculated by using following command:
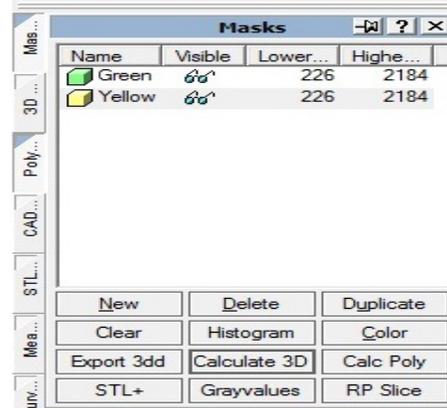
Project Management>Mask Tab>Calc Poly.

Fig 7: *Calculation of the Poly lines window*

g. Patching of contours:

Since the outer contours are the only region of interest, they need to be selected and are to be grown into new set of polylines. The polylines are created by eliminating unwanted region and by adding the useful region.
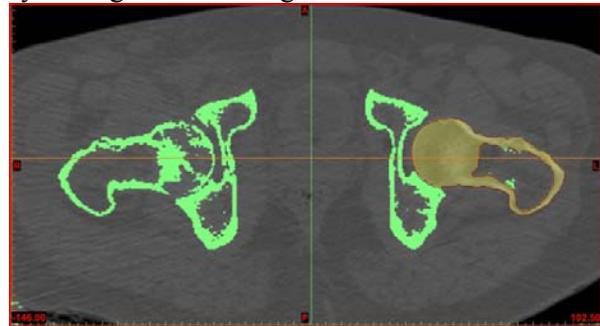

Fig 8: *Calculating the Polylines*

The final wireframe and 3D model of the hip joint created from the CT scan data is shown in the Fig. 5.11. And e*xport 3D file into .stl* format.
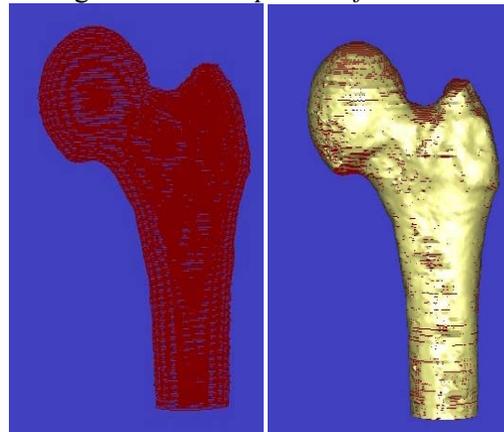

Fig 9: *Wireframe and 3D model of the hip*

3. *Determining the geometry of the prosthetic hip*

The inner diameter of the thigh bone can measured by using 3 point radius measuring tool at different heights.

The Distance between the Z-Axis and one point at the inner surface of the thigh bone is measured by 2 point distance measuring tool at different heights.
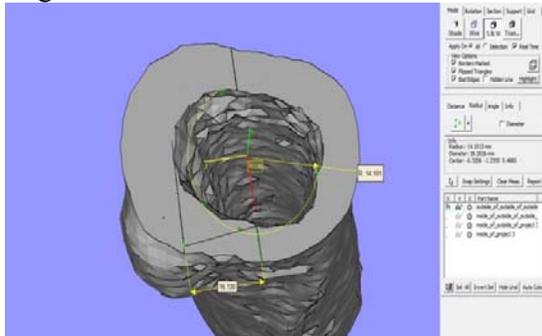

Fig 10: Measuring the inner diameter of the Thigh bone

Determining the Distance between centre of the circle to the Z-Axis:

Diameter of Circle = 2.8 cm (Approx)

Distance between Z-Axis and inner surface = 1.6 cm (Approx)

Distance between Centre of the circle to the Z-Axis = Radius of circle – distance

= 1.4 cm- 1.6 cm

= -0.2 cm

The two points at the inner surface of bone are (-1.4, 0) and (1.2, 0) mm

Similarly the distance between centre of the circle to the Z-Axis are determined at different heights. Table 1 shows the dimensions of the stem of the femur. Table 2 shows the dimensions of the femur head.

Table 1: Dimensions of the Femur stem

Point	X(mm)	Y(mm)
1	0.0	10.0
2	1.5	10.0
3	1.5	8.5
4	0.0	7.0
5	-3.0	3.5
6	-6.0	0.0
7	-7.0	0.0
8	-7.0	1.0
9	-4.5	3.5
10	-3.0	6.0
11	-1.5	8.0
12	-1.5	10.0

Table 2: dimensions of the Femur head

Point	X(cm)	Y(cm)
13	2.0	10.0
14	0.5	11.0
15	1.0	12.5
16	2.0	13.0
17	2.5	13.5
18	0.0	14.0
19	0.0	11.5

4. *Modeling of hip prosthesis using Pro-E*

Stem and head of the artificial hip femur is modeled by obtaining the dimensions from magics.

Tables 1 and 2 are shows the dimensions of the hip prosthesis.

Dimensions of the hip prosthesis:

Height of the stem: 10 cm

Thickness of the stem: 1 cm

Radius of the Head: 2 cm

Height of the head from the top of the stem: 4cm

2D geometry of the stem is created by using key points and 3-point/Tangent end tool. And it is extruded by 10mm to get 3D model. Fig. 6.19 shows the 2D Model of the stem.

Fig 11: Modeling of the stem

2D geometry of the head is created by using key points, line and 3-point/Tangent end tool. It is revolved with respect to y-axis to get 3D model. Fig. 6.20 shows the 2D Model of Head and Fig. 6.21shows the Final Model of the hip prosthesis
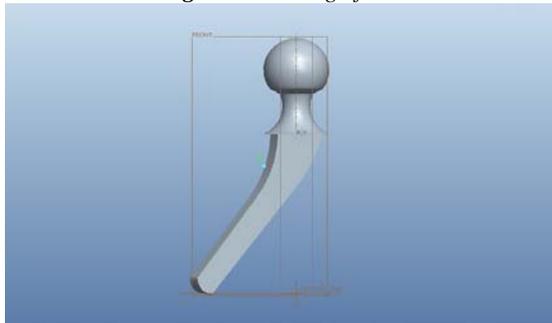
Fig 12: *Modeling of Head*

Fig 13: *Final Model of the hip prosthesis*

IV. CONCLUSIONS

This paper presented the Modeling of Prosthetic Hip Joint generated from the CT scan data which will be helpful for medical practitioner to understand the abnormalities associated with the patient.

Following are the conclusions drawn from the above work

   i. 3D CAD modeling of Biomedical (Anatomical) Structure using mimics was done.
  ii. Geometry of prosthetic hip joint was determined by using Magics.
 iii. 3D CAD model of the prosthetic hip joint was developed in ProE WF5.

V. REFERENCES

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