Developing 3D Finite element model of Head using Magnetic resonance imaging and algorithm developed in MATLAB

Dr Chandrashekhar Bendigeri[1], Sachin Patil[2]

[1] Associate Professor, Department of Mechanical Engineering UVCE, Bangalore
[2] ME, Department of Mechanical Engineering, UVCE, Bangalore

Abstract - Neurotrauma is the physical damage that results when the human skull and brain are suddenly or briefly subjected to intolerable levels of energy that is usually transmitted mechanically. Current trends suggest an increase in the number of survivors of neurotrauma throughout the world. This demands a new outlook giving high priority to establishing long-term goals in preventing, treating and rehabilitating people with an injury to the central nervous system. Multi-modal imaging has become increasingly important in medical research and clinical practices, particularly in skull fractures, therapeutic monitoring and brain functional imaging. The process of converting anatomical data from images to 3D models is called segmentation. In this research we would like to discuss various methods for developing 3D finite element model of human head from MRI scanned volumetric images. This information is then used to recreate a 3D model from the segmented structures.

Key words - Human head, MRI, Dicom, Medical imaging, Finite element model, MATLAB, Rapid prototype

1. INTRODUCTION

The initial step in developing 3 dimensional finite element model of the human head is to obtain some set of MRI scanned images of human head. After the Preprocessing of the image data, the set of images are imported to MATLAB and using suitable algorithm developed the 3Dimensional meshed finite element model can be obtained.

In the medical field, for any case of skull or head fractures, the custom implants are being developed from various materials. Reviewing of the implants developed can be made easy to the doctors efficiently by creating the rapid prototype model of the generated model from the MATLAB. The important parameters which affect the FEM model of the human head is mesh method and mesh quality. The difficulty in generation of model directly from grey scale Images can be eliminated through developed algorithms. Under segmentation there are three tools in the main tool bar: Thresholding, Region growing and Calculate 3D.Several operations need to be performed during model generation of MRI scanned human skull [2]. Some of those are noise reduction, filling holes in image, contrast modification and edge detection .After completion of Surface or volumetric geometry extraction from 3D voxel image, further the model need to be meshed properly. This paper presents methodology of developing 3Dimensional finite element model of human head from MRI scanned set of images. There are various steps involved in generation of the finite element model of human head which include, preprocessing of Dicom images, importing of images and finally surface mesh generation. Below methodologies discuss all the steps involved in developing the rapid prototype of the human head.

2. METHODOLOGY

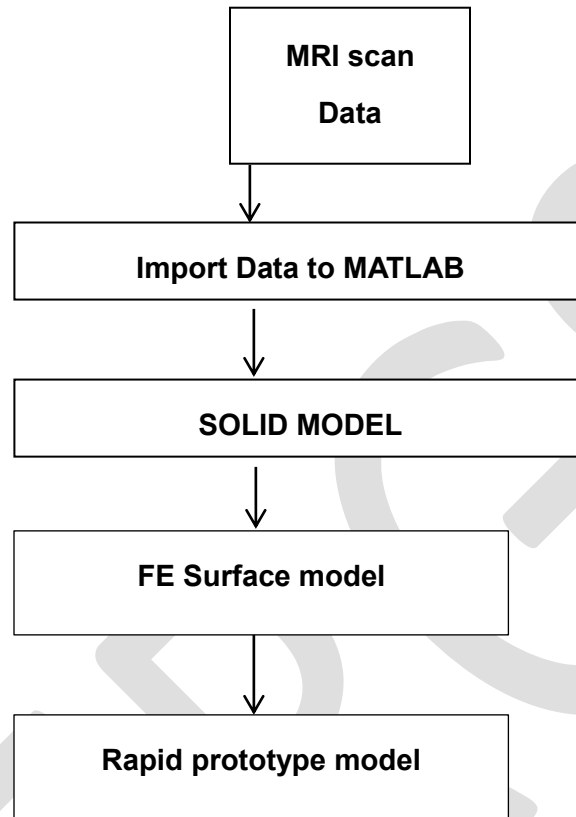The steps involved in generating 3D finite element modeling of human head are as follows,

```
┌─────────────┐
│  MRI scan   │
│   Data      │
└─────────────┘
       │
       ▼
┌──────────────────────┐
│ Import Data to MATLAB│
└──────────────────────┘
       │
       ▼
┌──────────────────────┐
│    SOLID MODEL       │
└──────────────────────┘
       │
       ▼
┌──────────────────────┐
│   FE Surface model   │
└──────────────────────┘
       │
       ▼
┌──────────────────────┐
│ Rapid prototype model│
└──────────────────────┘
```

Figure 2.1: Steps of finite element modeling from MRI data in MATLAB

2..1   MAGNETIC RESONANCE IMAGING(MRI) METHOD

The image acquisition done in MRI (Magnetic resonance imaging) scan result in a series of 2D images displaying a density map of the sample, stacking these images creates a 3D representation of the scanned area. In this method the set of images obtained will be in Digital Imaging and Communications in Medicine (DICOM) format. Raw data from MRI Scanner were transferred to a computer and later processed. DICOM format images of the MRI Scan are effectively viewed in MATLAB if they are converted into specific image formats like JPEG, TIFF, and PNG and so on. So the DICOM format of Skull needs to be converted to these formats to as these can't be viewed in computer [3]. In order to convert DICOM images to desirable formats like tiff, software named DICOM converter can be used [4].
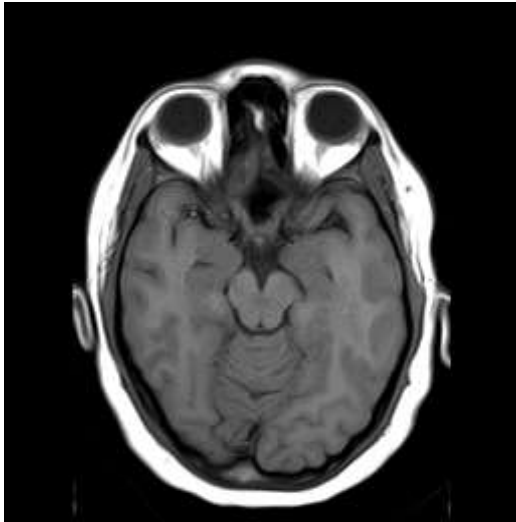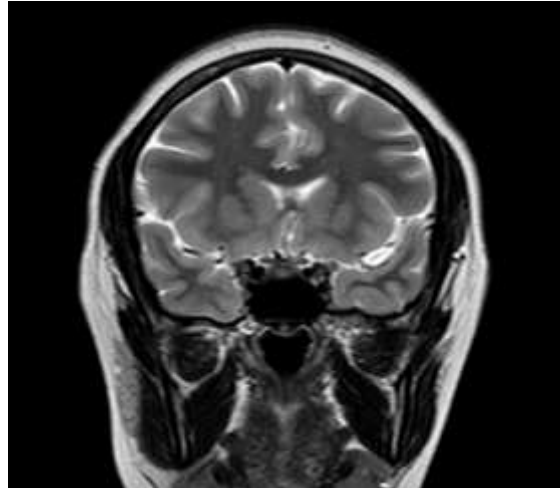
Fig 2.2 Axial sliced section of MRI scan data

Fig 2.3 Coronal sectional view of MRI scan data

2.2 IMPORT MRI DATA TO MATLAB

In this process the set of MRI images converted into tiff format are imported to MATLAB in stack. After importing the images, several processes like repairing the images, cleaning of the images, noise filter reduction are being performed. 3D binary images of the MRI can be denoted by 0 or 1. These files can be used as input for the MATLAB [7].

2.3 GENERATION OF SURFACE MESH

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The Delaunay triangulation mesh can be generated from a proper algorithm. One such algorithm for tetrahedral mesh generation using Delaunay refinement can be derived from cgal 4.8 3D mesh generation [11]. This tool box can be installed in MATLAB externally and it can provide the proper refined mesh structure on our application basis. The mesh generator is customized to output a mesh that fits as much as possible the user needs, for instance in terms of sizing field or with respect to some user customized quality criteria. The meshing engine used in this mesh generator is based on Delaunay refinement [7]. It uses the notion of restricted Delaunay triangulation to approximate 1-dimensional curve segments and surface patches. Before the refinement, a mechanism of protecting balls is set up on 1-dimensional features, if any, to ensure a fair representation of those features in the mesh, and also to guarantee the termination of the refinement process, whatever may be the input geometry, in particular whatever small angles the boundary and subdivision surface patches may form. The Delaunay refinement is followed by a mesh optimization phase to remove slivers and provide a good quality mesh.

By converting the generated file to specific file formats like inp, the generated meshed file can be viewed in any finite element solver softwares like Abaqus or Ansys.

2.4 RAPID PROTOTYPE GENERATION

For any implant generation for fractured head or skull, the main step after generation is to evaluate the implant specifically whether it fits for patients head. Hence for effective review and analyzing of the implants one need to develop the rapid prototype of the model. In order to obtain the rapid prototype of the model one needs to have model in stl file format. After generation of surface mesh from the model, for converting the file to stl file suitable algorithm needs to developed [10]. In development of algorithm in MATLAB, use of node, face, element matrices is mandatory. By defining the triangular coordinates from nodes, element and face matrices stl file can be obtained.

Effective rapid prototyping is being done by 3D printing technique. In 3d printing technique the model in stl file format can be printed out by suitable material. Acrylonitrile butadiene styrene (ABS) is one such thermoplastic material which can be used for 3d printing technique. The styrene in ABS gives the plastic a shiny, impervious surface. The polybutadiene, a rubbery substance, provides toughness even at low temperatures. The ability of strength and toughness property of ABS makes it to use as preferable material for 3D printing. Below is the 3D printed rapid prototyped model developed from the output of the MATLAB [2].
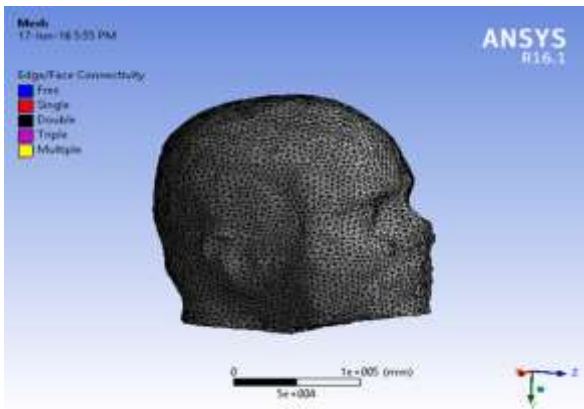

Fig 2.4 Tetrahedral meshed Finite element model   Fig 2.5 Rapid prototype model of human head

3. CONCLUSION

The following conclusions can be drawn with regard to the methods for developing 3D finite element model of human head:

In order to develop a 3D finite element model of human head from the set of MRI scanned images, a specific algorithm can be written in MATLAB which effectively generate the model with various cleaning operations such as, gap filling of holes, noise filter reduction. Further the tetrahedral meshed model can be used for finite element analysis of the head under various loading conditions. By assigning the material properties of human head surface like cortical and trabecular bone, one can carry out the finite element analysis. Using the above mentioned all the steps involved image processing technique for converting the binary grey scale volumetric images to the 3D finite element model we are able to get the effective result of the model.

REFERENCES:
[1] N. Kishore Kumar, K. Ashok Kumar Raju, 2015. Modeling and analysis of human liver by finite Element method. International journal on science and research

[2] Saeid Samiezadeh, Pouria Tavakkoli Avval , Zouheir Fawaz, Habiba Bougherara,2015.Journal of biomedical Engineering

[3]   Pranita Balaji Kanade et al."Brain Tumor Detection Using MRI Images". International Journal of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering Vol. 3, Issue, February 2015

[4]   Shaima Abd El-Kader et al."Curvature Anisotropic Gaussian Filter for MRI brain Images enhancement and edge preserving",IJCSNS International Journal of Computer Science and   Network Security, VOL.15 No.11, November 2015

[5]   Biplab Chatterjee, Prasanta Sahoo,2013." Finite element based parametric study of elastic-plastic contact of fractal surfaces". International Conference On Design And Manufacturing, IConDM 2013,p 552-561

[6]   Chougule, V. N, Mulay, A. V, Ahuja, B.B.3,2013. Conversions of CT Scan Images into 3D Point Cloud Data for the Development of 3D Solid Model using B-Rep Scheme

 [7]   Qianqian Fang ,David A. Boas ,2009." Tetrahedral mesh generation from volumetric binary and grayscale Images". IEE 2009.

[8] Carolina Dopico-Gonza lez , Andrew M. New, Martin Browne, 2009. "Probabilistic finite element analysis of the uncemented hip replacement-effect of femur characteristics and implant design geometry". Journal of bio mechanics

[9] F. S. Azar, X. Intes , 2008. Translational Multimodality Optical Imaging, Artech House, Norwood.

[10] O. Courchesne, F. Guibault, J. Dompierre and F. Cheriet, 2007."Adaptive Mesh Generation of MRI Images for 3D Reconstruction of Human Trunk", Springer Berlin / Heidelberg,.

[11] L. Rineau and M. Yvinec. 2008"3D Surface Mesh Generation," In CGAL Editorial Board, editor, CGAL User and Reference Manual. 3.4 edition.

[12] Craig A. Simmons, Shaker A. Meguid, Robert M. Pilliar, 2000. "Mechanical regulation of Localized and   appositional bone formation around bone-interfacing implants". Journal of Biomedical materials research

[13] Mikhail Yakhnis and Robert Zhang. "Analysis of 2D Deformation and Creep Response of Articular Cartilage".