

Chapter 42

Computer Aided Modeling and Finite Element Analysis of Human Elbow

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ABSTRACT

Finite element modeling (FEM) plays a significant role in the design of various devices in the engineering field of automotive, aerospace, defense etc. In the recent past, FEM is assisting engineers and healthcare professional in analyzing and designing various medical devices with advanced functionality. Computer aided engineering can predict failure circumstances, which can be avoided for the health and well-being of people. In this research work, computer aided engineering analysis of human elbow is presented beginning with modeling of human elbow from medical image data, and predicting the stresses in elbow during carrying heavy loads. The analysis is performed by using finite element method. The results predict the stress level and displacement in the human bone during heavy weight lifting. Thus, it can be used to predict the safe load that a particular person can carry without bone injury. The present analysis focused on a particular model of bone for a particular individual. However, safe load can be determined for various age groups by generating more detailed model including tendons, ligaments and by using patient specific material properties.

INTRODUCTION

Computer aided engineering (CAE) in the past has been applied for mechanical systems to design a component, to automate the manufacturing process and to predict the stress level in the working condition of the machine (Finger & Dixon, 1989; Molina, Al-Ashaab, Ellis, Young, & Bell, 1995). The same process can be used for biological systems such as bones, tendons, etc. to model them, and to predict stress and strain during working condition of body parts (Rekow, 1987; Sun & Lal, 2002). This can help

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in predicting the safe working condition of the person. Researchers have used biomedical imaging for making 3D CAD models of different body parts (Ameddah & Assas, 2013; Starly, Fang, Sun, Shokoufandeh, & Regli, 2005; Sun, Starly, Nam, & Darling, 2005). Author has also used medical imaging data to develop multi-component CAD model (Mehta, Vishnoi, & Gupta, 2014; Vishnoi, Mehta, & Gupta, 2014). Finite element method is often used for orthopedic and biomechanical study (Bhardwaj, Gupta, & Tse, 2014; Huiskes & Chao, 1983; Tan, Tse, Lee, Tan, & Lim, 2012).

Safety is of utmost importance, whether it relates to workers in industries or passengers travelling on highway, it is very important to predict the consequence of some injury so that it can be avoided. Sometimes the injury or accident can be person specific, for e.g., a sportsperson can have specific stresses due to action on certain bones, such as in weight lifting. Similarly sometimes the injury prediction has to be made patient specific, such as for elderly persons; their bone skeleton property would be quite different compared to normal human being.

This paper presents computer aided modeling and engineering analysis of human elbow. The elbow joint is a complex structure. It is one of the important joints in human body consisting of bones, ligaments, tendons and cartilages. The computer aided modeling is done by using the medical imaging data (MRI and CT-Scan). Open source software is used to convert the 2D medical imaging data to form a 3D CAD (Computer aided design) model. The CAD model is then pre-processed and meshed to generate a finite element mesh. Finally finite element analysis is performed on the developed model to predict stress and displacement for a specific loading condition of human elbow.

DEVELOPMENT OF A MULTI-COMPONENT CAD MODEL OF HUMAN ELBOW STRUCTURE

Grey scale images are processed to understand the visual aspects of 2D data and to enhance the images. The input data was 2D grey scale bio medical images of human elbow as shown in Figure 1.

The image is further processed to get better visualization by varying parameters such as intensity and contrast. This manipulation in parameters improves the resolution quality and clarity level. Figure 2 shows the final input 2D image. As it can be seen, the image is significantly enhanced, showing clearly the soft tissue region and bone separately. This distinction will be used for the development of multi-component model, i.e., for separating bone from the soft tissue.

Figure 3 shows the three different sectional views of grayscale image viz. axial, coronal, and sagittal planes view.

Segmentation work on modified 2D data is carried out by using an open source software ITK snap. Method implemented to carry out the segmentation work are image edge based method and image intensity based regions.

The process of automatic segmentation was used to extract different features such as bone and soft tissue as shown in Figure 4.

PREPROCESSING OF CAD MODEL

The CAD model developed was pre-processed using software Altair HyperMesh to remove sharp edges and redundant data that was created as a part of segmentation process. Since the segmentation process

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