CHAPTER 1
INTRODUCTION

1.1 CHAPTER INTRODUCTION

Figure 1.1 illustrates the flow of Chapter 1. Chapter 1 begins by giving an introductory about this research. A brief introduction about the research is given in Section 1.2. Statement of problem, research objectives, rationale and limitations are addressed in this section. The motivations to conduct this research along with research contributions are presented in Section 1.3. The organization of this dissertation is explained in Section 1.4.

Figure 1.1 – Overview of Chapter 1
1.2 INTRODUCTION

Segmentation is an important process in creating 3D models from medical images. It is the key process to extract information from complex medical images. Thus, segmentation is a challenging problem in the medical image analysis field [134]. Segmentation has extensive applications in the medical field. It provides surgeons with useful information for bio-modeling, surgery planning [94], robotic surgery [135], implant design [95], obtaining dimensional measurements of human anatomy and quantification of tissue volume [96].

Researchers have used many traditional methods such as thresholding, edge-based segmentation, classifiers and clustering approach to segment medical images. These methods are easy to implement and do not require heavy computational power. They are best used for visualization purposes.

Newer, intelligent methods such as artificial neural networks, deformable models, and atlas guided approaches have higher accuracy than traditional methods. Research efforts are concentrated in these areas to enable its use in the clinical environment. Research is also being conducted using hybrid methods that combine 2 or more techniques, for example, neural-fuzzy and wavelet neural approach. The newer methods provide better accuracy to obtain dimensional measurements for bio-modeling, surgery planning, robotic surgery and implant design. Traditional methods do not provide the accuracy required for the applications mentioned. However, intelligent methods are computational heavy and time consuming, compared to
traditional methods.

Medical image segmentation is still a crucial problem due to the complex nature of medical images [134]. Automatic segmentation methods are applied to very specific anatomies of medical images with prescribed parameters. On the other extreme, manual segmentation is labor intensive, costly [43,28] and time consuming [42,28], while requiring knowledge from experts. Interactive segmentation is a trade off between these two methods, where the initial apriori knowledge is used to steer the segmentation direction [42,45,29]. The segmentation methods proposed have their advantages and disadvantages, making them suitable for certain types of medical images. For example, Computer Tomographic (CT) images can be segmented using the simple thresholding method.

Artificial neural networks (ANN) provide an intelligent technique to segment magnetic resonance (MR) images. ANN selects the pixel in the original images and classifies it using the pixel intensity and pixel location. Fuzzy logic provides the means to classify pixel at boundary areas, where tissue mixture is apparent. Segmentation of the human femur from MR transverse cross-section images is the focus in this thesis. The research aims to extract the femur bone from the MR images and a construct 3D model.

In the previous paragraphs, the techniques used for segmentation and its applications are discussed. Accuracy is stressed as an important factor in segmentation. CT
images provide good contrast of bone, thus making segmentation an easy task. However, CT scans emit radiation, making it an unfavorable for femur imaging. Medical professional are reluctant to do CT scan of the femur region as it is near the reproductive organs. MRI is preferred in this research as it is safe from radiation.

The femur bone is segmented from MR images. A 3D bio-model of the femur is created to aid in the implant design process. Accuracy plays an important part in this process, as implants have to fit the patients perfectly. If the fit were loose, patient's recovery would take longer or may even require re-surgery, this prolonging the patient's suffering.

Surgeons are not able to visualize the bone directly before surgery, as it is an internal anatomy. They depend solely on the medical images acquired from the scanners. Thus MRI scanners have to be calibrated often, using physical phantom to reduce errors in scanning. This would provide the health care professionals the best and accurate representation of the internal organ scanned.

MR transverse images used in this research are of the human thigh. The images are segmented to extract the femur alone, disregarding other tissues such as fat, skin and bone marrow. Two methods are experimented to segment the femur bone. They are the neural fuzzy method and the fuzzy neural method. The self organizing maps (SOM) neural network classifies pixels in the images based on the pixel value and location. Fuzzy logic is used to classify boundary pixels which belong to a mixture of classes.
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MR images scanned are read into the application developed for processing. The region of interest (ROI) containing the anatomy of interest (femur) is determined manually using apriori knowledge. The ROI is then segmented using the neural fuzzy technique and fuzzy neural technique. Post processing steps are performed to reduce artifacts and to improve the final results. The performance of each of the technique is analyzed and criticized. The segmented images are used to construct a 3D model of the femur.

1.2.1 STATEMENT OF PROBLEM

In the previous section, the techniques used for segmentation and applications are discussed. Accuracy is stressed as an important factor in segmentation. CT images provide good contrast of bone, thus making segmentation an easy task. However, CT scans emit radiation, making it an unfavorable for femur imaging. Medical professional are reluctant to do CT scanning of the femur region as it is near the reproductive organs. MRI is preferred in this research as it is save from radiation.

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Surgeons are not able to visualize the bone directly before surgery, as it is an internal anatomy. They depend solely on the medical images acquired from the scanners. Thus MRI scanners have to be collaborated often using physical phantom to reduce errors in scanning. This would provide the health care professional the best and accurate representation of the internal organ scanned. The images produced would also be consistent for reproductively.

MR transverse images used in this research are of the human thigh. The images are segmented to extract the femur alone, disregarding other tissues such as fat, skin and bone marrow. Two methods are experimented with to segment the femur bone, namely the neural fuzzy method and the fuzzy neural method. The self organizing maps (SOM) neural network classifies pixels in the images based on the pixel value and location. Fuzzy logic is used to classify boundary pixels which belong to a mixture of classes.

1.2.2 PROJECT OBJECTIVES

The objective of this research is to extract the human femur from transverse MR images. Two methods are explored in this research, the neural fuzzy technique and the fuzzy neural technique.

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1.2.3 RATIONALE

The MR images scanned are stored as 2D slices in the scanner as proprietary file format. Then the files are transferred into a 5.25 inch MOD and brought into the research laboratory. The files are transferred into a common file format using suitable applications.

Apriori knowledge of the human thigh is required to determine the femur region in the images. This is done to define the ROI region. ROI helps to remove major artifacts while helping to reduce the computational power needed.

It is well known that neural networks are suitable for classification tasks. Neural networks are robust and tolerant to noise in the input data [136]. Unsupervised SOM network do not require training data sets, saving time and effort to acquire the training data set.

Fuzzy logic is an intelligent method that is used to help classify boundary pixels in the area where tissues overlap and are mixed. It is able to classify pixels based on the degree of their belongingness to a tissue group. The combination of neural networks
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and fuzzy logic technique gives it an advantage over conventional segmentation algorithms.

1.2.4 LIMITATIONS

There are three limitation on the images used in this research. The first is due to the sampling process. The images used in this research are gray scale images since the scanned data is stored as gray scale matrices. The images are converted from its proprietary format to a common file format of 12-bits per pixel \((2^{12} = 4096\) gray levels). The minimum distance between the 2D slices scanned is 1.5 mm.

The second limitation is the subject characteristics imposed. It is difficult to obtain large set of samples due to high cost of scanning and sophisticated machinery required. The MR images used for research are from a male and a female Asian subjects. Asian femur structure differs from Caucasian femur structure. Asian femur shaft is more curved than Caucasian femur and the Asian femoral neck angle is larger than of the Caucasians [137,138].

The third limitation is due to the MR scanner. The magnetic field used in the scanning process is non linear. This produces images that are distorted in both ends of the scanned region. To obtain scan of the whole femur, the scanning has to be conducted in separate region, creating referencing problems. This does not enable the construction 3D model of the whole femur.
1.3 MOTIVATION AND CONTRIBUTION

MR scanning does not impose any health hazard unlike CT scanning [24]. Thus, a large population could be scanned to provide useful statistical data for medical analysis. The population study results can be used in areas such as femur morphometry and the development of implants specific for Asians.

With the assistance of femur segmentation algorithm and 3D visualization, the process to recognize bone fractures and diseases would be easier than the traditional way of mental reconstruction. For this process, the knowledge of normal femur anatomy is required. Using the 3D model created from segmentation algorithm, it is possible to visualize and take dimensional measurements of the femur. The accuracy of the segmentation plays an important role in this process, as femur is not symmetrical. MR images provide good shape and texture information of the anatomy structure, making it an excellent modality to identify bone fractures, diseases and anomalies.

The segmented 2D images can be used to create 3D model of the femur and also for implant prototyping. The images can be converted into stereolithography (SL) file (STL format) to create rapid prototypes (RP). The prototypes help in designing custom implants and prostheses [17]. The custom made implants eliminate bone cutting, reaming and implant shape adjustment, shortening the surgery time and patient recovery time.
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The human anatomy varies from individual to individual. The RP technology, SL technology and advanced medical imaging has great impact on medical image design, pre-operation planning and medical instrument building. 3D computer aided design (CAD) models could also created from the MR images. The CAD models could be used to design implants. CAD packages allow finite element analysis to design implants that fit precisely for a patient [17]. A precise fit reduces recovery time, re-surgery procedures, ensuring patient comfort and maximum mobility.

Bio-models aid in doctor-patient communication, making it simpler, faster and more precise [137]. The models would help the patients understand the situation and help the doctor gain patient's confidence. Bio-models are very useful for diagnostic and surgery planning with the use of visualization tools. Physical models would give the surgeon a look and feel advantage before surgery, allowing surgeons to plan better surgeries. This would reduce surgery time, cost and also patient recovery time.

Applications of segmentation algorithms are not limited to bio-models. Segmentation plays an important part in robotic surgery as well. The accuracy of robotic surgery depends on the accuracy of segmentation algorithm. Segmentation is also used in radiotherapy planning. The progress of patients who undergo radiotherapy can be monitored quantitatively with the use segmentation methods. Radiographers would be able to direct radiotherapy to anatomy of interest without damaging other tissues. The effectiveness of radiotherapy can also be monitored using segmentation algorithm. Other application of segmentation is explained in detail in Section 2.5.4.
1.4 THESIS ORGANIZATION

Planning plays an important role in dissertation writing. This dissertation is divided into 5 major chapters. Figure 1.2 illustrates the overview of this dissertation. The first chapter presents the introduction of the research conducted. Research problems are stated along with the research objectives. The motivations and contributions of research are addressed after that.

![Diagram of Thesis Organization]

**Figure 1.2 – Thesis Organization**

Chapter 2 is the literature review chapter. It provides the knowledge required to conduct the research. Introductory knowledge about digital image processing is presented first. Magnetic resonance imaging (MRI), the 3D imaging pipeline, biomedical image segmentation, artificial neural networks (ANN) and fuzzy logic is
examined thoroughly in this chapter.

Chapter 3 explains how the data used for this research is acquired. The two methodologies used in this research, neural fuzzy technique and fuzzy neural technique, are presented in detail in this chapter.

Chapter 4 presents the results of the experiments using both neural fuzzy technique and fuzzy neural technique. The results of segmentation methods are evaluated. The intermediate results of the segmentation algorithm is provided and discussed. Finally, the 3D model of the femur created from the segmented images is illustrated.

Each chapter begins with an introduction to its contents and is summarized at the end. The bibliographic section list the references consulted for this research. In the appendix section, the results of experiment using different data are provided.

1.5 CHAPTER SUMMARY

Segmentation of medical images is an important process that provides useful information to health care professionals. Researchers have developed many segmentation techniques and each of the techniques has its advantages and disadvantages. The objective of this research is to extract the human femur from MR images. Neural fuzzy technique and fuzzy neural technique are utilized in the segmentation process. This research has potential application in the medical analysis field, education field, surgery planning, implant designing and other fields.