CHAPTER IV METHODOLOGY

4.1 Method Overview

MRI scanner was used to obtain MR images of heart. The segmented heart images were stored in Tiff format. The object in the region of interest of these images was then modeled using Active Shape Modeling (ASM) toolkit and stored as parts, points and model files. The location of modeled images was linked in the database with associated patient information. The model was then used to retrieve similar images, which had a similar region of interest.

The steps of modeling, storing and retrieving the segmented heart MR images are shown in Figure 4.1 below.

![Diagram showing steps of methodology](image)

**Figure 4.1 Methodology**
4.2 Modeling and Retrieving Segmented Heart Images

Step 1: Image Acquisition

The set of 27 MR heart images was obtained from Department of Radiology, University Hospital. This belongs to a healthy Malaysian male. The 27 images are shown in the Appendix A. This chapter looks into the method of modeling these images and storing them in the database for easy retrieval.

Step 2: Modeling

Modeling the segmented heart images was done using ASM Set-Up tool. The object in the region of interest was identified and marked using points marker. The shape of heart itself was used as the region of interest for this study. The MR heart images were modeled using setup tool in ASM toolkit software to keep track of the size of a normal heart.

ASM toolkit software runs on top of Matlab application. Appendix H lists the software and hardware used for this study. Matlab application must be installed first before installing ASM toolkit. The marker utility in ASM toolkit set-up was used to label and mark the points in each heart images in the training set. There were 27 gray level heart images and were named in sequence from 12_1 to 12_27. The first heart image is 12_1.tiff and was marked and saved as points file called 12_1.pts.
Each ASM points file was saved using the same name as the image name but with different extensions. At least ten images should be trained to build a reasonable model [7]. The points file (.pts), parts file (.parts) and shape model data file (.smd) were created when the training data was saved as shown in Appendix F. Figure 4.2 shows the marking in the heart image.

![Figure 4.2: Marking of Heart Image](image)

At least five images were modeled before using ASM search tool to add more images and to search for modeled object in the region of interest in a given heart image. Modeled images can be viewed using static view or dynamic view as explained in chapter 3. The search can be a static search or a multi-resolution search. Modeled images were stored in flat files, which could be easily retrieved.

**Step 3: ASM Search to Add Training Data**

ASM search option was used to search a gray-level image for an instance of the modeled object. It starts the search from an initial pose and shape of an image that was trained. ASM search was used to train subsequent
17 images to speed up the model building process. Figure 4.3 shows the model built was loaded in ASM Search to search for a matching image.

![Figure 4.3 ASM Heart Model](image)

**Figure 4.3 ASM Heart Model**

The static search is an iterative refinement of the heart model poses and shape parameters. This gives a better match between landmark gray-level descriptions and image structure [20]. The ASM file that shows the search function in Matlab coding is in Appendix B. Figure 4.4 shows the model that matches the heart area of the MR image loaded.

![Figure 4.4 Matching of the Heart Image](image)

**Figure 4.4 Matching of the Heart Image**

Graphics dialog box in options menu in ASM search menu allows the search option toggle the display of the iterative steps of the search. The
Show Coarse Images option toggles the display of the multi-resolution of heart MR images.

At coarse levels, the heart image was composed of fewer pixels so the search makes larger steps, quickly finding a rough estimate of the area of interest. As the search proceeded with increasingly higher resolutions, image size increased, and so the steps became smaller allowing for a refined fit. Appendix B shows the ASM multi-resolution search coding using Matlab programming. Figure 4.5 shows the 3 iterations of multi-resolution search.

![Figure 4.5 Iterations of Multi-resolution Search](image)

The ASM viewer tool was used to see the ways in which the modeled heart shape varies from the mean shape. The principle mode of variation of the heart shape was useful to view the static view and dynamic view of the heart. Figure 4.6 shows static view of heart model.
The start button was selected from the dynamic model options menu to view the dynamic movement of heart model variation. Figure 4.7 shows an example of dynamic view.

**Step 4: Image Database Development**

The modeled heart images, patient’s diagnosis report and the type of treatment given were stored in the database. The database must be able to handle large amounts of data as the images and information about
patients grow over time. Image storage and retrieval are well supported by Oracle, DB2 and SQL Server programs as compared to simple database programs like Microsoft Access [31]. However, these database programs are too expensive to be acquired for this study.

For the purposes of this study, Microsoft Access database is used for storage and retrieval of the images due to its' availability and low cost of acquisition. Appendix E shows the features of Microsoft Access and SQL server. The Access database can grow up to one gigabyte in size and it can support 255 concurrent users. The images were stored in flat files and were linked with database through Object Linking Embedding (OLE) feature for easy storage and retrieval.

A sample database called MRI_DB.mdb was created to link the MR images and patients' information. The database was modeled using relational data model. This model ensures reliability, consistency and integrity of data stored in database. There were five relations identified to collect and store patients' information and the images in the database.

The database consists of patient, doctor, diagnosis, treatment and MR_image tables. The patient table consist of patient identification (patient id), name, date registered as patient, date of birth, age, notes or complications detected by doctor and doctor's identification (doctor id). The doctor's table consists of doctor id, name and field of expertise. The
diagnosis table consists of diagnosis identification (diagnosis id), patient id, treatment identification (treatment id), date, diagnosis and doctor id. The treatment table consists of treatment id, patient id, doctor id, date, drugs prescribed and the treatment success. The MR image table consists of image identification (image id), patient id, name of the organ that is scanned, link to ASM Model of the image and link to image location. Please refer to Appendix C for the data stored in MRI_DB.mdb. The normalized Entity Relational diagram of the database is shown Figure 4.8.

![Figure 4.8 Entity Relational Diagram (ERD)](image)

The Entity Relational Diagram (ERD) was drawn based on the assumption that each patient may have only one doctor and each doctor may have many patients, each patient may have MR images and each MR image may belong to a patient, each patient may be diagnosed of once of the disease and each diagnosis may belong to only one patient, each patient may undergo many treatments based on diagnosis and each
treatment may belong to only one patient, each doctor may do many diagnosis and each diagnosis may be done by only one doctor, each doctor may do many treatments and each treatment may be done by only one doctor. Patient_id, doctor_id, treatment_id, image_id and diagnosis_id are compulsory fields called as primary keys in the database. These primary keys uniquely identify each patient record. These primary keys were used as foreign keys in the link tables to retrieve information.

The images were stored in flat files with a pointer in the database to retrieve them. This allowed the images to be stored in different drives and locations. As the numbers of patients grow, the images can be compressed and backed up in CDs for future reference. Through this way, the database will not be overloaded and queries can be processed efficiently. The image and model links in database is shown in Appendix C.

**Step 5: ASM search for matching images**

To search for the image that matches the heart model created, the ASM search option was activated. The heart model called heart.apm was loaded first before the image to be searched was loaded. The search button was clicked to search for the match with region of interest. ASM
stopped the search once the model fitted into the region of interest of a given MR image.

**Step 6: Retrieval of Images from Database**

Once the model fitted into the region of interest of a given MR image, the information about all related patients and their MR images stored in the flat files were retrieved from the database for accurate diagnosis and treatment purposes.

### 4.3 Chapter Summary

Six steps were involved in developing an MR image search database system using Active Shape Modeling technique. Scanned and segmented MR images were modeled using Active Shape Modeling toolkit. The modeled images were then saved in flat files for easy search and retrieval. Relational model was used to draw the entity relationship diagram, which was mapped to develop a sample Microsoft Access database. The heart models, images and patient information were retrieved from the database. The next chapter discusses the use of this method.