Development of An Online Image Repository System for Cardiac Modeling

Fariza Hanum Nasaruddin, Maryam Zakeryfar, Rodina Ahmad
Faculty of Computer Science and Information Technology
University of Malaya
Lembah Pantai, 50603, Kuala Lumpur
MALAYSIA
fariza@um.edu.my, maryami@perdana.um.edu.my, rodina@um.edu.my

Abstract: -
The development of digital cardiac models has become an area of research all on its own. These researches intend to assist in the understanding of the heart. The data needed to build a digital cardiac model may come in various formats, including medical image data, such as MRI, CT scans, and other scans such as PET and SPECT. The availability of cardiac images is very important in cardiac modeling research. These images are difficult to come by for researchers who are not in the medical field. Thus, any of such available data stored in an on-line system can be made available to other researchers. This paper discusses and elaborates on the design and the development of this on-line cardiac image repository system. The requirement of the system was acquired using the Attribute Driven Design (ADD) method, which is a method for designing software architecture to satisfy both quality requirements and functional requirements. The online system which was developed has only taken into consideration image data, and not others formats of cardiac data such as ASCII flat files, and video files. The online system allows for downloading and uploading of data. With the availability of the data, researchers can spend more time focusing on the modeling processes rather than on the preprocessing and searching for data.

Key-Words: - online repository system, image data, cardiac data, cardiac modeling, attribute driven design, digital heart model

1 Introduction

There is a great interest in the human heart mainly because it is possibly the most important feature of the human body besides the brain. A number of researches have been, and will continue to be conducted to understand and predict the behavior of the heart. As with many other fields of researches, computer has become a valuable tool to assist researchers in various ways. Using computer as a tool, heart researchers can make use of digital heart models in their study. The development of digital heart models by itself has become an area of research all on its own. As a result, the research in the field of heart study have attracted researchers outside the medical field such as researchers from the bio-engineering, bio-mechanical, bio-medical, and also computing background to conduct research such as cardiac segmentation, shape analysis of left ventricle, cardiac modeling, and so on[1, 2]. Other researchers have embarked on this journey and are finding ways to build digital heart models using digitized data [3, 4, 5, 6, 7].

The data needed to build a digital cardiac model may come in various formats. Digital models can be built from medical data, in the form of images such as CT scan images, magnetic resonance images, ultrasound images, and other scans such as PET, SPECT, etc In other words, the data used in cardiac research are multi-formatted and multi-modal [8,9].

Data can be newly acquired at the initial stage of a research project or it can be an already available data which has been stored somewhere. For example, data can be freshly acquired by the research team, or the team may use data which has previously been collected by someone else, processed and maybe even developed into a particular model. Articles written by researchers who carried out such projects reported that this is not an unusual practice. In such a case, the previously collected data, the previously processed data, and the initial model that was developed earlier could be kept somewhere for easy access.

The objective of this research is to enable these data to be made available to researchers in the area of cardiac modeling. These data can be stored in a repository which can be made available either to all researchers or only to a limited groups of people depending on the needs of the users.

This paper begins with a short discussion on the approach used for this research project. Then, it continues with a discussion on the findings which explains the types of data that are used for cardiac modeling researches, the places in which these data can be obtained, and the availability of such data. Next, the model of the proposed system is presented. The paper ends with a discussion and suggestions for future enhancements.

2 Medical Image databases

A variety of medical image database have been developed. Each of them serves different purposes [10,11,12,13,14]. These image database systems allow images to be retrieved using different retrieval techniques such as keyword search or via specifying attributes or analogy position. Some of these systems have clinical purposes. For such systems, their users generally are doctors and medical staff. Typically, the patient's information is mostly considered and usually the goal is to enable doctors to browse patient's image at anytime, and anywhere [15]. The aim is to supply a resource of imaging data to aid in daily medical operations, in diagnosis, and in the development of innovative techniques to detect cancer or other diseases.

There are numerous examples of such medical related systems. For example, EDiaMond [16] presents a resource of breast imaging data for a national database of digital mammograms to support the United Kingdom's breast imaging community. Then there is MEDIMAN [17], which is another web information system (WIS) which is currently being used by neuroscientists and clinicians at several medical and research centers in Spain for research and clinical trials. Users for these mentioned systems are mostly students, radiologist or researchers in clinical fields.

Other than medical purposes, there are other online systems which are developed to offer electronic teaching files on the Internet. An example of this is Case Image [10], which is a digital teaching file system for radiologists and researchers (available at http://casimage.com). From our initial study, we found that most, if not all of these databases are focused towards servicing clinical needs and medical teaching. We did not find any image database system which specifically addressed the needs for organ modeling, simulation or segmentation in the area of biomedical, biomechanical, or computing purposes. In addition to that, there are currently many databases which store image-based information of human anatomy. However, the availability of a database especially for heart data is scarce. To our knowledge, this is the first publicly available online cardiac repository system with this specific purpose in Malaysia. Table 1 briefly shows the Comparison table of features of available medical image data base and online cardiac database which we propose.

Table 1. Comparison table of available medical image data base

System name	Advance search	Share case	Image software	Download Raw data	Case of the week	Diagnostic description
MYPACS	⊗	⊗	⊗		⊗	⊗
MED PIX	⊗	⊗	⊗		⊗	⊗
MEDIMAN	⊗	⊗		⊗		⊗
CARDIAC REPOSITORY	⊗	⊗		⊗		

3 Research Approach

Before a repository for the datasets can be designed, we have to analyze the cardiac data and understand how they are used. In this particular study, the scope of research data is confined to image data used for research and the development of cardiac models by the research team at University of Malaya (UM). The findings from the study are compared with articles written by other cardiac modeling research teams, and it can be concluded that the usage of data for the purpose of building cardiac models are similar among a number of research groups. Review of articles has shown that data used for the heart modeling research mentioned above may come from various sources. In order to understand this, the data flow of the UM research team is studied. Again, the findings from the study of the data flow are compared to the articles written by other cardiac modeling research teams for reaffirmation. After verifying that the process flow is valid and acceptable for many research cases, system analysis and design is performed for the development of the repository.

3.1 Problem Statement

This development work was triggered by the problems faced by a group of researchers of a virtual heart research team at the Faculty of Computer Science and Information Technology, University of Malaya. The data needed to build a digital cardiac model may come in many modalities such as from heart MRI and heart scans such as SPECT, PET and CT scans. In Malaysia, the availability of cardiac data is very limited. Digital heart data are especially difficult to find. Researchers may have to buy data from internet resources such as from 3D science.com web site or they can a obtain models from local data suppliers. In the case of 3D science.com web site, a 3D heart model may cost around USD1200. In one case, the research team at Faculty of Computer Science and Information Technology at University of Malaya has had to purchase data from a local supplier

for RM4500. In another case, the team were able to do MRI scan on a volunteer. Data from the scan were used for a number of research projects [18, 19, 20].

It is clear that it takes considerable money, time and effort to create datasets from scratch. Therefore, whenever the raw data has been acquired, processed into readable data formats, segmented, or processed in any way, these new datasets should be made available to other potential researchers to avoid any wastage of time in finding new datasets, preprocessing [21], and cleaning up the data, before it can be used to construct the same or similar cardiac models. The final aim of this project is to build a repository for such datasets.

3.2 Findings

The development for the cardiac repository system will be based on the requirements given by the UM virtual heart team. Data needed for such non-medical researches are very limited and mostly prepared exclusively by each research team. However, among the main key finding is that within the same research group there is reusability of the raw data, processed data and even the models which are built. By reusing the processed data and the model built by one research group or person, the next group or person who wants to conduct a new research does not have to reinvent the wheel. Instead, the data which has been collected by an earlier person or group, data which has been processed by a person or group, can be used by the new team. This is apparent in many journal articles and in the study of the research group at FCSIT, UM [22, 23].

This sharing of data is also apparent in a number of articles describing works done in the area of virtual heart modeling. For example, to reconstruct the electrical activity of the heart, as well as detailed models of the individual myocytes, detailed models of the cardiac anatomy (geometric models) are required. The geometric models may be built by some other researcher or research group. So it can be concluded that there are similarities in the usage of data for the purpose of building cardiac models in research groups, whereby the work of a person of a group may be reused by another person or group.

The next question is whether these data can be made available to researchers outside the immediate research group. A questionnaire was placed online and emails we sent to various cardiac modeling researchers for their views on this issue. Although we did not get many feedback from the international community, the feedback from the FCSIT group in UM was sufficient to help us in determining the outlook of these researchers. This is because the initial data that will be placed will be provided by them and they will be the owner of the repository and the datasets. The questionnaire not only confirmed the views of the researchers in terms of data sharing, it also provided us with the user requirements of the repository system should it be developed.

From the feedback received, first of all, it is clear many researchers are willing to share their data. However, they will only share it with authentic researchers. Secondly, the questionnaire confirmed the flow of data usage and this is similar to the data flow for other digital modeling projects. The following is a diagram to show a similar data flow that is used in femur modeling which is applicable to the data flow in cardiac modeling project.

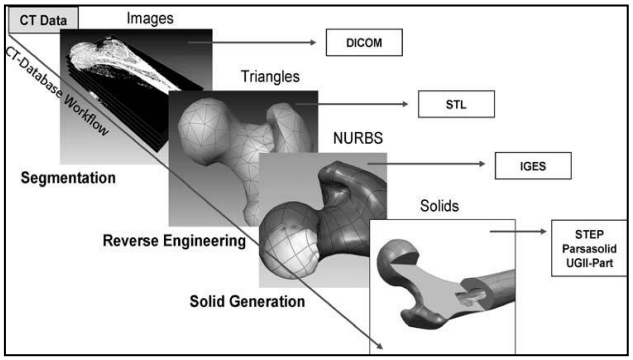

Fig.1 Adopted from Messmer [24]

Based on these findings, we are confident that in order to accommodate the needs of the virtual heart research group, an online cardiac image repository system is proposed. The online system is proposed because the team would like to share their data with other researchers and they hope that other researchers will want to share their data with them and others. For that, the system not only allows for data searching and downloading, but also provides uploading module to enable other researchers to upload their data to the repository. However, it is important to remember that only authentic researchers are welcomed. Therefore, the system will require users to register and approved before any transactions are allowed.

4 Design Methodology

The design and development of the online cardiac image repository system is carried out using the rapid prototyping approach. This approach is considered to be the most suitable approach in this particular case due to the fact that the users who themselves are busy researchers are not able to spend long hours of discussions on the requirements and the design of the system. They prefer to see a working model, comment on them and expect the system to be improved as per their comment. The figure 2 illustrates the steps involved in the development of the online repository system. Even so, prior to the actual design and

development, analysis of the users requirements are needed. The following section discusses the requirement analysis, the architecturally design requirements, and the architectural pattern applied in online cardiac image repository.

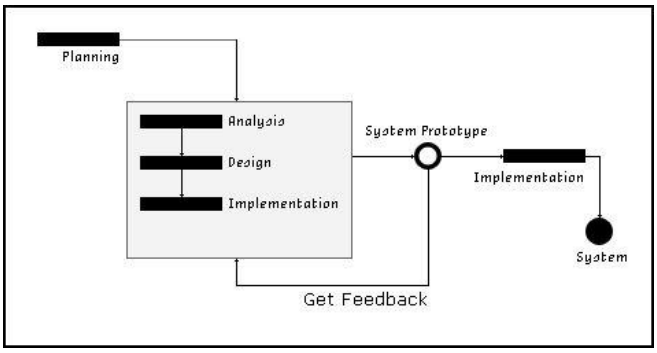

Fig.2 Online cardiac image repository methodology

4.1 Overview of Attribute Driven Design

There are many available approaches one can take when it comes to determining software design, especially when developing web-based or online systems [25]. One of them is the Attribute Driven Design (ADD). ADD is a method for designing software architecture to satisfy both quality requirements and functional requirements. ADD takes as input a set of quality attribute scenarios and employs knowledge about the relation between qualities attribute achievement and architecture in the design process. The output of ADD is the first several levels of a module decomposition view of architecture and other views as appropriate. ADD steps are as follows:

(1) Choose the module to decompose.

(2) Refine the module according to the following steps:
   (a) Select the architectural drivers from the set of concrete quality scenarios and functional requirements.
   (b) Select an architectural pattern that satisfies the architectural drivers. Identify child modules required to implement the tactics.
   (c) Instantiate modules and allocate functionality from the use cases and represent using multiple views.
   (d) Define interfaces of the child modules. The decomposition provides modules and constraints on the types of module interactions.
   (e) Verify and refine use cases and quality scenarios and make them constraints for the child modules.

(3) Repeat the steps above for every module that needs more decomposition.

4.2 Requirement analysis and design

The requirements and design analysis of the online cardiac image repository system is facilitated by the use of Attribute-Driven Design method (ADD). It is a method for designing the conceptual architecture. The ADD method is mostly focused on the initial design phases of the development life cycle [26]. It helps designers to comprehend quality tradeoffs as early as possible in the design process. Using ADD method, all system requirements especially quality requirements, functional requirements and constraints are considered as drivers in the design process, which produces the system's conceptual software architecture.

In terms of cardiac data analysis, we have determined the types of data used by research group which can be categorized into raw data category, processed data category, and simple model category. Figure 3 illustrate this categorization.

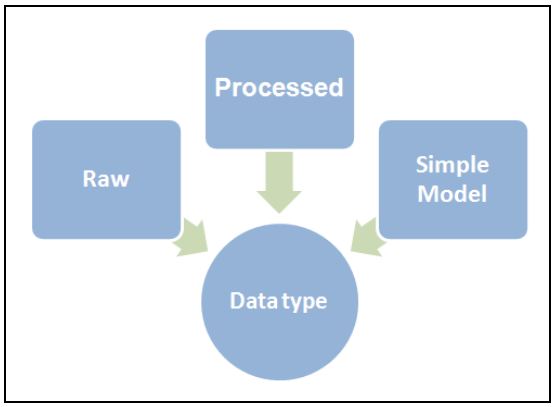

Fig.3 Three categories of data used by the research group

The raw data category includes data such as MRI files, CT scans, and other images which may be in DICOM format or any other formats. These DICOM files can be processed into bitmap or jpeg files so that they can easily be accessed and read by computers. Before these bitmap or jpeg files can be used by a researcher, he may process the images further by selecting only the region-of interest (ROI) so as to remove as many artifacts or unwanted images from the selection. Further process can include segmentation of the images. These processed files are categorized as processed data. These processed data can be later used to build simple models such as 2-dimensional and 3-dimensional models. Here lies an important reason as to the need of the repository system.

Substantial time has been used to pre-process the data before they can be used. And if the pre-processed data can be stored, other researchers can choose to use the pre-processed data rather than the raw data, and this can save considerable time.

In summary, the data can be categorized as raw data which are data collected directly from the scan or the original files, and the processed data which are raw data which have been pre-processed into region-of-interest (ROIs) or segmentations or other processes.

4.3 Architectural Design Requirements

From the initial requirement analysis, the main functionalities of the online cardiac image repository system are extracted, and are listed below:

Authorized System Access: User shall be able to access the system based on valid user name and password. The administrator should have access to registered accounts and be able to perform appropriate operations through the various subsystems, according to their role privileges.

Search Image: System shall provide a complete search engine with different categories such as image format and image segment to help users to find their specific images. Search via keyword is implemented as well.

View Images: User shall be able to view the images of various formats using specific image viewers. Links to required image viewers are provided for user to download certain viewer if needed.

Upload Images: User shall be able to upload the data into the system and let other user access the data. However, uploaded data will be screened and approved by system administrator for security purposes.

Download Images: Registered users shall be able to download images from the website.

Edit Images: System shall provide simple image editing functions, such as change of spatial resolution, cropping and contrast/brightness setting. Using the copy/paste function the user can copy images from the database to any image editing software to do more complex changes to the images, such as applying special filters, removing part of the image or adding arrows or legends on an image.

Database Backup: Database must be backed up regularly so that data recovery process can be executed upon data-related system failure.

System Usage Tracking: System will keep track of all events that take place and document these events by specifying facts such as what time the user login into the system, what did he/she upload or retrieve to/from the system, etc.

System Guideline: System guidelines should be provided for new users including simple and easy to learn instruction of using the system.

Convert Images: System shall provide image convertors for medical image like DICOM to JPEG and other possible image formats.

Edit Case: User shall be able to edit the information of self-modified case.

Add image to an existing case: Once users download image data and change or simulate image data, they should be able to re-upload their simulated data into the system.

Forum Management: Users shall be able to participate in a forum to raise questions or offer comments.

Besides the functionality requirements, the quality requirements are crucial to the development of a system [27]. Table 2 summarizes the non-functional requirements which drive the design of the system architecture.

Table 2. System Architectural Drivers

Architectural Driver	Rationale
Security	The online System and the database must be secured.
Availability	The system shall be available 99% of the time because any downtime in system may have a negative influence on user trust on the system.
Modifiability	A new module that specifies for flexible requirements accommodation allows significant development of future sub system module modification to be featured.
Usability/ Accessibility	System shall provide a search engine with different categories to help user to find their specific data.
Reliability	System shall be able to provide accessibility to data and consistent data access. This requires back-up facilities.

4.4 Architectural pattern

The online cardiac image repository system architectural pattern consists of four main layers:

1) The "Web Server" layer, which is responsible for displaying and reading data from "web client" layer,

2) The "Image Repository Database layer" which has the responsibility of communicating with the database section,

3)The "Application Server" layer which comprises of three sub-layers:

One is the "User management" layer which has a direct access to the "Security layer".

This allows the user to access "Image Management" layer by accessing security layer. In view of the fact that the security has the highest priority in quality goals of the online cardiac image repository system, in the main pattern for our system, we have considered a separate layer for Security layer.

Given that, all users and data should pass "Security" unit, so that their security would be guaranteed. In the Security layer, we utilized tactics including Authenticate user, Authorize user, Resisting Attacks, Detecting Attacks and Recovering from an Attack.

4) The final layer is the "Database Backup" layer. By applying this pattern, the availability requirement, can be achieved as the result of Recovery Preparation and Backup tactic in database backup layer, which is the last tier on the online cardiac image repository system's pattern. Figure 4 illustrates the mentioned layers.

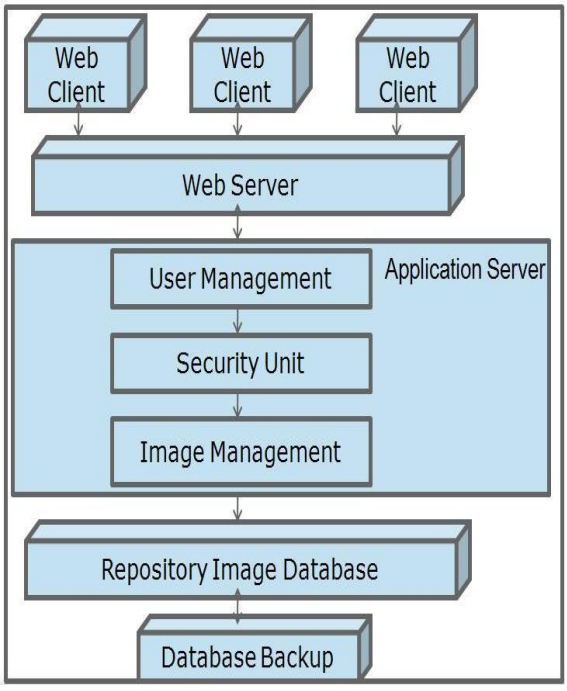

Fig.4 Pattern for Online cardiac image repository (Layered, N-Tier)

4.5 User access control

Some of the data that can be stored in the online cardiac image repository are heart MRI and heart scans such as SPECT, PET and CT scans. Therefore preserving patient's privacy is a major concern for repository. Achieving a high security level is mandatory but security is always a tradeoff between inconvenience for the users and the desired level of protection. In order to convince users (researchers) to use Online cardiac image repository for their data storage and processing needs, several functionalities need to be provided such as:

- Reliable authentication of users.
- Secure transfer Data
- Secure storage of data on database
- Access control for resources such as data, storage space
- Anonymity of medical records to make them available for research.

To achieve acceptable level of security in online cardiac image system, user access control tactic is used and is detailed in the table 3.

Table 3. Access Control of Online cardiac image repository

	Image	Case	Topic
Admin	Add/Edit/ Delete	Add/Edit/ Delete	Add/Edit/ Delete
Owner of image	Add/Edit	Add/Edit	Add/Edit Topic
Registered User	View Image- Download Image- Download Viewer	View Case- Download Case- Download Viewer	View Topic- Add Topic
Guest	View Image	View Case	View Topic

5 Repository System Development

Designing an on-line repository system is challenging work. During the study and design phase, we faced many limitations and possibilities that require design decisions in each stage. In this section, we describe in detail the design process for the online cardiac image repository system from different aspects. These aspects are elaborated in three sub-sections to further explain the motivation behind the task for repository of cardiac data

and models. The discussion covers the design constraints in developing the system, the explanation of the modularization of the system based on the main requirements, and the development of the online cardiac image repository system.

5.1 Design Constraints

Design constraints are decisions about a system's design that must be incorporated into any final design of the system. They represent a design decision with a predetermined outcome. Since online cardiac image repository system must be accessible through the World Wide Web (www), the website will be developed in a standard language by using ASP.NET technology. All common browsers within the last three years should be able to access the system to provide accessibility to a wide variety of users.

Microsoft SQL Server 2005 is used for storing and retrieving image data after considering the factors of manageability, extensibility and flexibility. It is used as the database for the online cardiac image repository system. The following figure 5 illustrates the data model for the application.

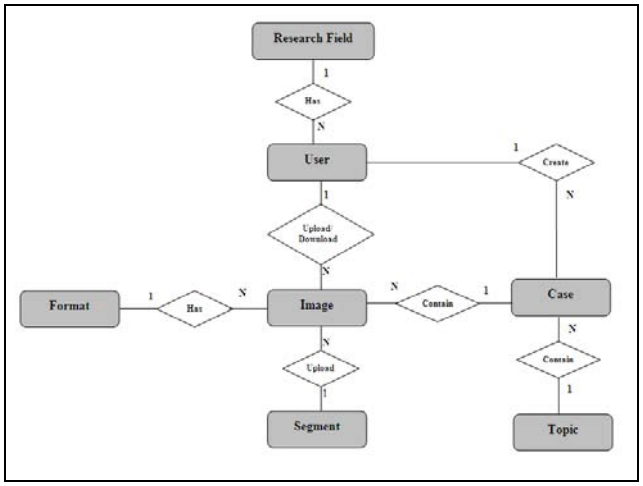

Fig.5 ER diagram for online cardiac image repository system

5.2 Module view of system

The main components in the online cardiac image repository system's module view are User Management, Security Unit, Image Management and Database Unit. User Management module comprises of functionalities of Authenticate User, Authorize User, Limit access and Profile user. Security Module consists of User Security, Data security, User access, Upload Limitation, Virus Check Module and Trace User.

Image Management Module includes main functionalities of Upload Data, Download Data, Search module, Viewer Manager, Segment module, Image Convert module, Format Module, Case module and Topic module.

Database Module contains Database Backup Module, which includes System Backup and Backup Scheduling, and Data recovery module. Figure 6 illustrates the module view of the system.

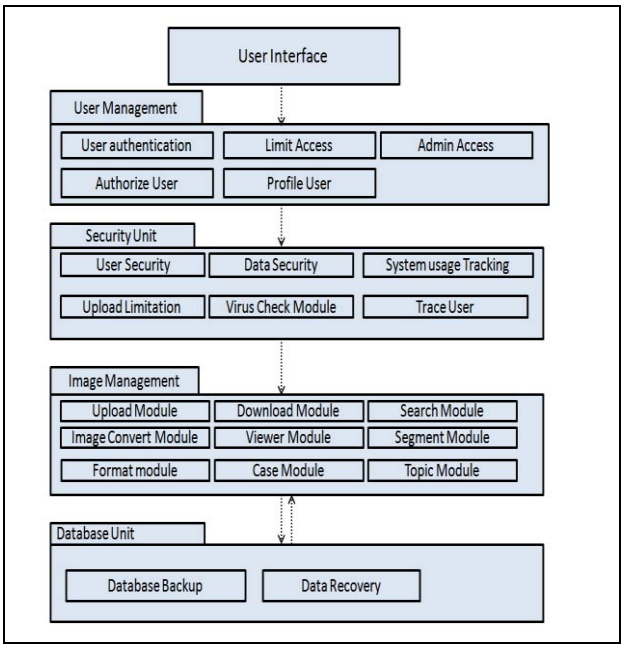

Fig.6 Module view of online cardiac image repository system

5.3 Functional decomposition of system

The functionalities of the on-line repository system are divided into two main categories; functions related to administrator and functions related to the registered user. User functionalities for the registered user consist of Login, Search, Upload, Topic, Case, and Profile and logout.

Administrator's functionalities comprise Login, User management, Data management, Information Management and Forum management.

User tracking is also considered under functionalities of the administrator. Figure 7 shows functional decomposition of online cardiac image repository system.

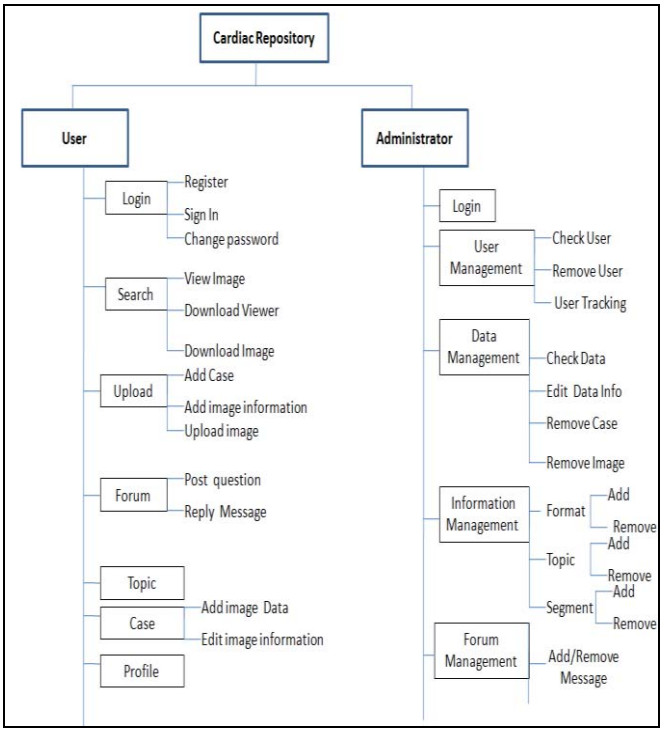

Fig.7 Functional decomposition of online cardiac image repository system

5.4 System Development

This section describes the brief explanation of two main modules of the online cardiac image repository system including the Upload Module and the Search Module. Screenshots of the developed system are provided for illustration.

Registered users can upload the image data into the cardiac repository. Therefore, to perform this functionality, user has to perform four steps. First, the user needs to identify and select the topic from the existing list. Topic is actually the categorization of images. For example the image data related to MRI data are categorized in one topic, while image data related to CT scan are categorized under another topic. If the intended topic is not in the list, the user can add new topic by selecting "Add New Topic module".

Next, the user is required to enter the information and description of the images that the user wants to upload. For the third step, the user will need to select the image data and upload it into the system. Only a few formats of images are allowed to be uploaded into the system such as JPEG, DICOM, ANALYZE, PNG, BTMP, TIFF, ACR and C. For the fourth step, the user will have to click on the "Finish" button and confirm the upload. The data will be published in the repository after it receives the approval from the administrator. Figure 8 shows screen shot of Upload page of online cardiac image repository system.

In order to enhance the accessibility of the uploaded data in the online cardiac image repository system, a search functionality has been implemented. Query by key-word has been used as a retrieval technique.
Data in the online cardiac image repository system can be searched by specific topic, case, segment and format. As a result of the search, a list of thumbnails of relevant images will be displayed. The registered users have the permission to download the original data while the guest users can only view the thumbnail of the images.
The screenshot of search page is shown in Figure 9 below.

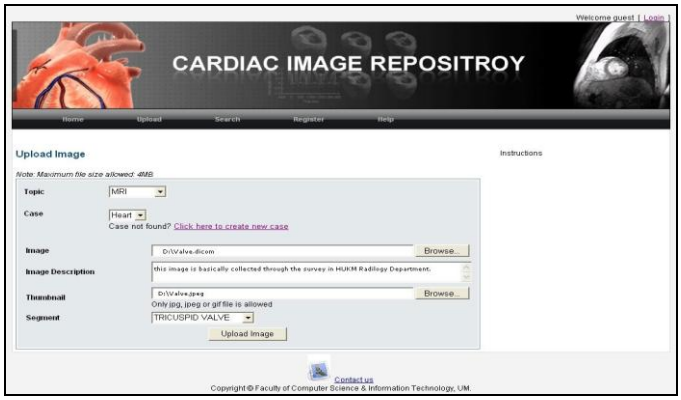

Fig.8 Online cardiac image repository system Upload Page

Fig.9 Online cardiac image repository system Search Page

The Administrator is the only user who has the access to the control panel of Online cardiac image repository system which is made up of Check user, Check data , Edit format, Edit segment, Edit topic, Check data and logout modules. Once the user registers in the system, the administrator will check the user information and give him/her the permission to access to the system. Administrator is also able to remove the user from the system, in case the user has broken any the rules stated by the repository system.

Fig.10 Online cardiac image repository system Control Panel

To enhance the reliability of data in the repository, before any data is published and made available to users, the accuracy of the data should be checked by the administrator. This can be done through "Check data" in the Control Panel. Likewise, new formats of data can be added in the system by Add format module in Control Panel. All data formats added through the Control Panel are available to users in both search and upload modules. Besides, Edit and Delete formats are also provided in the Control Panel.

Another module provided in Control Panel is the Segment management module. Through this module, the Administrator is able to add, edit or remove the segment types from the database. Administrator can also delete the segments in case the segment is no longer appropriate for repository.

Topics in the repository are the categorization of images. They can be suggested by the user or Administrator. New Topic should be checked by the administrator before it is published in the online repository. This can be done through Edit topic module in Control Panel. Figure 10 shows screen shot of Control Panel of the online cardiac image repository system

6 Limitations and Future Work

Up to this point in time, the online system has only taken into consideration image data captured from various modalities such as MRI, CT, PET and SPECT scans. However, there are various others formats of cardiac data that can be used for cardiac modeling such as ASCII flat files, video files, and so on. In order to include such data, a more complex data model is required, and this project is currently on-going to accommodate those types of data. Future work will include the use of ontology rather than key-word retrieval in order to optimize the searching facility [28].More work can be done to identify an optimize way to keep the image data in more accessible or higher performance database. Another possibility is to find a more structured way to keep the data images so as to accelerate the process of access if the amount of images increases.

7 Summary and Conclusion

The online repository system is a repository system designed to solve problems faced by a group of cardiac modeling researchers in sharing data that they have collected and processed. Many existing researchers have indicated their willingness to share their data with other authentic researchers.

Development of the online repository system was facilitated by the use of Attribute-Driven Design method (ADD), which is a method for designing software architecture to satisfy both quality requirements and functional requirements. Using ADD method, all system requirements especially quality requirements, functional requirements and constraints are considered as drivers in the design process, which produces the system's conceptual software architecture.

From the requirement analysis, the main functionalities of the online cardiac image repository system are extracted, which include downloading and uploading of data by registered users. With the availability of the data, researchers can spend more time focusing on the modeling processes rather than on the preprocessing and searching for data.

References:

[1] D. Metaxas, T. Chen, X. Huang, and L. Axel, Cardiac Segmentation from MRI-Tagged and CT Images, *WSEAS Trans. On Information Science and Apllications*, July 2004. pp. 587 – 592.

[2] A. B. Abdallah, H. Essabbah, and M. H. Bedoui, Shape analysis of left ventricle using spherical harmonics functions, *WSEAS Transactions on Computers*, Issue 1, Volume 5, January 2006, pp. 230-235.

[3] Computer Models of the Heart Can Help Cure Cardiac Ills, Headlines @ Hopkins, http://www.jhu.edu/news_info/news/home97/jul97/heart. html Accessed 15-05-2006.

[4] McQueen D.M and Peskin C.S, Heart Simulation by an Immersed Boundary Method with Format Second-Order Accuracy and Reduced Numerical Viscosity, *Proceedings of the International Conference of Theorstical and Applied Mechanics*

(ICTAM), 2000.

[5] Kohl, P., Noble, D., Winslow, R., and Hunter, P., Computational Modelling of Biological Systems : Tools and Visions, *Kluwer Academic Publishers* , 2001.

[6] The Bioengineering Institute, University of Auckland web site, http://www.bioeng.auckland.ac.nz/projects/projects.php Accessed January 2005.

[7] The Center for Cardiovascular Bioinformatics and Modelling website, http://www.ccbm.jhu.edu/ Accessed 10-01-2006.

[8] Strauss, E, P.B., 4 Dimensional modeling of the human heart, *Computer Analysis of Images and Patterns*, Springer Berlin: Heidelberg, 1995, pp. 376-383.

[9] Murray, W., et al, Building Biomedical Models Based on Medical Image Data : An Assessment of Model Accuracy, *Medical Image Computing and Computer-Assisted Intervention - MICCAI'98*, *Springer Berlin: Heidelberg*, 1998, p. 539.

[10] Antoine Rosset , et al., Casimage Project - a digital Teaching files authoring Environment. *journal of thoracic imaging*, 2004. 19(2): p. 1-6.

[11] C.S.Candler, S.H.Uijtdehaage, and S.E.deniss, introducing HEAL:The health education assets library. *Academic medicine*, 2003. 78(3): p. 249-253.

[12] Jon J. Campa, et al. System for the analysis of whole-bone strength from helical CT images, *SPIE*, 2004.

[13] Muller, H., et al., Evaluation Axes for Medical Image Retrieval Systems-the Image CLEF Experience, *ACM Press*, 2005.

[14] Wei Wang and P.M. Barnaghi. Semantic Support for Medical Image Search and RetrievaL, *International Conference on Biomedical Engineering (BioMed 2007)*. February 14-16, 2007.

[15] Cao, P., et al., An integrated medical image database and retrieval system using web application server. *international journal of medical information*, 2003. 71: p. 51-59.

[16] Power, D., et al. A relational approach to the capture of DICOM files for Grid-enabled medical imaging databases. *ACM symposium on Applied computing*, 2004.

[17] Marcos, E., et al., a database for medical image management. *Computer methods and programs in biomedicine*, 2007: p. 255-269.

[18] Gnaneswaran, S., *Application on the Structure and Measurement of Kay Cardiac Parameters from MR Images of the Left Ventricle*, Masters Thesis, Faculty of Computer Science & Information Technology, University of Malaya: Kuala Lumpur, 2003.

[19] Tan, S.Y., *Dynamic Cardiac Mechanics Based on Fiber-Fluid Model*, Master Thesis, Faculty of Computer Science & Information Technology, University of Malaya: Kuala Lumpur, 2005.

[20] Nasaruddin, F.H., Narainasamy, Selvanathan. Segmentation of Heart MRI using Pulse Coupled Neural Network (PCNN), *Proceedings of the Joint Conference on Informatics and Research on Women in ICT (RWICT)*, Kuala Lumpur, 2004.

[21] N. Shahcheraghi, A. Y. Cheer, and H. A. Dwyer, Computational Study of Blood flow Through the Thoracic Aorta, *WSEAS Multiconference: Mathematics and Computers in Biology and Chemistry (MCBC 2000)*, Montego Bay, Jamaica, 2000.

[22] Mooney,R., et al , The Construction of a Volumetric Cardiac Model for Real-time ECG Simulation, *WSCG POSTERS Proceedings, Plzen, Czech Republic*. 2003.

[23] Wünsche, B. and Young, A., The Visualization and Measurement of Left Ventricular Deformation Using Finite Element Models, *International Journal of Visual Languages and Computing - Special Issue on Biomedical Visualization for Bioinformatics*, VOL.14, NO.4, 2003, pp. 299-326.

[24] Messmer, P., Matthews, F., JACOB, A. L., Kikinis, R., Regazzoni, P. & Noser, H., A CT Database for Research, Development and Education: Concept and Potential. *Journal of digital imaging*, VOL.20, NO.1, 2006, pp.17-22.

[25] Tarawneh, H., ElSheikh, A., Lahawiah, S., A Proposed Software Framework for : Web-Based Applications Development in Small Jordanian Web Firms, *WSEAS Transactions on Computer Research, Issue 2, Volume 2*, February 2007 : p. 234 – 239.

[26] Bachmann, F. & Bass, L., Introduction to the Attribute Driven Design Method. *23rd International Conference on Software Engineering*, 2001.

[27] Bass, L., Clements, P. & Kazman, R *Software Architecture in Practice*, MA: Addison Wesley,2003.

[28] V. Detschew, A.-K. Kaeding, and G. Funkat, The Use of Ontologies for Medical Guideline Servers, *WSEAS Multiconference : Information Science and Applications (ISA 2002)*, Mexico, 2002.