An Online System for Sharing Image Data for Cardiac Modeling

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Abstract: -
This paper discusses the need to make available images of cardiac data that can assist in digital cardiac modeling research. Such researches are increasing in number to assist in the understanding of the heart. In modeling a digital heart, images from MRI, CT scans, and other scans such as PET and SPECT can be used. These images are difficult to come by for researchers who are not in the medical areas. Thus, any of such available data stored in an on-line system can be made available to other researchers. The design and development of this on-line system is discussed in this paper.

Key-Words: - online repository system, image data, cardiac data, cardiac modeling, digital heart model, data sharing

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, the computer has become a valuable tool to assist researchers in various ways. Using the 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 [1], [2]. As a result, the research in the field of heart study have attracted researchers outside of the medical field such as researchers from the bio-engineering, bio-mechanical, bio-medical, and also computing background. Many researchers have embarked on this journey and are finding ways to build digital heart models using digitalized data [3, 4, 5, 6, 7].

The data needed to build a digital cardiac model may come in many 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 paper is to present a possibility that these data can be made available to researchers in the area of cardiac modeling, by sharing them with each other. These data can be stored in a repository which can be made available either to all researchers or to limited groups of people depending on the needs of the users. This paper will begin with a short discussion on the approach used for this project. Then it will continue with a discussion on the findings which explains the types of data that are used for such researches, where these data

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can be obtained, and the availability of such data. It then discusses the model of the proposed system which will be followed by an explanation of the system which has been developed for the purpose of sharing these data. The paper will end with a discussion and suggestions for future enhancements.

2 Methodology
Before a repository for the datasets can be designed, first we need to understand the data and how they are used. 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 a particular research team is studied. The findings from the study are compared to the articles written by other cardiac modeling research teams to reaffirm the findings. After verifying that the data flow is correct and is acceptable for many research cases, requirement analysis is conducted. Based on the needs of users, a system architecture was designed followed by the system model. In this paper, the first version of the system is made available for discussion. However, the final system is still in development stage at the time this paper is written.

2.1 Problem Statement
This development work was triggered by the problems faced by a group of researchers of a virtual heart research team at 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, such cardiac data are limited and if available are very distributed. 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 also 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 [10, 11, 12].

It takes considerable money, time and effort to create datasets from scratch. Therefore, whenever the raw data has been processed into readable data formats, or 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 [13], cleaning up the data, and then reconstructing the same or similar cardiac models. The final aim of this project is to build a repository for such datasets.

2.2 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 person or team. This is apparent in many journal articles and in the study of the research group at FCSIT, UM [14,15].

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 (ie, geometric models) are required. So it can be concluded that there are some similarities in the usage of data for the purpose of building cardiac models a number of research groups.

The next question now is whether these data can be made available to researchers outside of the immediate research group. From the feedback received, many researchers on the whole are willing to share their data with authentic researchers. In order to accommodate this need, an online cardiac image repository system is proposed.

3 Design Methodology
The design and development of the online cardiac image repository system is carried out using the rapid prototyping approach. This approach is the most suitable 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. Even so, prior to the actual design and development, analysis of the users requirements are needed. The sections below will discuss the requirement analysis, the architecturally significant requirements, and the architectural pattern applied in online cardiac image repository.
3.1 Requirement analysis

The requirements analysis of the online cardiac image repository system is performed by using a method known as 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 [16]. It helps designers to comprehend quality tradeoffs as early as possible in the design process. Using ADD method, all system requirements, including 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 the analysis of the data, during the beginning of the requirement analysis, we have determined the types of data used by the research group can be categorized into raw data category, processed data category, and simple model category. 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. A lot of time has been used to pre-process the data before it 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.

As a conclusion, 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 ROIs or segmentations or other processors.

3.2 Architectural Significant Requirements

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

**System Access:** User should 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 should include 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 should be implemented as well.

**View Images:** User should be able to view the images of various formats using specific image viewers.

**Upload Images:** User should be able to upload the data into the system and let other user access the data.

**Download Images:** Valid users should be able to download images from the website.

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<thead>
<tr>
<th>Architectural Driver</th>
<th>Rationale</th>
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<tr>
<td><strong>Security</strong></td>
<td>Online System and specially database must be secure.</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>The system should be available 99% of the time because any downtime in system may have a negative influence on user trust on the system.</td>
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<tr>
<td><strong>Modifiability</strong></td>
<td>A new module that specifies for flexible requirements accommodation allows significant development of future sub system module modification to be featured.</td>
</tr>
<tr>
<td><strong>Data retrieval</strong></td>
<td>System should provide a search engine with different categories to help user to find their specific data.</td>
</tr>
<tr>
<td><strong>Upload Data</strong></td>
<td>It can help to enhance the quantity and quality of the data in the database.</td>
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Besides the functionality requirements, the quality requirements are also important to the development of a system [17]. Table 1 summarizes both the functionality and non-functionality requirements into the system’s architectural drivers.

### 3.3 Architectural pattern

The online cardiac image repository system architectural pattern consists of four main layers: The "Web Server" layer, which is responsible for displaying and reading data from “web client” layer, the "Image Repository Database layer" which has the responsibility of communicating with the database section, “Application Server” layer which comprises of three sub-layers: “User management" layer which has a direct access to the "Security layer", therefore the user can 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. By applying this pattern, the availability, 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 1 illustrates the layers mentioned above.

#### 4  Proposed Repository System

Designing an on-line repository system is challenging work. During the study and design phase, we faced many limitation and possibilities that requires design decisions in each stage. In this section, we will 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 will cover the design constrains in developing the system, the explanation of the module view of system based on the main requirements, and the prototype of the online cardiac image repository system.

#### 4.1 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, so 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 website.

On the other hand because of the strengths of SQL Server for storing and retrieving image data and other features including Manageability, Extensibility, Flexibility, we considered Microsoft SQL Server 2005 as the main database of online cardiac image repository system.

#### 4.2 Module view of system

The main elements 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 Authenticate User, Authorize User, Limit access and Profile user. Security Module consist of User Security, Data security, User access, Upload Limitation, Virus Check Module and Trace User.

Image Management Module includes 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 2 illustrates the module view of the system.

![Pattern for Online cardiac image repository (Layered, N-Tier)](image-url)
4.3 System Prototype

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 current developed system are provided to refer.

Registered users can upload the image data into the cardiac repository. Therefore, Upload module consists of four steps. Firstly the user needs to select the topic from the list and if the topic is not in the list, the user can add his topic form “Add New Topic module”. In the next step the user needs to enter the information and descriptions of the images that he wants to upload. After the user click on the next button, for the third step, the user should 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. In the last step user just need to click on finish button and conform the upload. The data will be publishing in the repository after the approval of the administrator. Fig 3 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 module has been implemented. Query by keyword 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 user has the permission to download the original data while the guest users can only view the thumbnail of the images.

5 Discussion of Limitations

Up to the point when this paper is written, 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 would include the use of ontology rather than key-word retrieval in order to optimize the searching facility [18].

6 Conclusion

The online repository system is a system designed and proposed to solve the problem faced by group of cardiac modeling researchers to share data which they have collected and processed. Feedback from the researchers indicated that they are willing to share the data with authentic researchers and would welcome any contribution from others. Thus, the online system allows for downloading and uploading of data to registered users. With the availability of the data, researchers can spend more time focusing on the modeling rather than the preprocessing and searching of data.
References:


