Honours Project Report

The E-Health Patient Record Management System

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Abstract

This thesis deals with the creation of an electronic, low cost, health care system primarily intended for use in Southern Africa. From our observations and interactions with hospitals within South Africa, we have noticed a need to update the systems currently in place. Currently, hospitals deploy a paper based record management system, relying heavily on files that are easily lost and are inefficient to use, ultimately to the detriment of the patient. Hospitals are becoming far more overcrowded and the possibility of human errors when processing these paper-based files is very real.

Through our interactions with real healthcare workers, we have devised a web interface that allows the creation of patient records, the ability to view ECG readings and the ability to add and read past doctor consultation notes. Our system also handles administration tasks by regulating who has access to what data within the system, as well as the creation and deletion of users of the system. Emphasis has been placed on creating a user-friendly system, as most healthcare workers are not familiar with computerized systems.

Our system was well received by the prospective users of the system when we presented it to them, and everybody surveyed felt that it would greatly streamline the working conditions within the hospital. As a result, more time can be spent consulting with patients and it is easier to query past data.
1. Introduction
The E-Health project deals with creating a low cost, non-intrusive medical system, primarily for use in South Africa, in order to help both health care workers and patients. The reason we devised this project is that it had become clear on our visits to healthcare facilities that a system needed to be implemented to update cumbersome paper based systems currently in use in most hospitals within South Africa. The use of Open Source technology has allowed us to develop this system at very little cost thereby benefiting the public.
We divided the project into three manageable sections, these are:

- The gathering of ECG data (electrocardiogram) through the use of Bluetooth sensors and displaying the results on a PDA.
- Storing this data securely in a peer-to-peer network.
- Creating a web based interface for a patient record management system that can create and manage patient records as well as display ECG readings sent by the peer-to-peer network.

This report deals with the last section, i.e. the patient record management system. The patient record management system is a key part of the project as it is the interface that majority of the users will interact with.

The nature of this project is primarily an HCI usability project that is focused towards the developing world. Thus thorough investigations with the prospective users of the system will occur and they will be heavily involved throughout the project’s lifecycle.

1.1 Key Features and Impact of the System
The Key features of the system are:

- A logically designed, user-friendly front end web interface
- A database storing patient records, doctor consultation details and access levels for specific users of the system
- The ability to visualize an XML file containing ECG data
- Administrative capabilities, i.e. manage users of the system
- Easy creation, updating and searching of the patient records based on Health care workers specific preferences.
- Layers of security that restrict users from accessing certain data based on their status within the system.
- The ability to add and view past doctor consultations
- A self user registration system that encrypts the users password

The expected impact of the project would be the creation of a stable system to illustrate to doctors and nurses of either hospitals or private practices, how an
electronic health care system would benefit them. The system will demonstrate, that by updating the paper-based systems that they are currently using, they will improve the care given to the patients by making their working environment more efficient.

1.2 Thesis Structure
This thesis is broken down into a number of sections, the next section is the background chapter, which identifies the pros and cons of creating an electronic patient record management system, a few real world examples of health systems in general as well as some theory behind some of the methodologies used.

The design chapter follows the background chapter, which outlines the steps taken to create a high fidelity prototype to be used to gather user requirements. The chapter also presents the user’s feedback of the prototype; and this is followed by a design specification for a working system.

The design specification would then be used to implement a working system, of which the system is explained in the next chapter, the implementation chapter.

We go on to test our system both by testing its features, and by conducting user investigations; this is outlined in the testing chapter along with the user’s feedback towards using the system.

Reporting the findings we made throughout the project’s lifecycle rounds off the thesis. Finally we give our conclusions and future work suggestions.
2. Background

2.1 Introduction
Advancements within the healthcare industry are happening at a rapid pace to cater for a rising number of people who suffer from daily afflictions and chronic illnesses. Technology has come to the aid in the form of providing storage for patient records and providing efficient ways to search for and access these records. Gone are the days of massive filling cabinets and long lines of people trying to obtain their patient records.

Unfortunately Southern Africa has been late in embracing this technology, for a variety of reasons, these are lack of funding, training and a stereotype that technology is exclusively to be used in the first world.

Currently most South African hospitals are extremely over crowded and understaffed. This leads to the patients ultimately suffering from the lack of attention. Patient's conditions can rapidly deteriorate while the patient is waiting to find his/her record, and thus a system that can store relevant patient data needs to be created so health care workers can act accordingly in a timely manner.

2.2 Medium of Display
The Internet has been used to display data over the last three decades and the concept of web applications is not new. Given its widespread use and ease of access, the Internet is an appropriate medium for the purposes that the E-Health project wishes to accomplish. The purpose being the presentation of data gathered by sensors as well as any other relevant data that health care workers might require. Very little development of this nature has gone into the medical field and very few systems that keep track of vital signs online exist, thus an opportunity is created to help people in hospitals better manage patients and ultimately save lives.

2.3 Human Computer Interaction (HCI)
A lot of research into what exactly customers require will have to be done in order to produce an effective solution. User specifications are an incredibly vital part of web application design and thus should not be taken lightly. Questionnaires and heavy user involvement during the design phases of the project will need to ensue.

Usability is often overlooked by software engineers [1], and is extremely important. Too often developers make software that is unusable by end customers simply because the developers failed to cater to the customers needs. Henninger et al [1] outline two guidelines that developers should follow for effective software, that being style guides and usability guides. Style guides are used to develop consistency across applications. Usability guidelines are those, which are followed by using techniques such as participatory design and user validation.
The nature of this project requires heavy interaction with medical staff. These healthcare professional’s time is extremely valuable as they are working to save human lives. Thus it is extremely paramount that efficient user centered design principles employed.

2.4 Heuristic Evaluation

Heuristics are experience-based techniques that help in problem solving, learning and discovery. Ben Nielsen states [2] that the use of heuristics can greatly alleviate costs and improve usability of interfaces. He further mentions that different ‘evaluators’ of differing skill sets access a system, these are novices, ordinary specialists and advanced specialists. Thus three different skill sets need to be catered for with the goal of leading everyone to advanced specialists. Nielsen [2] points out some of the most valuable heuristics as follows:

* Simple and natural dialogue
* Speak the user’s language
* Minimize the user memory load
* Be consistent
* Provide feedback
* Provide early marked exits
* Provide shortcuts
* Good error messages
* Prevent errors

2.5 Web 2.0

Web 2.0 is a new direction the Internet is taking whereby Internet applications are changing to cater for a more user-defined experience [3]. That being users have become the producers of content and the designers of each other’s viewing experience. Thus the users take ownership in the system once deployed, and providing further reason in involving them in development stages and incorporating the former mentioned heuristics. A web application deployed in a medical setting will take on this form, as doctors and nurses would be in charge of managing the content within the website, and thus ultimately controlling how the website would function.

2.6 Record Confidentiality

Patient records and any data pertaining to a patient are deemed to be confidential. A system dealing with such data needs to be protected from intentional and unintentional misuse of this data. Thus any access of data needs to be controlled and regulated if it is to comply with medical standards.

2.7 Assessing a Computer Based Record Management System

Lehnart et al. [4] defines a patient record management system as a system that
stores demographic, and medical information from ancillary services such as registration, lab, radiology, pathology, pharmacy, consultation and transcription. They state that a record management system is not simply automated updates of paper based charts, but rather a dynamic system used to help health care workers make better informed dragonesses.

According to Gaillour et al. [5] a record management system is only effective at achieving the goals of increasing quality of care and lowering costs if the organization re-designs it’s current workflow and practices. Hence a very user-friendly system needs to be created to mitigate the risk of user dissatisfaction towards the new system.

Fromberg et al. [6] claim the clinical benefits to such a system include:
* Easier, more rapid access to patient data charts
* Improved clinical decision making and disease management
* More educated patients about their own ailments
* An increase in time to spend consulting with patients
* An increased perception of patient care and theoretically a better working environment

All these benefits overall translate to better patient care. More benefits include a more efficient workflow, as duplicate tasks would not be performed as the need to re-gather information would be eliminated as all data pertaining to the patient is readily available at all times. Time taken to execute administration functions, such as capturing patient demographics, drop dramatically. According to Dassenko and Slowinski, [7] an average of up to 15 minutes was saved per patient on the patients first visit and a further 20 minutes on each subsequent visit as a result of implementing a computer based patient record.

There are however some challenges when developing a record management system. The main hindrance of which is the initial startup cost. Hardware, software and training make up the bulk of this cost. While there has been a reported high return in investment [4], the initial costs and the fact that is a large change from the current system often scare away would be investors.

As healthcare is a governmental responsibility, heavy support is required by them in order to have wide spread deployment of such a system, and according to Drazen [8] this is lacking and is another reason why so many hospitals still use paper based systems today. Data security has also been a main issue although Bergman [9] states that when compared to a paper based system, password based file access can actually improve the internal security.

2.8 Similar Projects

It is useful to analyze similar projects in this field to utilize successes and learn from mistakes made.
2.8.1 The Salford Diabetes Information System

The Salford Diabetes information system [10] is a system developed in Britain to store and monitor around 200000 diabetic patients. The system stores relevant patient data pertaining to that individual patient and can be accessed by a doctor enquiring the record. The data stored is specifically aimed for diabetic patients and as a result diabetic patients were consulted when developing the system. The system makes use of a number of security features in order to keep the data stored within the system secure and can be summarized in Table 1:

<table>
<thead>
<tr>
<th>Problem</th>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>User authentication</td>
<td>How does the hospital system know that a remote user’s identity is genuine?</td>
<td>Strong user authentication</td>
</tr>
<tr>
<td>Establishing access rights</td>
<td>Which parts of the database does a known user have access to?</td>
<td>Access controls on the database</td>
</tr>
<tr>
<td>Unauthorised data capture</td>
<td>How do we ensure that no one can take a copy of data being transferred across the internet from the hospital system to a remote user?</td>
<td>Strong encryption of messages</td>
</tr>
<tr>
<td>Entry into the hospital network</td>
<td>How do we protect hospital intranet from unwanted traffic entering it while allowing wanted traffic to pass through?</td>
<td>Firewall between the intranet and Internet</td>
</tr>
<tr>
<td>Easy to use interface</td>
<td>How can we develop a simple yet secure interface that most users will be familiar with and will need minimum training to use and that is low cost?</td>
<td>Web browsers</td>
</tr>
<tr>
<td>Correct data source</td>
<td>How can remote users know they have accessed the genuine hospital system and not a site masquerading as the hospital?</td>
<td>Strong authentication of the hospital system</td>
</tr>
</tbody>
</table>

Table 1. Salford Information System features

The main points of the system is restricting access to the records by providing layers of security within the system that is accomplished using user authentication. The layers used were ‘general practitioner’ and ‘consultant’. Each group had access over certain portions of the data. A database holding information regarding these statuses was created and checked whenever a user logged into the system.

The patient record forms were designed in HTML by taking actual paper based forms that doctors would use, then converting them into an electronic format. The system made use of a SQL database to store information collected by these forms. According to the report, editing patient data could take weeks by means of the regular paper based system, and now the system takes care of this almost instantaneously.

The project was deemed to be a success and it was suggested that it could be extended to include all patients, rather that just diabetic patients. They concluded that redundant files and duplicate investigations were virtually eliminated thus saving time and money to both the hospitals and the patients.
2.8.2 SMART

Curtis et al. [11] outlined a medical system known as Scalable Medical Alert and Response Technology (SMART). SMART’s purpose is to monitor various physiological signals from patients in the waiting areas of a hospital. Specifically, it measures the SpO2 content within the blood stream (oxygen level in the blood), the ECG activity and the patient location at a given time. The project ran for over a year (June 2006- December 2007) in a hospital located in Boston Massachusetts.

The main aim of the sensors was to monitor patients in the waiting room. A wait can range up to 3.2 hours in the Emergency Room alone [12]. During this time, a patient’s condition can deteriorate rapidly. Sensors send data to a central server, and if an abnormal situation arises, suitable personnel can be alerted. With this architecture, there is a very strong possibility that the central server can become overloaded, or worse, fail completely, which could result in loss of life. The architecture involved sensors located inside a waist pack worn by the patient which connected to a PDA wirelessly. These PDAs would transmit to the caregivers PDA data pertaining to the patient.

SMART’s interface is not web-based however; it is all operated in-house and all under one central server. This could be problematic under high demand.

As mentioned earlier a lot of medical research has to occur so as to know when to flag emergency situations. SMART has managed to outline a few situations and these are given below:
Table 2. SMART Alarm causes

<table>
<thead>
<tr>
<th>Oximeter Medical Alarms</th>
<th>Condition that triggers the alarm</th>
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</thead>
<tbody>
<tr>
<td>High HR</td>
<td>Heart rate from oximeter sensor above patient-specific threshold</td>
</tr>
<tr>
<td></td>
<td>(default: threshold is 100bpm)</td>
</tr>
<tr>
<td>Low HR</td>
<td>Heart rate from oximeter sensor below patient-specific threshold</td>
</tr>
<tr>
<td></td>
<td>(default: threshold is 60bpm)</td>
</tr>
<tr>
<td>Low SpO₂</td>
<td>Oxygen saturation below patient-specific threshold (default: threshold</td>
</tr>
<tr>
<td></td>
<td>is 90%)</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>ECG Medical Alarms</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Asystole</td>
<td>No beat detected in 3 seconds</td>
</tr>
<tr>
<td>VT</td>
<td>ECG shows artifacts, abnormal skewness, wide waves or no waves,</td>
</tr>
<tr>
<td></td>
<td>lacks QRS complexes, and the SpO₂ heart rate is missing or below</td>
</tr>
<tr>
<td></td>
<td>20bpm or above 150bpm</td>
</tr>
<tr>
<td>VT</td>
<td>ECG has wide QRS complexes and heart rate is over 100bpm</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>ECG heart rate above patient-specific threshold (default: threshold</td>
</tr>
<tr>
<td></td>
<td>is 100bpm)</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>ECG heart rate below patient-specific threshold (default: threshold</td>
</tr>
<tr>
<td></td>
<td>is 60bpm)</td>
</tr>
<tr>
<td>Irregular</td>
<td>ECG QRS complexes are irregularly spaced</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Alarms</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mismatch</td>
<td>ECG diagnosis inconsistent with SpO₂ heart rate</td>
</tr>
</tbody>
</table>

2.8.3 ECG Wrapper

Gonçalves et al. [13] propose a system to tackle the problems of patient home care. They devise a web interface that is linked to a patient's data sensors, providing real time ECG updates to them. The interface of the system comprises of an “ECG Wrapper” whereby a number of layers interact to deliver data to the user. The GUI allows a user (Doctor or patient) to enter personal data, and to add any additional records. This interface links with a wrapping layer that combines with data acquired by the sensors (Data Processing Layer) and converts it into a readable format for the web interface (classified as the delivery layer).

The delivery layer publishes the ECG data on the Internet for the users through a web service. The user has to actively specify on the web when an ECG recording session is to begin. Data about the session as well as the actual session is recorded. All this data is stored in an XML file and is sent to a database. Any user can then invoke a get command to obtain this data. A notable point is that there is a time delay when sending XML data around the layers. The system was said not be meant for long-term usage.
2.9 Conclusion

To conclude we can take what is currently in the market and build upon it for our E-Health system. Of course a number of usability surveys will have to be done for the intended market as it differs from the aforementioned systems, which were developed in the first world. The Salford Diabetes system [10] presents us with a good foundation on how a web based record management system should behave and would be a good basis when designing our system except we would extend it to cater for all patients and not just those with diabetes.

The visualization of the data will include the pros outlined by the current systems reviewed. That being, easy to use Web interfaces that presents data in a logical manner. The web interfaces should also be able to be accessed at any time and all relevant data displayed in the form of online records, line graphs and any other mediums that the health care workers see fit.

We have seen the pros and cons of implementing a patient record management system. Implementing such a system would most probably improve patient care and provide better job satisfaction for all the relevant stakeholders involved, and although paper based systems still get the job done, there is reason enough to implement an updated system, with South African requirements in mind.
3. System Design

3.1 Introduction

This chapter outlines the process we took in gathering information in order to design the best possible E-Health system. We will look at the design methodologies used as well as the UML models of the final design of the system.

The first step in the iteration was to design a high fidelity prototype consisting of non-interactive displays detailing how the potential system might look and behave.

When designing final the system, one has to take into consideration the users wants and needs. We as computer scientists have little idea of what medical practitioners actually need, and hence our assumptions could be incorrect. The only way to gauge these assumptions is to interview these healthcare professionals on how it would be best to improve our prototype into something of use to them.

As the projects focus is a usability priority project, the design methodology we used is an iterative development process. The sequence of events for each iteration is as follows:

1. Gather user specifications
2. Design Iteration of the system
3. Implement iteration of the system
4. Test iteration to check suitability
5. Evaluation by users
6. Repeat from Step one until a viable system emerges.

This methodology is also known as stepwise refinement and is very effective in a usability project, as users are heavily involved with the creation of the system, and are consulted multiple times in the design process.

As outlined in the background chapter, User Centered Design principles were deemed the most effective way of creating effective software for our users: - Health Care professionals (doctors and nurses).

3.2 Design of the Prototype

The first Iteration of our system began by designing and implementing a high fidelity prototype.

For the design of the prototype system, we selected components from similar systems (e.g. The Salford Diabetes Information System [10]). We planned to have a web interface that displayed data taken from a variety of sensors and provide the ability to the users to search through this data using a number of search criteria.
We also had some informal interview sessions with two doctors outside of working conditions to gather their thoughts on how the system should be implemented. In the interview we explained the project proposal. There input was that they thought the project was very interesting, but they worried that the project would not have any real industry use if displaying sensor data were the only focus of the project. We took what they said into consideration and proceeded to design the prototype website.

3.3 Implementation Of the Prototype
A medical system will store large quantities of data (Images, patient records etc.) and thus needs to play a huge part in considering a solution. There are currently a number of database systems available on the market today such as Microsoft SQL Server, Oracle SQL and MySQL database systems. It was planned at the start of the project to use a peer-to-peer database system to store ECG data for scalability reasons.

The prototype website implementation was accomplished using HTML, (Hypertext markup language) the foremost language used for web pages [14]. It allows users to create structured documents by specifying semantics for text such as headings, paragraphs, lists as well as creation of external links. It allows images and objects to be embedded and can be used to create interactive forms.

The prototype website itself used images of data rather than actual data and lacked the ability to actually process data. The reason behind this decision was for rapid deployment of the prototype coupled with our uncertainty of whether or not our prototype would be favorable towards the healthcare workers. The screenshots of the prototype system can be found in Figures 1-4. The prototype itself outlined the capability of the website to display the sensor information.

![Figure 1. Login screen](image)
Figure 2. The Home Page

Figure 3. Search Screen
Figure 4. An Example of a Patient Record

The screenshots show the login page, Figure 1, where we would explain that each user had their own login details that had to be entered in order to access the website. Figure 2, displays the homepage which serves as a base of operations for the website. Figure 3, shows the searching functionality envisioned to be implemented in the final system, that being searching by name and sensor data. Finally, Figure 4 displays how we think a patient record would look in the final system.

3.4 Testing The Prototype

In order to test the prototype before presenting it to the users, we ran through each of the pages and made sure links were correctly mapping to the desired page. The next step was to test this prototype on potential users and gather their thoughts and opinions.

3.5 User Evaluation of the Prototype

We interviewed five health care professionals to gather as much information as possible to create an effective system. Given our lack of medical experience, the information we received was valuable, and difficult to obtain any other way.

When it came down to actually speaking to the prospected users, a lot of problems arose. It was fairly difficult to schedule a time to see the doctors and nurses, who are very busy. Eventually the five individuals we were seeking were interviewed, comprising of three doctors and two nurses, all from the Red Cross Memorial Hospital, Cape Town.

The prototype website was taken to the healthcare workers and demoed to them, this coupled with a questionnaire (Appendix A), formed the material that was to be used to conduct the interview.
3.5.1 General Observations

Unfortunately no photographs were allowed to be taken inside the hospital. The first thing that was noticed when entering the hospital was a lot of people waiting at the reception area. One individual standing in the multiple queues was questioned on what she was waiting for, and she promptly responded that she was waiting for her patient record to be found and she had been waiting for at least ten minutes after which she expressed her discontent. The hospital’s record system was fully paper-based, with the exception of the finance system.

The general course of events from when a typical patient enters the hospital until when he/she leaves is summarized in Figure 5:

![Figure 5. Current System Activity Diagram](image)

Analysis of this diagram shows a heavy reliance on physical delivery of the files. At each of these points, the risk arises that files are misplaced or lost ‘under a stack of other files’ as one doctor put it. This is particularly the case when it comes to the external doctors, i.e. sometimes tests such as x-rays occur but do not get recorded.

The roles and responsibilities of the actors in the current system are summarized in Figure 6.
Figure 6. Current System Use Case Diagram

From this diagram, one can see how each role interacts with the system. Special attention must be paid to the fact that a patient cannot ever really see their file, and that the system is entirely paper-based.

3.5.2 Interviews

The first interviewee was a pediatric doctor who had also spent some time in the intensive care unit. She was very interested in the system and offered a lot of suggestions to add once everything had been explained. She noted that most of the history of sensor based information was not very useful to doctors as they would prefer to take their own present data. The exceptions were blood pressure levels and blood glucose levels in diabetic patients. She also stressed the need to upgrade the hospital's record system, as it was very cumbersome. She stated that hospitals would be the main users of such a system, as opposed to old age homes or patient's homes, and said that it could easily be extended to a private practice as well. She thought that both nurses and doctors would make use of the system, but nurses slightly more. When asked if she foresaw any problems with the system, she noted power outages and system failure as they main points of concern. She thought that only doctors and nurses should be able to view the patient data, given its confidentiality, and that password protection should be sufficient. Other Fields she recommended were Hospital ID number and Date of birth. She also noted that she could not think of a practical situation where one would need to query patients based on vital signs, unless it was for research purposes. Thus the search function could be simplified to search either by name, surname and hospital ID (A number each patient is assigned to avoid name collisions). She said if we were to pursue the system to be used for research purposes then to condense the search criteria into combo boxes otherwise the
interface would get too cluttered. She then suggested that by changing the direction of the project to focus on patient record management, a more useful system to the healthcare workers would emerge.

The second interviewee was another doctor who deals mainly with respiratory infections. The doctor was a little intimidated by the demonstration of the prototype. She thought the only important sensor to use was the temperature sensor, and that all the other sensors were very specialty specific, i.e. ECG for cardiologists. She said that such a system could fit in any clinical setting. She thought that mainly doctors would use the system. She couldn’t think of any problems with the system but said it would be a steep learning curve for her, as she did not like to use computers very much. She said that we should add some functionality to record notes from a patient consultation to the patient records.

The third interviewee was a nurse who had grown accustomed to the paper based system but thought the idea of modernizing to reduce waiting times and ease searching for records was a brilliant idea. She said that she would be interested in seeing mainly blood pressure data and any abnormal data found in tests prescribed by doctors. She also said that the system could be implemented in any health care centre. She thought that both doctors and nurses would use the system equally. Her concerns for the system were the effort required in training the staff to use the system and the contingency plans for system failure. She also said that the system should find the records in a timely manner and if it did this it would be ‘brilliant for administration’. In terms of access to the information, she thought that the nurses would access certain information and more information would be accessible to the doctors (Consultation notes). Thus a two-tiered security system would need to be put into place for access control. She said that the system needed to include information about diagnosis done by the doctor as well as if any external tests were done (e.g. x-rays ultrasound etc with dates included). Her final thought was that the patient should also be informed of what is going on and some form of information divulged to them, her example was on how to use certain medication.

The fourth interviewee was an allergy specialist who had many thoughts on the topic. She had heard of electronically updating patient records and the means to use them online, and was waiting for such a system to come to South Africa. She thought that sensor information was not particularly useful and that background history of the patients was more important. This was to include previous serious illness diagnosis and any ‘red flags’: that being allergies, drug cross-reaction sensitivity, diabetes and HIV diagnosis etc. She gave an example of an old man that had 18 visits with different doctors within the hospital and as a result had a huge file that was incredibly hard to use, and thus was sent on a few duplicate tests and x-rays for no reason. Thus a system that outlined important diagnosis on a computer screen would mitigate such a situation. She thought the best place to install the system would be in a day hospital or general practice. She stated that nurses and doctors would use the system equally. Her main concern was confidentiality, and that a two-tiered system needed to be put into place that allowed access based on the individual logging in to the system and thus display only relevant information. In terms of searching functionality, she said to remove searching for specific vital signs. Patient name searching should still be present.
as well as ID searches. She suggested that an extension to the system would be to link it to the financial system as well as the pharmaceutical dispensing system. For finance it could have certain billing conditions outline on the form (e.g. if the patient has medical aid or not) The pharmaceutical dispensing system could be put into place so as to alert doctors if bad reactions will occur if certain drugs are prescribed that do not go well together. The doctor concluded that if an electronic patient system were to exist it would save cost and time. She stated that currently they have to rely on files being delivered throughout the hospital that take a day on average to obtain, or through tedious phone calls in emergency situations. She further stated that investigations would not be repeated and that we should also add a section for doctor notes (Consultation notes).

The final interviewee, a nurse, had very similar views on what the prospected system should be. She, too, thought it should be implemented in a hospital. She also thought that most sensor data was not too useful and should rather be substituted with patient history of what tests and the results they underwent (e.g. patient went for a chest x-ray for tuberculosis and was found to be normal etc.). She thought there would be equal usage amongst the staff and could not see any problems with the system. She thought a password system should be sufficient for keeping files secure.

It was interesting to note that all three doctors had heard of an electronic patient recording system before, whereas both the nurses had not. This is probably due to the fact that the doctors are more internationally exposed to technology.

3.6 User Requirements Conclusions

Thus, from the user's specifications we can see that there is a need to update the cumbersome paper-based filing system into an electronic system. The focus of the system would be to display patient diagnosis data and external test data rather than just visualizations of sensor data. Security should play a huge part of the system and the users themselves suggested an access control list type of security system allowing levels of data to be accessed depending upon the level of clearance an individual had. The general consensus was that an electronic web based system, would save time and money for both patients and staff. If an effective system were to exist, the hospital would run much more efficiently, thereby improving the livelihood of patients and allow the health care professionals a means to do their jobs more effectively, thus it is justified to carry on with another, more refined iteration.
3.7 Design of The New System

The second iteration in the life cycle of our system began by taking the specifications obtained by the users while evaluating the high fidelity prototype and outlining the new system, which is a web based patient record management system.

3.7.1 Components of a Web Application

Most Web applications utilize a three-tiered architecture: the main interface layer which users interact with, the business logic layer which handles user queries and actions, and the data layer which is responsible for storing the data to be used in the form of a database.

PHP is a widely used, general-purpose scripting language that was originally designed for web development, to produce dynamic web pages. Thus PHP was chosen rather than HTML for the final system design, as it is a more powerful language to process forms and link to databases, thus allowing more functionality. Security implementations would also be more robust in a PHP page, thus strengthening the reason for the change.

3.7.2 Security and Administrators

As previously mentioned, security is very important within the system. Various ‘layers’ of security need to be created according to the user accessing the data. Thus an access list needs to be created. Currently the system has minimal security features and files are kept in a filing cabinet. A web interface will improve security from within the system, as it will restrict access of these files to only the relevant people via a password protection scheme. There is never perfect security however, as it is always possible to break ones password, but with proper instructions on password creation, it could prove to be very difficult to do so.

An administrator role to monitor the system will be created. This administrator will be responsible for managing access control lists as well as general functionality of the system.

3.8 Overall System Design

From the above facts we can devise the way the participants in the new system should be in Figure 7:
The major changes from the prototype are:

- The fact that a new actor is introduced to the system: an administrator whose purpose is to manage the site, as well as set up the security layers within the system. If one individual needs to access more data about a patient than they have access to, they would contact the administrator to get clearance.
- A patient can view certain bits of his/her file as well.
- Everything is now electronically based, thus hopefully easier to access and backup
- More emphasis on creating a patient record management system, as opposed to sensor monitoring
- Modify the searching to be by name rather than by sensor data

These changes were justified by analyzing the user feedback given to us in the preceding iteration.
The system itself will be as follows:

![Design Class Diagram of the Proposed System](image)

**Figure 8. Design Class Diagram of the Proposed System**

The design class diagram in Figure 8 outlines the overall structure of the proposed system. The system will rely on different classes of people. As seen in the use case diagram, these different people will have different abilities within the system. An important note is that each of these classes will be allowed access to certain files i.e. a patient has access to only their own file, nurses will have access to all files but not consultation notes and doctors will have access to everything. Administrators will have access to the administration section of the system where they have the ability to change access rights and manage the users of the system. Each individual would have to be given a unique identifying number as well.

A session is a single instance of the web site, and hence multiple sessions can exist. The web site uses a local server that hosts the website over the Internet.

To conclude, a summary of the proposed system is to update the current paper based system within a hospital into an electronic, dynamic system that caters for the needs of the health care professionals found during the analysis stage. These needs include:

- Various layers of security implemented by dividing the website into clear areas that can only be accessed by certain roles, e.g. doctors can have access to all patient data and consultation notes, whereas nurses can only access the patient data.
- Ability to create, read, update and delete files easily
- Ability to search through files quickly
- Ability to add consultation notes to a patients file
• Ability to store relevant data according to the patient, e.g. blood pressure at a specific visit
• Have the Administrator manage the users of the system easily
• Have the users self register in order to use the system

3.9 Database Design

The database containing all the user and patient data forms the heart of our system and thus special attention must be made in designing the tables to be used by our system. The system would require the use of three separate tables, with foreign keys to link the tables together. A table would be created to store the user data, i.e. the data required for any user to log into and use the system. The second table to create would be a patient table storing all the necessary details a patient in a hospital setting might have. The final table would be to store the consultation data that a patient would have with a doctor. The table structure can be summarized in the following entity relation diagrams; PK indicates the primary key for the tables and FK are the foreign keys to link the tables together:

![Entity Relation Diagram]

Figure 9. Entity Relation Diagram of the Database our System uses
3.10 Website Design

The website was designed to have the following structure:

![Diagram of website structure]

Figure 10. Status select

Figure 10 shows the idea that a prospective user of the system will choose his/her status in order to enter the relevant section of the website, each section is planned to have a login screen to filter out unwanted guests.

![Diagram of login process]

Figure 11. Doctor/Nurse section

Figure 11 shows the capabilities and sequence of events a healthcare worker goes through within the system where each bubble represents a new web page within the site.

![Diagram of patient section]

Figure 12. Patient Section
Fig 12 shows the capabilities a patient can use in the system, i.e. only view his/her own record.

![Diagram](image)

**Figure 13. Admin Section**

The Admin section allows the admin to edit the users of the system, thus controlling access to the system, as well as deleting any users that should not every use the system.

### 3.11 System Requirements

#### 3.11.1 Hardware Requirements

As the system is an electronic record management system, there will be some basic hardware requirements:

*A computer server: - Used to store all the E-Health Website files including the MYSQL database where patient consultation and user data will be stored. This server will thus host the E-Health website for the healthcare workers to access.*

*A Reliable ADSL router or other form of Internet connectivity: - This will be used in conjunction with the server so that the E-Health system is online at all times*

#### 3.11.2 Software Requirements

The software required in order to operate the E-Health record Management system is as follows:

*The Actual E-Health PHP pages loaded onto the server: - This includes all the necessary interfaces that interact with the Health care workers and patients, as well as the back end administration system that deals with the user access controls*
*Database software: - The database software used is MYSQL server. MYSQL server is a free open source package that is trusted and widely implemented by many web developers. In order to use the MYSQL database easier, a graphical user interface called PHPmyadmin was used to interact with MYSQL to create the necessary tables to be used as outlined in the design chapter. MYSQL can be found at www.mysql.com and phpmy admin at www.phpmyadmin.net

* Web server Software: - In order to host the Website server side software needs to be installed. The web server directs all incoming traffic to the appropriate file by using the servers IP address. We decided to use Apache web server, also open source and widely used. Apache is available at http://www.apache.org, once installed, the apache web server needed to be configured to handle PHP pages. Adding a PHP package to the web server did this. This was found at http://www.php.net.

3.12 Database Security
Entering in a username and a password accesses the MYSQL database located on the server. It is envisioned that the administrator only would have access to the MYSQL database and it is his/her responsibility to assign an appropriate password to access it and change it on a monthly basis to prevent anybody from maliciously entering the system.

3.13 Conclusion
The next step in the software development lifecycle is to take all the design specifications outlined by the users and implement them in a working system. We feel confident that we have designed a system that would meet the users requirements and implementation can proceed.
4.0 Implementation

4.1 Introduction
This chapter builds upon the preceding chapters design specifications, and outlines the steps we undertook to create a working system as well as illustrate the website’s functions and features.

4.2 The Implementation Process
In order to begin the whole process all the necessary software needed to be installed onto our testing server. Once MYSQL and Apache was installed and configured, the tables outlined in the design chapter were created to store the data entered in by the website.

The next step was to create all the necessary PHP pages to be used as the website.

The website development was divided into four sections, namely the patient access record section, the Doctor/nurse system section, the user registration/login section and the admin section.

Figure 14 summarizes the entire web site in the form of a site map.

![Figure 14. Site Map of the E-Health Website](image)
4.2.1 The User Registration/Login Section

This section of the website deals with creating users that will use the system (i.e. the doctors, nurses and patients) thus web pages in this section interact with the users table created in the MYSQL database. The section also deals with verifying the users of the system so that there is a layer of security in place.

A simple login screen, Figure 15, was created prompting the user to chose the area of the website he/she wishes to visit.

![Login Screen](image)

**Figure 15. Login status screen**

Once the user chose the appropriate link, he/she is redirected to the appropriate login screen.

Patients are prompted to enter their login details i.e. username and password, in order to access their own individual record. If they do not possess login information, they have to register their name in the system. A registration page was created, Figure 16, such that the patient enters all the required fields. The patient is stored in the system and their status is set to ‘patient’ meaning they only have access to their individual record and not the actual patient management system.
The registration page makes use of a number of PHP functions. Firstly it uses the INSERT SQL command to insert into the users table. Secondly it checks the existence of duplicate user names and prompts the user if one is found, this is so collisions cannot exists and data integrity is always intact. The third function encrypts the users entered password and stores it in the database as an encrypted string. The encryption algorithm used is a one-way AES encryption algorithm. This provides a high level of security, as even the administrator would not know what the user password is. The downside to this is that if a user forgets his/her password it will be impossible to retrieve. To counter this it is hoped that the user will fill in the contact details section of the registration form so if this problem arises, the administrator can issue a temporary password until the user can change it again manually. In order to prevent unnecessary spamming of the users database, many input validation checks are used. The first of which is that a user always has to enter a first name, surname, date of birth, password and username, as these are vital fields. The user also has to enter the password twice so as to prevent typographical errors of the password as the field is masked and the user has know way of seeing if his or her password is spelt as he/she wished. The format of the date is also checked. If any mistakes do occur the user is notified of what the error was and is asked to rectify it. The username and password length are also checked to make sure that a secure combination exists and a username and password less than 6 characters is disallowed. Figure 17 shows some sample error messages generated when some fields were left blank.

The exact same process outlined above is used for the health care worker registration. The exception being is that the status of the user in the user table in
the database is set to ‘unknown’ and the user will not have access to any part of the system. This is to prevent any random individual from accessing the confidential information present in the system. The administrator then has to physically verify the healthcare worker by contacting him/her and checking that it was actually the correct individual trying to register into the system. Once the user is verified, he/she has access to the system with that username and password.

The admin login screen is a simple login area that checks the administrator’s password and verifies that he/she is actually the administrator. The administrator is assumed to be a trusted individual hired by the hospital to control who has access to the system. He/she cannot actually access the system itself but controls who can.

4.2.2 The Patient Record Access Section

Once a patient has logged into the system successfully, he/she has only access to his/her record fully and not the system itself. The way this occurs is through the use of a shared key within the database. The patient enters his/her user name; this username is checked with the username of the patient file in the Patients database. The data pertaining to that patient is then displayed. In order to get the consultation data, another shared key, the patientid, is used. A record set containing each consultation that the patient has undergone is displayed. A navigation bar to page through the consultations is also provided as well as the navigation status (i.e. total number of consultation’s and which consultation is displayed). Almost all data displayed is dynamic and is received from the database, e.g. all the fields are filled with the relevant data and the patient is greeted by name.

The SQL queries used to extract data from the database are as follows:

For the patient information

SELECT patientid, name, surname, chronic_conditions, medication, allergies, username
FROM Patient
WHERE username = colname

And for the consultation information

SELECT *
FROM Consultation
WHERE patientid = colname
ORDER BY `date` DESC

Where colname is the patient id number of the logged in user
There is also a logout function that clears the colname so that another user could log into the system.

4.2.3 The Doctor/Nurse System Section

Once the doctor/ nurse logs into the system, he/ she is taken to the system homepage. A session variable is created storing the users status (i.e. ‘doctor’ or ‘nurse’) Session variables are variable PHP uses to keep track of data across multiple pages, this way we can restrict access to certain pages by imposing a criteria upon them that the session variable has to match.

The homepage, Figure 18, basically sums up what each tab in the system navigation bar does. There are three tabs that the user would be interested in that direct the users to different parts of the site. The first of which we will describe is the ‘create patient’ tab. The add patient tab works in a very similar way to the create user function in the login screen, the difference being the data entered, and the table the data is inserted to. The data is inserted into the Patient database, and it too makes use of the input validation checks used in the user registration section. The homepage is also where a user would go to view ECG data of a patient provided by the other sections of the E-Health project.

![Figure 18. Patient Record Management Home Page](image)

The next section is the list patients section, Figure 19, this lists all the patients in the system in groups of 10. This functionality was primarily envisioned to be used to edit patient data, e.g. add a chronic illness or a change a name etc. A navigation bar along with status similar to that in the patient access record is also implemented. Each patient name has a link to the edit patient data screen where these changes occur. A redirect page occurs by taking the patient id of the name that is clicked and attaching it to the URL string, as seen in Figure 20, where the next page reads it and outputs the necessary data pertaining to that patient id in the form of an edit patient screen, Figure 21. An update SQL command is executed when the details are edited.
The next section of the system is the search for records function. A health care worker will enter the last name of the individual at hand, and a list of patients will come up. The correct patient is chosen (identified by the first name surname and date of birth) and the correct detailed patient record is loaded.
It is through this function that a new consultation is created. In the current paper based system, a patient comes in for a consultation and the doctor has access to his/her file. The doctor then might decide to go through this file before starting the new consultation. We achieved a similar outcome with our system that being all the consultations are displayed one by one in chronological order, and there is a link to start a new consultation just underneath the past consultation data. Patient allergies, medication and chronic illnesses are displayed at all times, as this was a feature requested by the health care workers during the design stages.

The patient record file is exactly the same file as accessed by the patients with the exception of the link for creating a new consultation available. There is also an access constraint based on the session variable within the page. Nurses only have access to patient data namely chronic illnesses, medication and allergies, whereas doctors have access to the full record. Nurses also cannot create new consultations. This is achieved by using PHP code to set up an access region where restricted data would go. Figure 23 outlines this by showing the exact same patient record, only one is accessed by a doctor, whereas the other by a nurse.
A doctor can create a new consultation to be entered into the database by clicking on the designated link; he/she is then envisioned to fill in the blank consultation form throughout the actual consultation. The data is then saved with the associated patientid.

4.2.4 The ECG Display

Although the healthcare workers did not place ECG data display at a premium, we still decided to implement it and provide it as a novel feature to our system. Sensors that send the data to a PDA gather the ECG data. The PDA then sends this data to a peer-to-peer database. This peer-to-peer database then sends an XML
file to the server on demand containing the desired ECG data to be displayed. Other members in the project implemented the ECG data capturing storing and sending. The job of the web interface was to display the data sent in the xml file. This was done by reading in the XML file then passing the data to Google charts API in the form of a string. The Google Charts API returns a graph with the relevant data plotted onto a curve. The Google charts API is a free Internet service made by Google for web developers to display data graphically. The web developer specifies the chart type, size, colors and data to be displayed. The result of a successful request results in a graph being displayed as an image.

Our interface takes each node in the xml file, and then displays the data accordingly. One has to be connected to the Internet in order for the graph to be generated.

4.2.5 The Admin Section
After an administrator has logged on he/she is presented with a list of all the users of the system. He/she then can edit the details or remove them entirely in the case of a fraudulent user. The edit details screen is where an UPDATE SQL command is executed according to the userid. This is also where he/she validates unknown users in order to gain access to the system. Delete user executes a DELETE SQL command according to the userid.

![Registered Users](image)

**Figure 25. Listing the users of the system**
4.2.6 Other Website Functions
Throughout the website other functionality has been implemented in order to make the website as user friendly as possible:

* Error screens when login has failed that link back to the previous page for all three login areas of the website.

* A navigation bar within the system that stays constant throughout the session.

* A more aesthetically appealing and logical organization of the site when compared to the prototype.

* The ability to logout at any time.

4.3 Conclusion
The implementation of our system went by according to the plans laid out by our design chapter, and we feel positive that we have addressed the users requirements in order to create a useful system. The next step in the development lifecycle is to test our system in a variety of ways to ensure a stable environment is present, as well as to confirm all the user requirement’s have been met.
5.0 Testing and Evaluating Our System

5.1 Introduction
This chapter deals with the steps we took in testing our system to make sure it was free of bugs and to ensure the system did what it was supposed to do. After which it outlines the user tests carried out and the subsequent results, then finally the chapter ends with how we implemented the changes suggested by the users to create the final system.

5.2 Software Testing
Before returning to the hospital, extensive testing was accomplished in order to make sure a fully functioning system was presented to the healthcare workers. We ran a series of white box and black box tests. White and black box tests are software engineering terms, where white box testing tests the internal structure of the code, and black box tests the external structure (e.g. the user interface interactions).

We tested the system during the implementation phase of the iteration, as we added functionality to the site, and was satisfied. But we needed to run through all the functions again to see if we had overlooked anything and to see how a user would interact with the site in its entirety.

We first tested all the links within the site to see if each one maps correctly to the desired page. We did this by starting at the login screen and systematically going through the website one site at a time, once happy we moved onto the next test case.

We then tested the user registration system. First we entered all the details in the fields as one would in the real world and see if it actually added it to the database, which it did. We then added the exact same user details within the form to see how the form will handle the duplicate, sure enough it threw an error and informed us that a duplicate username was being used and the details were not saved to the users table in the database. We also proceeded to test the other error functionalities we had coded within the form, all of which performed to expectations. It was also noted that when a user registers here his/her status is set to patient automatically, this was verified to be true and the next section of the site was tested. We also checked the password string saved in the user database. The expected outcome was a string of indiscernible data, which was noticed. This was used as an encryption technique for the password. The system uses this string of data to log into the system this was checked and only the encrypted string would work for logging in (i.e. if the password was manually changed to something it would not work, only if it was entered and encrypted by the user).

The next form we tested was the doctor/nurse registration form. It was tested in exactly the same way as the patient registration form, although we checked to see if the status of the doctor/nurse we had entered in was set to ‘unknown’, which it did.
The next step was to test the admin section of the website. The login username was set to ‘admin’, and the password was ‘ehealth’, we first tried to use a wrong name and password to login, but was met with the appropriate bad login screen, we then used a name and password that was already in the system (a doctor we had previously entered in) but also was met with a bad login screen, this is because the status of the person logging in has to be set to ‘admin’. After the correct combination was entered the next screen emerged. We then tested the ability to edit user details, we edited one of the users arbitrarily and checked the actual database to see if it had done so. We also changed the random users status and again this was reflected in the user table in the database. The last step was to delete a user, once clicked all traces of the user were indeed removed from the system.

We moved onto the doctor/nurse section of the website. First we tried to log in under a patient username and password and a bad login screen occurred, which was the expected outcome. We also used the admin username and password, which was also sent to the bad login screen. A doctors username and password were then used, thus we were taken to the E-Health system Homepage where a Welcome Doctor message was displayed. We then chose the ‘List patients’ Tab and checked that the patients listed coincided with the patients table in the database, which it did. We also created a new patient and checked to see if it added to the database, again the expected outcome was noticed. We checked the edit patient details of the website and the relevant fields of the form were populated by data taken from the database. Changing some of the patient information tested the update SQL statement and the database was updated correctly.

The search tab was then used. First we entered random data into the search field and the expected outcome of 0 search results was seen. Then we entered in the patient name we knew was in the system and the expected outcome of ‘found 1 of 1’ along with the appropriate link was seen. We also entered in a patient name that we knew had duplicates present (i.e. sharing of the surname amongst patients) and the expected outcome of displaying both patients was seen. They are easily distinguishable by their patient ID and their date of births being displayed with the search results so a healthcare worker can choose the correct patient.

We then proceeded to click one of the names we had searched for to check to see if the correct patient record was displayed. A header displaying the name of person that was clicked was displayed along with the appropriate patient data found in the patient table. There is also a consultation notes section within the patient record and this was checked to see if it coincided with the consultation table in the database, and in this case the patient record was expected to have two consultation files, which was correctly displayed and scrolled to using the arrow keys on the website.

We then clicked the logout function on the website and we were taken back to the main login screen. To test the security we clicked the ‘back’ button in the web browser, but a bad login screen was shown, as we coded the system to not allow this. We entered a nurse username and password and the home page greeted us
with a welcome nurse header. We tested the Website functionality exactly the same way as the doctor login described above and the expected results were seen. We noted to see if our layer security system worked (Disallowing the nurses access to the consultation notes of a patient) and sure enough there was no way of the nurse seeing these files. We logged out the nurse and proceeded to the patient section.

The patient login was tested in the same manner as the other facets of the website. Correct test outcomes were noticed and only the patient record pertaining to the respective login information was displayed. The ‘patient’ had no way of accessing any other patient files except if he/she knew the login details of the other patients which is an unlikely scenario.

We stress tested the system by adding a relatively large number of patient records to the database (500 patient records). The system was able to display all of the records when prompted and we were able to search through these records effectively. Theoretically the system would be able to process as many records as the database can store and larger database size testing would be reserved for future work.

Thus after our testing we deemed the system to be stable enough to be taken to the actual prospective users of the system.

5.3 User Evaluation Of The System

In order to test that the system is built according to the users standards, and see if there was anything to be added to the system, another visit to the Red Cross memorial hospital was needed. We managed to see exactly the same doctors and nurses that were interviewed in the first prototype iteration plus an extra nurse. We also held a small focus group session with three patients to gather their ideas on the patient side of the system.

In order to gauge the users reactions a survey was formulated. The survey was set in an SUS format, which is a survey style that has been deemed very efficient [15], as it is both easy to fill out and at the same time a thorough evaluator of the system. The survey [Appendix B] consisted of ten questions, the first nine were ratings questions where the user was asked to rate a specific aspect of the system on a scale from one to seven, seven being the best outcome and one the worst. The tenth question was used as an open ended question to gather existing thoughts on how to improve the system.

The way the interview was conducted was to have the users run through the system functionalities while we were present. We answered any questions they had about certain functions, though there were not many as the system proved to be very intuitive. The users were then presented with the user evaluation survey.

The survey touched on a number of pertinent issues that were addressed by the system. These issues included:

*How the security of the records were handled.
*How useful the record management system actually is.

*Gauging the learning curve required in order to start using the system.

*Overall efficiency and ease of use of the system

*The overall aesthetic appeal of the system.

5.3.1 Results of the Survey

The response to the system was generally very positive, but a few concerns were raised that need to be addressed in the final iteration of the system.

The Users as a whole felt very satisfied after using the system, they found the system very easy to use and navigate across. They generally felt that the record management system would improve efficiency greatly. One nurse commented on how she did not think such a system could exist in South Africa and if implemented for real might provide a huge benefit.

The security aspect was also deemed to be handled very well, although one doctor very rightly pointed out that there are always ways to break the system but she later concluded that what our system handled security adequately and there was hardly much else we could add to improve on it that she could think of.

The system was praised as very easy to learn and use and one nurse said that it was a breath of fresh air when compared to other highly confusing systems she had worked with in the past.

The visual appeal of the site was also very positive and the site map was reported to be designed well and links were placed in a logical manner.

The results of the survey [Appendix B] can be summarized in the following graphs, one being the lowest score and seven being the highest:

![Graph](image)

**Figure 27. Doctor answers**
As one can see from the above graphs, results were extremely favorable towards the system. Question one of the survey dealt with the overall satisfaction of the website system that they tested. The average answer for all the participants was 6 out of 7, indicating that users were very happy with the system.

The second question dealt with how easy it was to navigate through the site and how logically the site was laid out. This scored very highly with all the healthcare workers surveyed which is very encouraging as it confirms we have created a very user-friendly system.

Question three queries how useful a patient record management system is to them; the question was put in to see if the users still felt that the system would be useful as they did at the start off the project. The resulting average of 6.5 out of 7 confirms this statement.

The fourth question deals with rating the security features of the system. The consensus was that it was implemented more than adequately, scoring a 6 out of 7.

Users were asked to rate the aesthetic appeal of the website for question five. The average answer was 6.2 and we were commended by many of the users that the site was very appealing and professional.

Surprisingly though are some results from question 6 which deals with how much training would be required to use the system. All the nurses found it very easy to use ‘right out of the box’ whereas two of the doctors thought they might need someone to go through the system for them beforehand.

Question seven was asked to gauge the usefulness and the extent of the error checking and backtracking options if the user made a mistake. The resulting answer gave an average of 6.3 and the users thought this aspect of the system was dealt with well enough.
The eighth question had the lowest answer value. It deals with the administration section of the website and the creation of an administrator. One of the nurse’s felt that it was not necessary and that they could do that admin work and site management. She was however alone in this opinion, as the other health care workers surveyed felt that it was a good idea to add an administrative role.

Finally, question nine deals with the ease of creating patient records and doctor consultations. This too was commented on being easy to do with an average rating of 6.5.

The averages for both groups is listed below in Figure 29:

![Figure 29. Mean Answer values for the doctors and nurses](image)

There were, however, a number of concerns given by the users that need to be attended to in the final iteration. Most of which are small cosmetic changes to the website and/or database, these are:

*Addition of a next of kin name and contact in the patient record (mainly for child patients but also extends to adults)*

*Addition of hospital name to the consultation as patients may not visit one hospital exclusively.*

*Addition of a diagnosis summary page. This way doctors and nurses can see any pattern in a patient’s reason to visit, rather than paging through all the records a patient might have.*

*Allow the nurses privilege to see diagnosis and symptoms of a consultation as well, in the form of the summary mentioned in the previous point, but still not the actual consultation notes (currently the nurse only has access to the patient medication allergies and personal details). These fields were deemed to be not confidential to the nurses.*
* Remove the privilege of patients to see consultation notes. This was justified by a number of reasons. Firstly a lot of medical jargon is used that would confuse the patient and could lead to the patient trying to self medicate themselves in a wrong manner. Secondly to avoid offending patients, e.g. a doctor might say that a patient is overly obese as a cause of something. Finally to not cause any unnecessary worry to the patient, as doctors would often times write many different diagnosis’s for a symptom and patients would hone in on the worst possible diagnosis, e.g. cancer could be a reason for something but is the least probable and patients would see cancer and get worried unnecessarily.

*Addition of any chronic illness information to a record e.g. if a doctor knew that a patient is diabetic then he/she would be more educated on how to act.

Once these changes have been made, it was agreed by the participants that an effective patient record management system would result that can be used within almost any hospital or private practice setting.

5.3.2 Focus Group Session

A focus group session consisting of three patients found in the waiting room was also carried out. The purpose was to gather a patient’s point of view with respect to the system. The session started out with a demo of the system, followed by a small discussion on their views. Two of the patients said they thought it to be extremely useful and the other said that she would not use it, but saw the value of such a system. The reason that individual gave was that she did not have ready access to a computer and felt that her doctor visits were not frequent enough for her to constantly check up on her status. The other two individuals stated that it would be very useful as a reminder on what happened to them in the past, as well as seeing what medication they were supposed to be taking. All three individuals commented on the ease of use of the system, and how they thought that nothing more needed to be added to such a system.

5.4 Updating Our System, the Final Iteration

We would then proceed to add the minor changes previously specified by the users. As the system was deemed satisfactory, major overhauling of the system was not required, thus we started the third and final iteration of our system.

5.4.1 Designing the Final Changes

The main addition specified in the second evaluation was a consultation summary page accessible by the nurses and doctors. A further requirement was to alter the tables used in the database to include the new fields requested by the healthcare workers.

In addition, after consultation with other members of the project group, a decision was made to improve the ECG display section of the website. We would add the functionality to automatically check to see if there are any updates to the XML file sent by the other parts of the overall honours project. The reason being was that we felt this would be more useful to the healthcare workers as more up to date data would be available to them. The interface used was also decided to need a facelift to make it more professional and streamlined.
5.4.2 Implementation Of the Final System

The first step was to edit the database to include the requested data. A next-of-kin field was added to the patient table, a chronic illness field to the patient table and the hospital name to the consultation table. All forms pertaining to the patient table and the consultation table were updated to include the new fields.

We removed the privilege of patients being able to view their doctor's consultation notes by removing the field in the patient record access page.

We also designed a new page displaying the diagnosis summary section of a patient record and made it accessible to both doctors and nurses. This was done using a SELECT * SQL command and choosing the right data to populate a repeating table. Figure 30 shows the consultation summary screen.

![Consultation Summary Screen](image)

The final step was to improve the ECG Display page. The previous iteration had all the data extracted from the XML file sent by the other section of the project displayed on the page. This led to a very confusing interface that needed to be refined. We accomplished this by having an interactive summary table that a user clicked to display the ECG graph. The web page also now has the ability to recheck the XML file to see if a new file has been sent, thus updating the page without the user not needing to refresh the page. The update timer was set to be 1 minute. This time was decided to be the compromise, as a short refresh rate exerts a huge strain on the web server whereas a large wait time would have proved pointless. The system also checks to see if there are duplicate nodes within the xml file and does not display them. Figure 31 shows the updated ECG display screen.
5.4.3 Testing the Implementation
The main areas to test were to ensure that forms that were edited actually updated the new fields to the database. This was proven to be true.

To test the Summary page, we added and removed consultations to the consultation table in the database and noted if it was displayed onto the table tested the consultation diagnosis summary page. The expected outcome was seen on all occurrences. We also ensured that both doctors and nurses could access this page.

5.5 Conclusion
As the users were extremely happy with the system and the changes requested were relatively small, we deemed it not necessary to go back for further user testing.

From the positive user evaluation of the system, it has become clear that a viable system has emerged. We feel that we have achieved a very practical system and that the final implementation would be ready for users to work with.
6. Findings
We encountered a number of interesting findings while developing the Web system. These findings would greatly help any development of a production system to be used in the industry.

The main discovery we noticed when developing the system occurred during the initial user requirements section of the project where our focus was displaying different data values from a variety of sensors. Remote sensor data was found to be not as valuable as expected, whereas we found out that there is a great need for a web based record system, thus this finding greatly influenced our subsequent work. That being the main emphasis of the project shifting from visualizing sensor data, to creating a web based patient record management system, which was thought of being incredibly useful in the current environment. We initially had no idea of a need of such a system, and it was through consultation with the health care workers that we were able to determine its value to the industry.

6.1 Other Findings When Analyzing the Current System
We found our project to encompass a broad range of research areas: sensor monitoring, network topology, network security, human computer interaction (HCI) targeted at the developing world and web development to name a few. The HCI aspect of our project has emerged to be incredibly important, as through our extensive usability studies, we have found a huge need to upgrade the record management systems currently within South African hospitals. The first worlds view on HCI cannot totally be considered in this country as people’s views on computers vary greatly from the western world. Thus this view played a part in us creating a user-friendly system that can easily be ported to other hospitals within the country, and possibly the continent.

An interesting point to mention is that the interviewees’ people’s mindset was that a computerized system could not be implemented in South Africa. They felt that technology such as this was exclusively for use in first world countries, and when explained to them that this system was being designed for them in mind, they were extremely optimistic as they thought how the system would improve the working conditions within the hospital.

It is also interesting to note the continued use of paper-based systems in many hospitals. When asked if they thought of updating their system, interviewees felt it would be far too expensive to do so, but when we told them that our system was developed using exclusively open source technology and that the main costs were hardware related, again they were shocked and extremely optimistic that an electronic update to their system could occur.

6.2 Other Findings During Software Development
The effectiveness of the Open Source aspect of our project was also an interesting finding. We achieved desirable results with our open source servers and database systems without having to purchase commercial software, thus suggesting that these Open Source software packages rival commercial packages in quality, reliability and capability.
During this project we developed a list of requirements for an effective web-based system for patient records. The users placed ease of use and logical organization of data highest on their list of requirements for a web-based system. Some of the health care workers interviewed had very bad experiences with systems they had used beforehand, finding them, extremely complicated to use and thus very frustrating. Security of data was also incredibly important for obvious reasons of confidentiality. Somewhat surprisingly, aesthetics was also placed as a huge factor in user satisfaction, thus a sleek, professional looking website needed to be developed.

Development of an actual production system will face a number of challenges. When we asked users how such a system could actually be implemented within a hospital setting, they responded that a proposal would have to go through a number of committees and superintendants for approval and would take quite a long time. However they stated that such a system could be implemented much faster at a smaller scale within private practices, as there is a lot more freedom to maneuver. The system was deemed appropriate by the users to be used in a hospital setting as well as a private practice. This is an obvious route for future projects.
7. Conclusions And Future Work
The original goal of the project was to create a system that would benefit health care workers and patients by providing a low cost system that they would be happy to use. We believe we have done this and that our system could be used in any health care setting. The main aims of the system were to have the ability to create, view and store patient records. Patient records consisted of a number of demographic fields and consultation notes, which would be stored in a database. The system also displays ECG data sent by other sections of the system as well as provide administrative capabilities to set access control lists of the users of the system.

The main challenges when developing the system was working around the healthcare workers schedule. They were often times understandably busy and we had to wait long periods of time before we could see them. It is also difficult to gauge whether we have met every single user requirement as often times users might have differing views on how data should be presented and we were forced to compromise on certain aspects of the system (An example of this in our system was exactly how much information a nurse should be able to access, so after much consultation with differing individuals a solution was found).

7.1 Significance of the Project
The system developed illustrates how a web-based healthcare system would greatly improve the working conditions of a hospital by creating a better patient caring environment. The fact that we used Open Source tools cut down the software costs tremendously and is important, as large funding grants would be difficult to come by in Southern Africa.

7.2 Achievements
Health care workers were consulted in the design, implementation and evaluation stages of each iteration of the system. Thus the resulting system is one that they would be happy to use. The system achieves the goals of being able to create and manage patient records, display ECG data from the other sections of the project, provide data access layers, self register to use the system, add and view doctors consultations and have administrators manage the users of the system. We also believe we have created an aesthetically pleasing website that is easy to learn how to use and can be deployed in a third world setting.

The methodology we used was an iterative development approach, which we felt was the most effective methodology to use when developing our system. With each successive iteration, we were able to determine specific user requirements as well as iron out any bugs and unnecessary sections to the system that might have occurred during development. We believe that through our iterative approach, we have created a viable system that can be used in the South African Health care industries today. The user involvement was crucial in formulating the system and implementing a system that they themselves would want to use and benefit from.
7.3 Future Work

While the prospective users of the system deemed the project a success, there are still a number of functions that could be added to the system to improve it if there was more development time. The first of which is to integrate the system to link up with the different medical aid companies present within the country, this way claims can be linked electronically and would decrease time taken to reimburse members. Another addition would be to link the system to a pharmaceutical prescription system that pharmacies have access to, this would reduce paper based prescriptions as well as errors in dispensing drugs. Finally we have created a very broad system that can be used in any medical setting. There are, however, many specialized fields of medicine that might wish to have more data fields within a patient record, thus an extension to the system would be to create very specialized subsystems related to each specialists requirements (e.g. a gastroenterologist might require completely different data than a plastic surgeon).

Further testing in a clinic environment could also occur; this would probably reveal new requirements that would need to be taken care of. A larger number of patient records would also need to be added to the database to see if the system can handle large loads as in reality there could be thousands of files to be stored and possibly even more.

Future work also includes the deployment of the actual system within the hospital and/or clinic setting. We would do this by first transferring the current data they have in paper form into our databases. In order to do this we needed to get ethical clearance assuring the hospital that the data would be kept confidential, which we obtained during the implementation phases of the project. Consulting the university ethics committee as well as the superintendent of the Red Cross memorial hospital accomplished this. The next step would be to physically enter the records. Following this would be obtaining all the necessary hardware to be installed within the hospital then training the staff to use the system. Of course funding would need to be acquired to accomplish this and would take place by formulating a business case document to present to potential investors of the system.

The health care administration procedures in Southern Africa are very backward when compared to first world countries, and we believe that by implementing this system, we could help improve hospitals and clinics throughout the subcontinent and possibly beyond.
8. Appendices

8.1 Appendix A, Prototype Questionnaire

E-Health Questionnaire.

Sena Allen, Gregory Chandran, Robert Koletka

We are fourth year students at the UCT Department of Computer Science. We are running a novel E-health project to gather vital signs from patients in a hospital environment. We use a variety of small sensors (measuring heart rate, blood glucose, temperature etc.) Which, when placed on an individual, transmit vital signs to a database. This database can then be accessed by a healthcare professional over the Internet at any given time.

In order for us to develop an effective system, we need to determine what is required for an effective system: the data, which would be important and useful for medical practitioners. Your participation would be extremely valuable to us.

Have you heard of a system like this before?

Yes [ ] No [ ]

Please tick all the sensor types you think will be most useful in such a system.

a) ECG sensors
b) Blood glucose level sensors
c) Temperature sensors
d) Other _________________________________

Where do you think the best place to implement such a system would be?

a) In a hospital
b) In an old age home
c) In patients homes
d) Other _________________________________
Who do you think will use this system more?

a) Doctors
b) Nurses
c) Equal usage

Can you foresee any problems with this system? If yes, please specify.

Yes ☐ No ☐

_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________

What sort of standards would be required for patient confidentiality i.e. who should be able to access information?

_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
Having seen the prototype website, what additional functions would you add, or present functions takeaway?

_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________

Please comment on anything else you think might be useful. Thank you for your time.

_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
_____________________________________________________________________________________________
8.2 Appendix B, Working System Survey

Thank you for your time.

For the following questions, please circle the number, which best represents, your experience with the web-based patient record management system.

1. Please rate your overall feeling of the website from 1 to 7, where 7 represents extreme satisfaction and 1 complete dissatisfaction.

   **Considering the website as a whole, I am:**
   
   - 1: Dissatisfied
   - 2: Very Dissatisfied
   - 3: 1
   - 4: 2
   - 5: 3
   - 6: 4
   - 7: 5

2. Please indicate ease of site navigation: was there a logical flow between the menus? Are items located where you would expect them to be?

   **I found the website:**
   
   - 1: Very Easy to Navigate
   - 2: Easy to Navigate
   - 3: 1
   - 4: 2
   - 5: 3
   - 6: 4
   - 7: Very Difficult to Navigate

3. Please rate the usefulness of the online material, i.e. keeping patient records on a computerized system as opposed to a paper based system.

   **Having an electronic web based patient management system is:**
   
   - 1: Incredibly useful
   - 2: Very useful
   - 3: 1
   - 4: 2
   - 5: 3
   - 6: 4
   - 7: No use at all
4. Our system uses an encrypted password service with access to files controlled by the rank of the user: patients can access only their file, while doctors and nurses have specific restrictions. Please rate these security features:

I felt that the security features within the website were:

1  2  3  4  5  6  7
Very badly implemented  Dealt with very well

5. Please rate the general look and feel of the website.

I found the look of website to be:

1  2  3  4  5  6  7
Unprofessional and boring  Very visually appealing

6. Please rate the difficulty of learning to use the website.

In order for me to use the website effectively I would need:

1  2  3  4  5  6  7
Intensive training  Hardly any training

7. Please comment on the ease of correcting yourself if an error was made.

I found the error messages and backtracking options were:

1  2  3  4  5  6  7
Difficult and cumbersome  Clear and easy to correct oneself
8. Please comment on the role of an administrator to oversee management of the site.

*The Administrators role is:*

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<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
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<tr>
<td></td>
<td>Pointless</td>
<td>Necessary</td>
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9. Please comment on the ease of finding and adding patient records.

*Finding or adding a patient record was:*

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<td></td>
<td>Difficult and cumbersome</td>
<td>Clear and easy to do</td>
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10. Please comment on anything that you would like to add that was not addressed.

_____________________________________________________________________________________________
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9. References


