

# **Wearable ECG/EKG**

Senior Project Report

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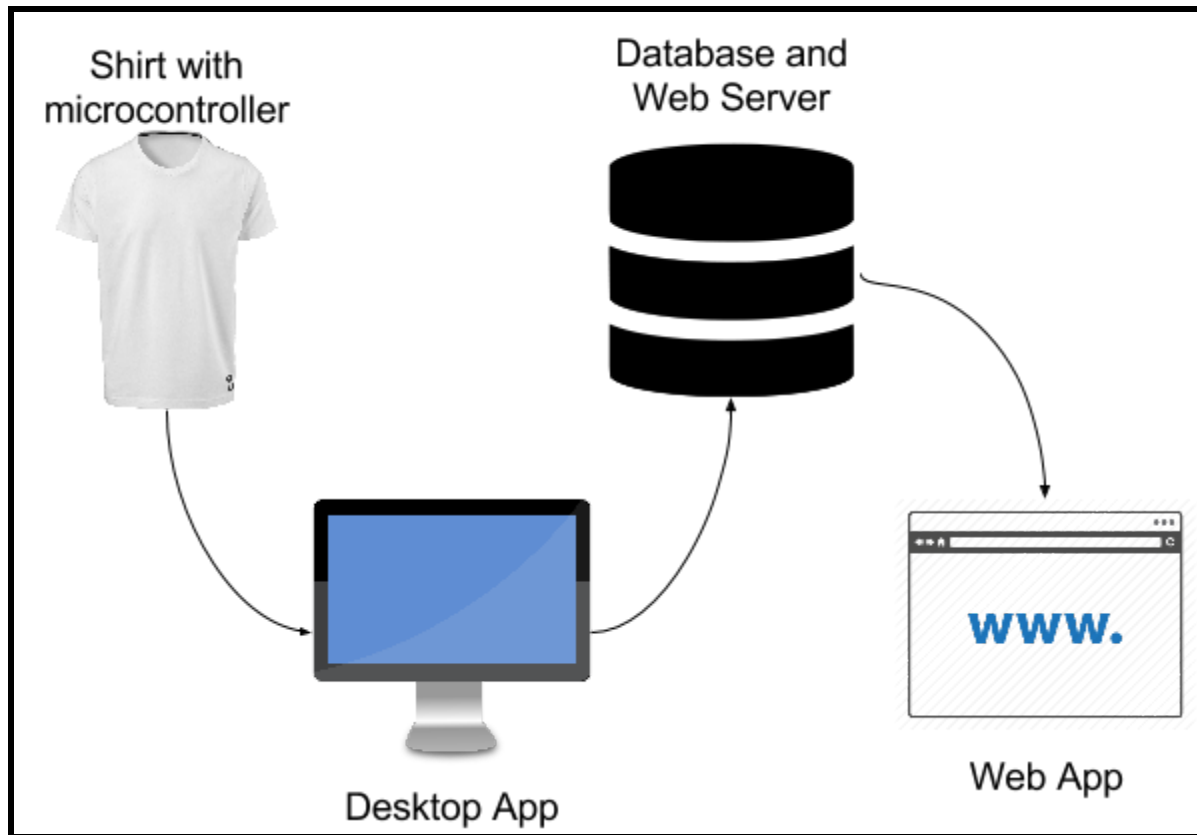
# 1 Introduction

## 1.1 Project Overview

Electrocardiogram or an EKG/ECG is an important part of the initial evaluation of a patient who is suspected to have a heart related problem. The EKG can provide important information about the patient's heart rhythm, a previous heart attack, increased thickness of heart muscle, signs of decreased oxygen delivery to the heart, and problems with conduction of the electrical current from one portion of the heart to another. So, our senior project is taking EKG recordings and displaying them for users and healthcare professionals to view. We are getting these EKG recordings from a current Cal Poly student's thesis project. This thesis project involves the creation of a shirt that can constantly log EKG readings. Once the EKG readings are logged to a microSD card, we take over. The drive is plugged into a computer and our desktop app reads the data from the drive and transfers the it to our database. The data that is sent is encrypted and is sent over a secure connection. From there, the database will send over the encrypted data to the web app. Again this connection is secured and the data is encrypted. The web app receives the data and displays the data for the user to view.

When dealing with medical data, security is always a factor and that is why we have security built into each and every layer. We are creating secure password and usernames for our users. We are ensuring that over every connection that that connection is secure and that our data is encrypted. Even the data that is on the microSD is encrypted to ensure that if the microSD is lost, others cannot see your private medical logs. Our project allows users to see their EKG logs right away and can alert the patient or their doctor of any irregularities right away.

## 1.2 Architecture



**Figure 1.0 Overall Architecture**

Our overall architecture can be found in figure 1.0. The shirt contains a microcontroller that is collected the EKG data. From the shirt, the data is then collected via a desktop app. The user will unplug a microSD card from the shirt and plug it into their computer. The desktop app will be opened by the user and this app will allow the user to send their data to the database. Once the data is stored in the database the files on the card will be deleted and the card will be plugged back into the shirt. In order for the user to see his or her data, they will open up our web app in a browser. The web app will pull the data from the database and display it for the user. The web app can also be used by the patient's health care professional. This allows the health care professional to determine the patient's health conditions if any.

### **1.3 Current Technology**

The Holter Monitor is the current prescribed EKG monitoring tool. A Holter monitor is a continuous tape recording of a patient's EKG for 24 hours. The EKG electrodes (circular white patches) are applied to the chest and thin wires are then used to connect the electrodes to a small tape recorder. The tape recorder is secured to the patient's belt or it can be slung over the shoulder and neck with the use of a disposable pouch. It takes approximately 10 to 15 minutes to apply the monitor and less than 5 minutes to remove it. The Holter Monitor results are read by a technician. This technician will return the results in a couple of days to the medical professional unless, the technician sees something life threatening right away.

### **1.4 Need Statement**

Heart disease is the leading cause of death in the USA even though it is highly preventable. To improve outcomes, better diagnostic screening tools are needed to identify at-risk patients early. Measuring the electrical activity of the heart with an electrocardiogram (ECG or EKG) is used as a screening tool. Our app will allow patients as well as doctors better identify problems with patients. EKG monitoring can be used to find the cause of unexplained chest pain or pressure. It can be used to check the heart's electrical activity, find the cause of symptoms of heart disease and much more. Patients need to be able monitor their heart all day and night in order to give them better information about their body. Using the Holter Monitor (see Current Technology), the health care professional cannot get the patients results right away. The Holter Monitor is taken off by the doctor and then the results are read by a technician which can take several days. The Holter Monitor is typically only used for a 24-hour span. This limits what health risks that the EKG can span. Our product allows the patient the ability to upload their own data. Our product also allows the patient easy access to their own charts that they can see right away. Our product will allow the user to take off the EKG monitor at any time for

showering or any other reason. Lastly, our provide a strong layer of security that will ensure the patient's data is kept confidential.

## **1.5 Project Goals and Objectives**

The goal of this project is to develop a desktop client, database, and web application in order to store and allow patients and doctors to view data gathered from the wearable EKG. One of the major objectives is to ensure that the data would be secure at all times. Because the device is meant to be used as a medical device instead of a consumer device, security of the data is essential. More specifically, the objective is to keep the data safe during transfers between the EKG and desktop client, the desktop client and database, and the database and web application. Also, the data needs to be secure while it is stored on the microSD card and the database.

Another objective of the project is to make the information universally accessible. In order to achieve this, the team decided to build a web application to allow patients and doctors to view and analyze the data. This should allow the database to be accessed by anyone with an internet connection. Although currently the plan is to build a desktop client that will run on Windows, the hope is that the scope of the project will expand to allow the possibility of building clients for multiple other operating systems as well.

## **1.6 Project Outcomes and Deliverables**

### **1.6.1 Outcomes**

- Once completed, the system will be one of the first medical grade wearable EKG.
- Streamlined EKG monitoring from the shirt to the web app.
- Secure and remotely accessible medical data for doctors and patients

### **1.6.2 Deliverables**

- Desktop application to read EKG data off of a microSD card and transfer over SSL to the database.
- WPF application source code to allow the improvement and analysis of techniques used in order to create applications for other operating systems.

- Installer to allow a user to easily install the desktop application on any Windows device.
- MySQL database that efficiently stores encrypted EKG data in an organized schema.
- SQL source code for creating and initializing the database;
- Web application that connects to the database using an SSL connection, authenticates the user, retrieves the EKG data, and displays it to the user.
- Web application source code to allow further improvement of user interface and development of a mobile site.

## **1.7 Team Mission and Objectives**

Our team mission is to work collaboratively with each other to complete this multidisciplinary senior project so that a prototype is ready by June, 2016. Our objectives include:

- Working with the mechanical engineer to make sure our applications fit the specifications of the wearable shirt
- Communicating effectively to ensure that different parts of the project are working together correctly
- Taking control of the design and implementation of our individual responsibilities
- Assisting other project members on their module when help is needed.

## **1.8 Team Membership and Roles**

### **1.8.1 Cale Hopkins - Web App Design and Development**

The web app designer and developer's role is to develop and maintain the web app for our product. Some responsibilities include:

- Defines site objectives by analyzing user requirements; envisioning system features and functionality.
- Taking in encrypted data from the database and decrypting it.
- Displaying the data so that a client or medical professional can easily view the EKG results.

### **1.8.2 Travis Michael - Desktop App Developer**

The desktop app designer and developer's role is to develop and maintain the desktop app for our product. Some responsibilities include:

- Creates a desktop app that a user can easily use.
- Recognize a microSD and send it's encrypted data to the database for storage.
- Create an installation package for the user to install the desktop app.

### **1.8.3 Tanner Papenfuss - Database/Backend Developer**

The database developer's role is to develop and maintain databases across the organization, while ensuring high levels of data availability. Some responsibilities include:

- Design and deploy data table structures, forms, reports, and queries.
- Development and maintenance of Data Warehouse.
- Ensuring safe and reliable data transfer from the desktop app to the web app
- Identify inefficiencies in current databases and investigate solutions.



## **2 Formal Product Definition**

### **2.1 Marketing Requirements**

1. Desktop application must be lightweight
2. Data must be accessible from any web client
3. Patient data must have medical level security
4. Web application must show a human readable graph to the user
5. Web application and desktop client must have an appealing visual design
6. Doctors must have access to all of their patients' data
7. Doctors must be able to share comments with patients through the system
8. Login and authentication must be seamless and intuitive
9. Users must be given a secure password and username to authenticate with

### **2.2 Engineering Requirements**

1. Desktop client must be able to parse through encrypted chunks of data and separate them with their associated timestamp
2. Desktop must not send more than 10 GB of data in one request
3. Desktop client must send data to the database using an SSL connection
4. Database must not accept duplicate data
5. Database must only accept certified connections using SSL
6. Database must have an uptime of 99%
7. Database must store any sensitive data in encrypted form using SHA224 encryption
8. Web application must be compatible with all modern web browsers
9. Web application must retrieve data from database using an SSL connection
10. Web application must perform lightweight analysis (Fourier transforms) on retrieved data

## 2.3 Security

Security is a major design consideration when building this project because it is designed to store and display patient medical data. The team had to ensure that data was secure at every point while it was moving from the shirt to the web application.

The data is placed onto a microSD card as it is being recorded from the shirt. To ensure that those who get a hold of the card would not have access to the patient's data, the data is encrypted before it is written to the drive. The data is stored in encrypted chunks with associated timestamps to give order to the data. This data is encrypted using SHA224 and a key derived from the patient's password during setup.

The desktop client is responsible for taking the data off of the drive and making a series of insert statements to store the data in the database. To keep the data secured during the transfer, the connection to the database is made using SSL. This requires additional setup for the desktop client so that it can acquire the appropriate SSL keys created by the database. To ensure that falsified data can't be inserted into the database, it will only accept SSL connections for all remote connections.

The web application will make a connection to the database using an SSL connection as well. Because the web application is where data is unencrypted, the user must authenticate with the database. The web application will be secure in a way that will minimize the chance of someone accessing private data if a user accidentally leaves their session open. It will have a timeout that will automatically log the user out after a certain time without user activity. Also, closing the tab with the open connection to the database will terminate the session, requiring the user to login again if they want to view their data.

## 2.4 Customer Constraints

1. Desktop client must run on a Windows environment (Windows 7, Windows 8, Windows 10)
2. Desktop client must be intuitive for inexperienced computer users
3. Database must be deployed on a Linux/Unix environment

4. Web application must work on most popular web browsers (Chrome, Firefox, Edge)
5. Web application must display data in a way that is easily readable by the user

## **2.5 Criteria**

1. Time of data transfer
2. Schema of database
3. Data access time of web application
4. Security of data
5. Size of database
6. Visual appearance of web application

## **3 User Experience**

### **3.1 Overview**

There will be two primary methods of interaction with our system - a desktop application and a website. The desktop application will be designed first and foremost with simplicity in mind. Its intent is simply to provide the user with a highly usable and intuitive interface from which to upload recorded data to the database. This will entail nothing more than starting the application, entering login information, and selecting a device to upload data from. Viewing data, creating an account, and other more complex interactions will be completed via the website. The website will also be designed with usability in mind, having a clear and concise user interface free from distractions and designed to be compatible with the user's browser of choice. This will allow access from any device with an Internet connection, from older computers to newer and from smartphones to desktop machines. From the website, a user will be able to view any uploaded data of their own or of a registered client, keep track of progress with notes, and communicate with their client (or health-care professional) quickly and easily.

### **3.2 Personas**

There are two different "types" of user that our system must be designed to cater to - "clients" (i.e. patients utilizing the physical EKG monitoring system) and "health-care professionals" (i.e. doctors who have prescribed this monitoring system to one or more of their patients). From there, a "typical" client or health-care professional can be hypothesized. Since the physical system is a medical device used to monitor heart health for those outside of the hospital, it can be presumed that a typical client would be someone with a heart condition (or other condition that can affect heart health, like obesity or simply old age), but who is healthy enough to live their day-to-day life without the help of a doctor. This would most likely include people of many ages who are in healthy mental states. These people may or may not be tech-savvy, but it can be presumed that they will be

able to follow a set of simple instructions. From a health-care professional’s perspective, our system would serve as a more convenient or “higher-tech” replacement for existing home EKG monitoring systems. Based on this, it can be presumed that the doctors prescribing this system are not averse to change and understand what the system will be requiring of them.

Based on the above cases, the system as a whole should be designed to be usable to users with a wide range of experience, especially on the client side. User interfaces should be designed in such a way that it is clear what needs to be pressed for someone who is less experienced, but not “clunky” or restrictive for someone who is more experienced. Of course, users should not be presented with situations wherein it is unclear what they should do in order to achieve the goal they have in mind. In addition, clear instructions should be available to those whom have no wish to spend time learning the user interface. Lastly, as our potential user base includes older users who may be visually impaired, it is important to design the user interfaces with layouts and color schemes that are friendly to visually impaired users - high contrast, large type and buttons, and not using colors that may be difficult for color-blind or otherwise impaired users to see.

### 3.3 Use Cases

Goal: Health-care professional uses the website to view client data.		
<i>Step</i>	<i>Action</i>	<i>Result</i>
1	User opens the website.	If user is not logged in, user is prompted to log in. Otherwise, no user action is required in Step 2.
2	User enters login information as health-care professional.	Website confirms authenticity of user information on the database. User is sent to “Overview” page.

3	User navigates to the “Clients” page via the sidebar or a link on the page.	Website displays all clients with the current user as their health-care professional.
4	User selects a particular client to view that client’s data	Client page is displayed, with a brief overview of recently uploaded data.
5	(Optionally) User navigates to the client’s “Data” page in order to view specific time ranges and/or a larger window of time.	A hierarchical list of uploaded client data is displayed, alongside a scrolling window of data that can be updated by loading next/previous data or data from a specific time.
6	User exits the website.	Website is closed.

Goal: Client uses the website to view his/her own data.

<i>Step</i>	<i>Action</i>	<i>Result</i>
1	User opens the website.	If user is not logged in, user is prompted to log in. Otherwise, no user action is required in Step 2.
2	User enters login information as a client.	Website confirms authenticity of user information on the database. User is sent to “Overview” page.
3	User navigates to their “Profile” page via the sidebar, top bar, or a link on the page.	Client page is displayed, with a brief overview of recently uploaded data.
4	(Optionally) User navigates to the “Data” page in order to view specific time ranges and/or a larger window of time.	A hierarchical list of the user’s uploaded data is displayed, alongside a scrolling window of data that can be updated by loading next/previous data or data from a specific time.
5	User exits the website.	Website is closed.

Goal: Client uploads his/her data to the database.

<i>Step</i>	<i>Action</i>	<i>Result</i>
1	User opens the desktop application.	Desktop application is opened and prompts user to enter authentication information.
2	User enters their email and password.	Desktop application verifies login information and prompts user to select a device to retrieve data from.
3	User plugs the microSD storage device from the shirt into a SD slot on their PC and selects the device on the desktop application.	Desktop application retrieves data and sends it to the database via an SSL link.
4	Wait for data transfer conformation.	Once the data has successfully been sent to the database, desktop application notifies the user it was successful.
5	Close the application.	Application is closed.

Goal: Client/health-care professional sets up account.

<i>Step</i>	<i>Action</i>	<i>Result</i>
1	User opens the website.	Website is opened and a login screen is displayed, with option to create a new account.
2	User selects create a new account.	Website navigates to a new page to allow for new account creation as either a client or a health-care professional.

3	User enters a valid email address and a password, and then selects “client” or “health-care professional”.	Information is taken in and verified for uniqueness. As a client, user proceeds to Step 4a. As a health-care professional, user proceeds to Step 4b.
4a	User selects their health-care professional from a list of registered users and submits their account creation.	Email verification is sent to the address of both client and health-care professional. Account will be created, but data will not be accessible until verification is complete.
4b	User submits their account creation.	Email verification is sent to the address provided. Account will be created, but data will not be accessible until verification is complete.
5	User exits the website.	Website is closed.

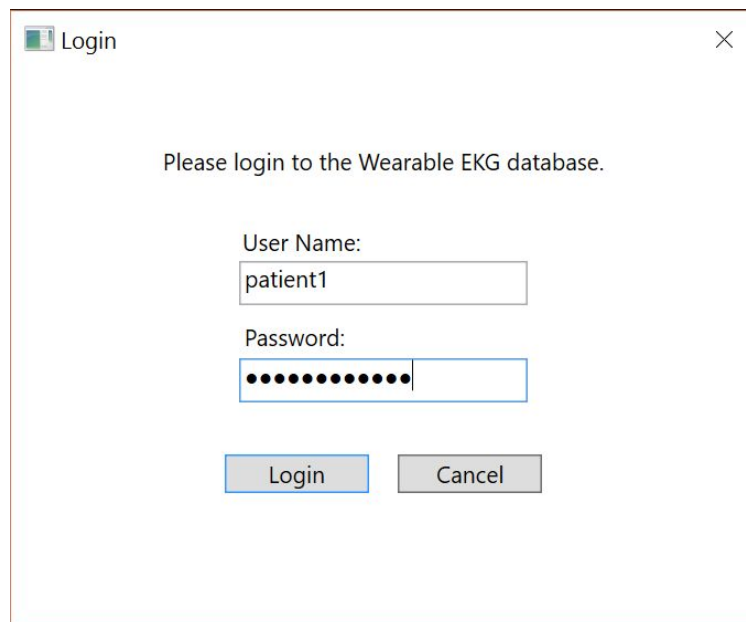


## 4 System Design and Justification

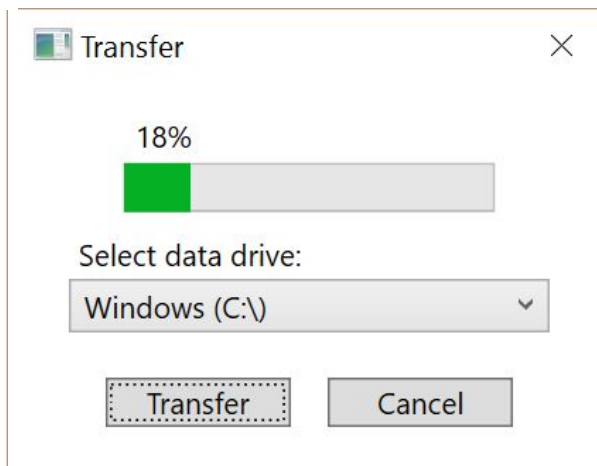
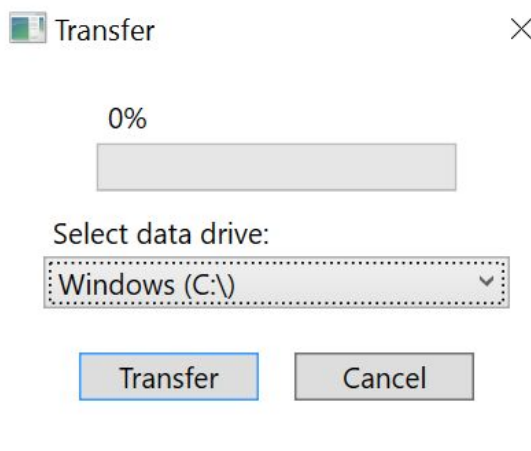
### 4.1 Description of figures, diagrams, schematics, tables, etc.

Our project involved integrating a three different technologies. The first is a desktop application written for the Windows operating system. Screenshots of the application are shown in figures 4.1 - 4.3. It is the desktop application's responsibility to locate the file containing the patient's data. The user is first presented with a login screen (figure 4.1), where they attempt to login to the database using their credentials. Any failed authentication results in a message declaring that the user was not found in the database.

If authentication is successful, a new window is shown that contains a drop down menu of the drives connected to the computer (figure 4.2a). The user must then select the drive that contains the data from the shirt. When the correct drive is selected, clicking the transfer button will start the transfer of data from the drive to the database, updating the progress bar as shown in figure 4.2b. If the transfer is cancelled with the cancel button, the progress will stop and the user will be able to start the transfer again (figure 4.2c). When the transfer has completed, the user will be shown a dialog box indicating that the transfer was successful, shown in figure 4.3, and then the application will terminate.

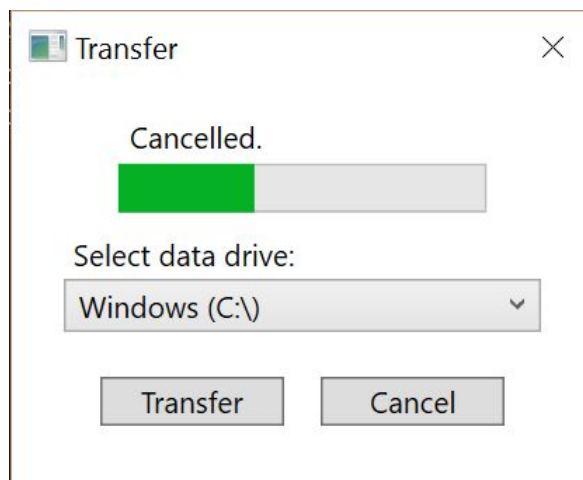


**Figure 4.1: Desktop login window**

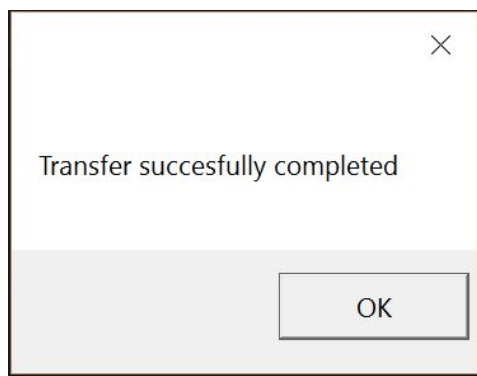


**Figure 4.2a: Transfer window**

**Figure 4.2b: Transfer in progress**



**Figure 4.2c: Transfer window after a cancelled transfer**



**Figure 4.3: Successful transfer message**

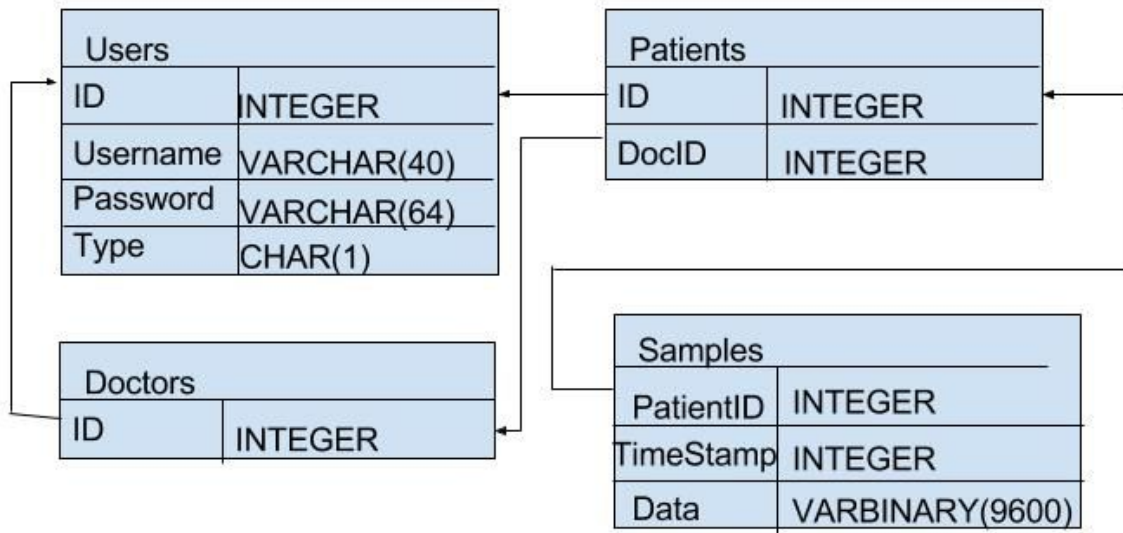
Our second technology that we developed was a database to store all of our information. A diagram of what that database looks like can be seen in figure 4.4. Every user, patients and doctors, will have an ID that will be their unique primary key. Users will also have a username and password. For the beginning we will be giving our users their usernames and passwords to ensure that they are secure. The last thing that users will have is a type which is either P or D indicating that they are a patient or a doctor.

Doctors in the current implementation will only have an ID that maps them to the users table. We still want this table however for two reasons. First and most importantly, it allows us to map patients to doctors. Secondly, it allows us to change in the future to add more information for doctors. Examples of future additions include Doctors office location and phone number. This can be used to get in contact with doctors if patients have any questions or concerns.

Patients have two fields. Like doctors they have an ID that will map them to the users table. Patients also have a DocID that maps them to their doctor. This allows doctors to view their patients data. Like doctors, this table will likely be upgraded in our future work. We would like to add in more information like phone number and email address. It could also be beneficial to see the patient's medical history or anything that has to do with their EKG results. Last for the patient's table, we may add in a table that allows a doctor to send a messages to a patient. This message could be dietary information or questions about certain aspects of the patient's EKG results.

Samples is where all the EKG data will be stored. First we have a PatientID which maps a particular sample to a specific patient. The timestamp is taken from the data that the microcontroller creates. This timestamp will be unique to make sure that a patient does not accidentally upload the same data. The last piece of information is the data. This is the actual EKG data that we want to store for the patients and doctors to view. The samples table is relatively simple and the one thing that we might switch around is the size of the chunks of data that we are storing. We may decide that 9600-bytes is too big of a data chunk and we would like to store data in smaller byte chunks or the opposite, storing our data in larger byte chunks.

To summarize, our current database implementation allows us to store patients data and easily allows us to map patients to data and doctors to patients. This implementation is simple yet effective and yields easy transition from the microcontroller and desktop app to the web app. In the future, we would like to upgrade the database to allow for a greater amount of data.



**Figure 4.4: Database implementation**

The final portion of our software design is our website. This is the largest piece of our system, designed to be the primary point of user interaction as well as the endpoint for all data access and communication. It allows for detailed views of any information uploaded to the database, easy access to a health-care professional’s client information, tracking of progress via notes, and communication between health-care professional and client via the same note system. Below is a sample of the user interface for primary elements of the website. Figures 4.5a and 4.5b show an example of a user’s “profile” page, in this case a patient - showing a brief sample of the most recent data the patient has uploaded as well as any notes written to them by their doctor or by them for their doctor. The user can, from there, link to the profile page of their registered doctor, or return to the homepage or overview page using the top and side bar. The sidebar may be easily toggled via a button in the top left - Figure 4.5a shows the layout with the sidebar active, while Figure 4.5b shows

the layout with the sidebar inactive. Figure 4.6 shows a sample of a patient data graph, with a list of all data samples below. Selecting a data sample shows a 6-second window of data centered on that time.

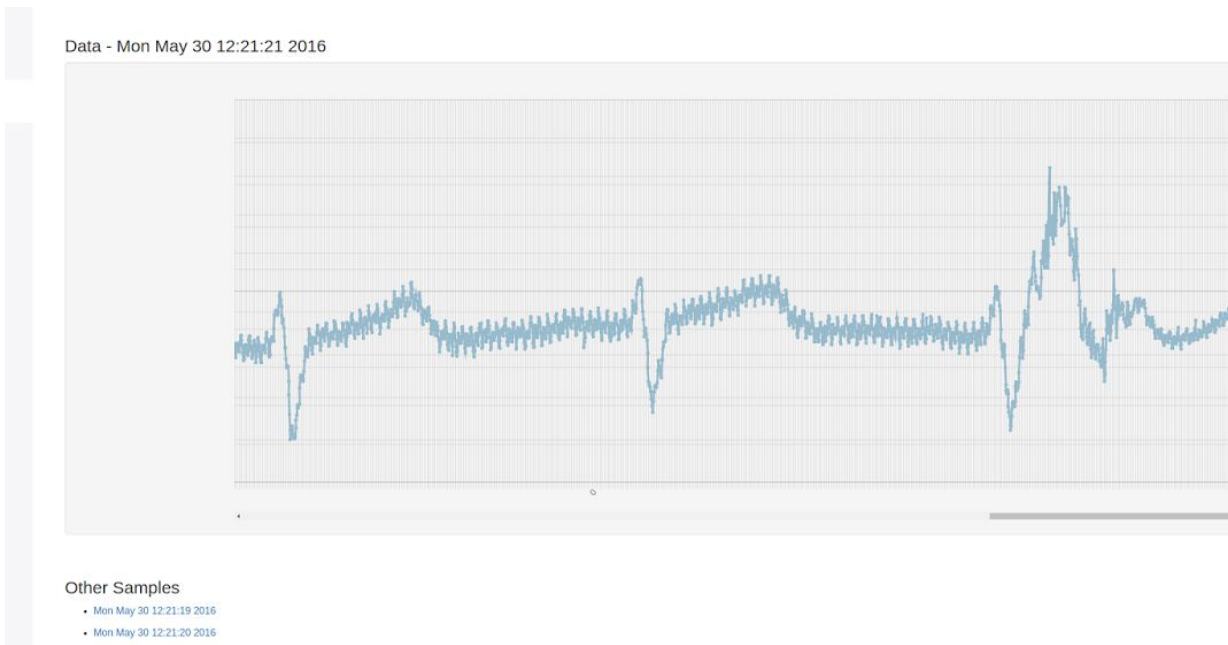
*(Click the link in the figure title to see full-sized versions)*



**Figure 4.5a: Profile page for a patient (with sidebar)**



**Figure 4.5b: Profile page for a patient (sidebar collapsed)**



**Figure 4.6: Snapshot of a graph of patient data**

## 4.2 Justification

Current technologies designed for at-home (or in general, out-of-the-hospital) EKG monitoring are currently highly restrictive, fairly low-tech, and have a high learning curve. The combination of the software being designed in this project and the physical device being developed alongside it is intended to provide a viable alternative to current widespread technologies. The hope is for this replacement technology to provide a superior user experience, simplify patient-doctor interactions, provide earlier and clearer access to potentially critical information, and allow for a longer monitoring period in order to achieve a more complete picture of the patient's heart health.

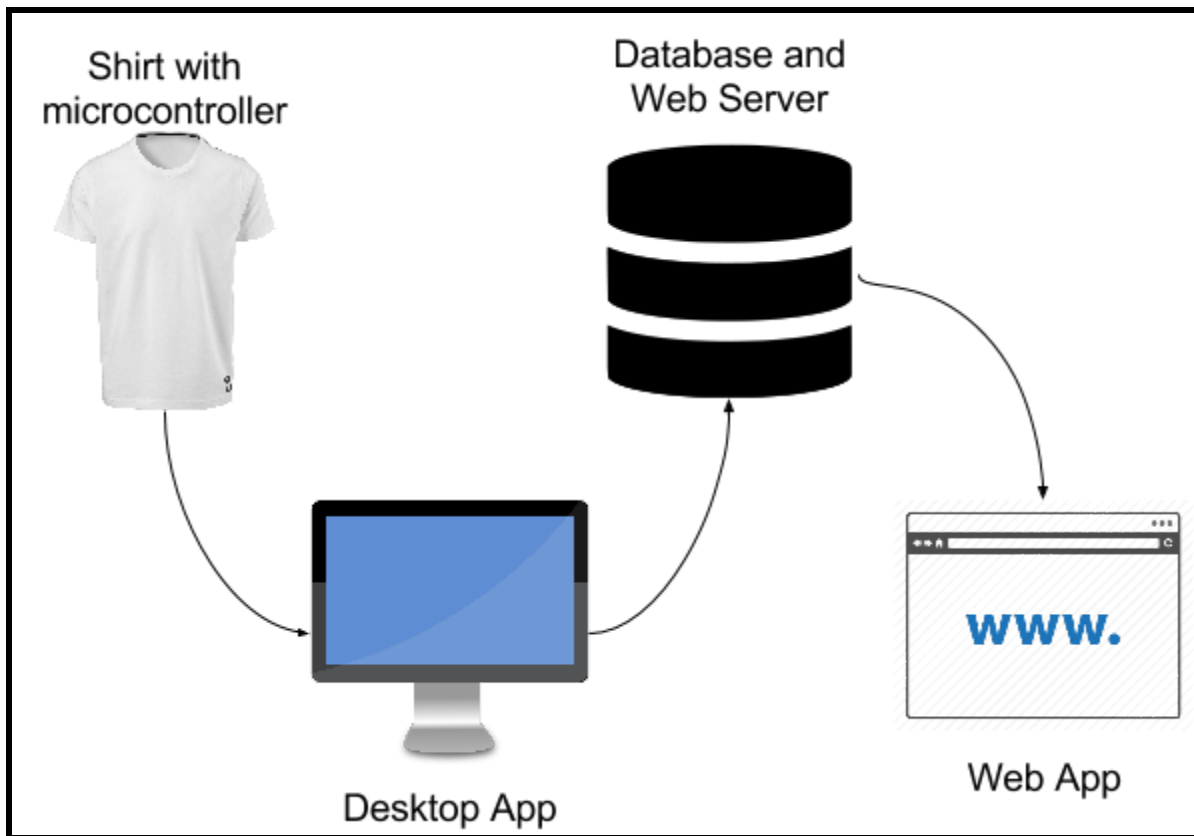
## 4.3 System Design

The wearable EKG system that we have designed focuses on streamlining data transfer from the shirt to the web application, keeping the patient's medical data secure, and providing doctors and patients with the ability to view their data wherever there is an internet connection. The shirt is where the data originates. Using a specially manufactured EKG, the shirt collects data through a microcontroller and then formats and stores the data onto a microSD card. The microcontroller writes the data in encrypted chunks, to ensure that only those with the decryption key will be able to access the raw data. The microcontroller also includes timestamps with each chunk of encrypted data so that the data may later be precisely graphed.

When the patient decides to upload his/her data, they simply detach the microSD card from the shirt and plug it into their personal computer. They will then launch the desktop application which will allow them to login and transfer their data into the database over a secure connection. The database stores the timestamp-data pairs for every patient, where it remains securely stored until explicitly removed.

When a doctor or patient wishes to view their data, they will log on to the web application. The web application allows doctors to login and view every one of their

patients' data. The patients can login and view their own data. The data is retrieved from the database for the user over a secure connection. A graphical display of the data is shown to the user which allows them to closely analyze the information. The web application allows doctors to analyze patient medical information without a visit from the patient to the office. Users can also be registered through the web application, allowing full control to anyone on any device.



**Figure 4.7: System Design**



## 5 Future Work

Our current project is good enough for a first pass but if we were to go public with this product we would need to add some extra functionality. One thing we would like to add is smaller file sizes. In our current implementation, we have one upload file that can get to be a pretty big size. We noticed that this gets exacerbated when the shirt is worn for a long time. The data builds up and can take a long time for the desktop app to send to the database. We would solve this by separating up the data into multiple different files. For instance, every hour creating a new file and putting the samples into those files. Then the desktop app would upload 5 files at a time using multithreading and when they were done, deleting those files and grabbing 5 more. There are some problems with this approach like what happens when the microSD is unplugged in the middle of the data? What happens if the file upload is interrupted in the middle? These are questions that we will have to deal with if we were to implement this upgrade.

We also would like to finish up a couple things on security. Especially when referring to logging on. We would like in the future to have public and private keys that could securely be passed from the web app all the way down to the shirt. We need to be able to more securely verify a patient. In our whole report we focused on security and this is one of our main security flaws. Dr. Smith had the idea of encrypting using a public/private key type of system. This would work but would require us to make sure that the web app and the microcontroller on the shirt were constantly on the same page. They would also need to be able to get the keys securely passed between each other.

We would like to add a way to verify the identity of new users, such as a medical license for a doctor and insurance information from patients. This would likely take some time to organize and we would need cooperation from insurance companies and doctors offices. This would provide security for patients and doctors, ensuring that users are regulated and authenticated and making sure no spoof accounts are active. Being able to store this data in the database and display it through the web application would also increase the functionality of the system.

Lastly, in the future we would like to be able to make our product from front to back cleaner and more user friendly. One way we could do that is when the microSD is plugged into a user's computer, an executable is run to automatically bring up the desktop app. Then the transfer to the database is done automatically so that way the user does not have to worry about selecting the right files to upload to the database. We also need to add some more information to the database so that the doctors can know everything about the patient that they need. For instance, the doctor can know if the patient has had certain heart conditions in the past. We would also like to add a notes function. This notes function allows the doctor to give the patients feedback on their EKG results. This can also be used to communicate what dietary changes needed to be made and so on. Finally, we would like to make the web app more navigable. We want patients to be able to have enough information without overwhelming them. And, on the other hand, we want the doctors to have the maximum possible information so they can adequately diagnose their patients. In general, making the whole experience more user friendly would help the patients and doctors be healthier and happier.

## 6 Conclusion

Heart disease is one of the leading causes of death in the USA even though it is highly preventable. To improve outcomes, better diagnostic screening tools are needed to identify at-risk patients early. Our project aims to combat this and make it so that Americans can better monitor their health using EKG recordings. The electrocardiogram (EKG/ECG) can provide vital information about patients including patient's heart rhythm, a previous heart attack, increased thickness of heart muscle, signs of decreased oxygen delivery to the heart and much more. In our senior project we are taking this EKG data and are displaying it for the patients and medical professionals to view. The EKG recordings are being gathered from a Cal Poly student's thesis project.

Currently, the Holter Monitor is the current prescribed EKG monitoring tool. A Holter monitor is a continuous tape recording of a patient's EKG for 24 hours. It takes approximately 10 to 15 minutes to apply the monitor and less than 5 minutes to remove it. The Holter Monitor results are read by a technician. This technician will return the results in a couple of days to the medical professional unless, the technician sees something life threatening right away. In order for the doctor to get the EKG results the patient has to go into the doctor's office, take off the EKG, give it to a technician to run the results and then a few days later the doctor can finally see the results. With our technology, the patient can upload his or her data from home and the EKG can be viewed right away. If a patient has a life threatening heart condition, every day is vital in detecting this to prolong that patient's life. The Holter Monitor is only prescribed for 24 hours, the patient cannot take a shower in that 24 hour span and if the monitor is subject to excess sweat or other adverse condition could yield incorrect results. With our technology, the patient can wear the EKG monitor for a week or even longer, the patient can take off the monitor by themselves whenever they desire and it can be used while exercising. Our technology is able to tell a longer story giving the doctor more information allowing him or her to give better medical advice.

Security was our main concern from the very beginning of this project. We are dealing with very sensitive medical data that we must protect and that is why we have

security built in from the beginning. We are creating secure usernames and passwords for our users. We are encrypting our patient's data on the microSD. We are using only secure connections when transmitting our data from the desktop app to the database and from the database to the web app. We want to make sure that someone trying to get at patient's data have to go through two layers of security in order for them to have access.

As one would expect, there is so much more that we could do to make our project even better. The desktop app could be expanded to work on different platforms (ie. OS X and Linux). The desktop app could also be used to make alterations to your account. For example, changing your address or changing your name. This could also be useful for medical professionals as well. The database could have more fields user fields to give us more information about the patients. We could add in information to let us know about previous health history. Has the patient had a heart attack, this would be extremely pertinent and could help with EKG diagnosis. Also, having a message field where doctors could leave messages for their patients (ie. ways to get better EKG results or diet alterations). The web app could use a general makeover. Making the web app more user friendly by doing case studies to figure out what it is that consumers would like. Similar to the desktop app, it would be nice if the web app allowed users to alter their database information. This however would mean that the web app would have to send and receive information from the database.

To conclude, this project has been such a great learning experience for us all. All three of us have gained a greater understanding of security and how to build good applications in general. None of us had extensive experience in any of the technologies that we were using. We would like to thank Dr. Smith so much for helping us along the way and giving us the tools we needed to create a successful project. Dr. Smith helped us to organize our ideas and help shape our project not to mention without him our project would be full of security holes.

## 7 Analysis of Senior Project Design

Please provide the following information regarding your Senior Project and submit to your advisor along with your final report. Attach additional sheets for your responses to the questions below.

Project Title: EKG Monitoring App Quarter / Year Submitted: Spring/2016

Student: (Print Name) Tanner Papenfuss (Sign) \_\_\_\_\_

Student: (Print Name) Travis Michael (Sign) \_\_\_\_\_

Student: (Print Name) Cale Hopkins (Sign) \_\_\_\_\_

Advisor: (Print Name) Hugh Smith (Initial) \_\_\_\_\_ Date: \_\_\_\_\_

### 7.1 Summary of Functional Requirements

Describe the overall capabilities of functions of your project or design. Describe what your project does. (Do *not* describe how you designed it.)

See section 2, [Formal Product Definition](#).

### 7.2 Primary Constraints

Describe significant challenges or difficulties associated with your project or implementation. For example, what were limiting factors or other issues that impacted your approach? What made your project difficult? What parameters or specifications limited your options or directed your approach?

From the very beginning, security was our biggest concern. Dr. Smith made sure that we keyed in on this aspect and made sure that this was on the forefront of every technological decision. This made it difficult when transferring data from one technology to the other (ie. from the desktop app to the web app). We also had to make sure that the data coming into the desktop app was secure/encrypted. This involved making the microSD card encrypted. Instead of decrypting the data at the desktop app we decided to

send that encrypted data straight to the database over a secure connection. This in effect provided two layers of security. The effects of this, however, were felt all the way up to the web app where Cale had to figure out the best way to decrypt the data. Decrypting the data and displaying it right away is expensive and proved to be a big challenge.

We also faced the challenge of actually connecting to the database. The database is on a virtual machine that we got provisioned from Cal Poly. Because we were using Cal Poly machinery, we had to go through a couple loopholes in order to open the correct pin holes or ports to access the virtual machine. We ended up having to go back to Dr. Smith multiple times because the wrong port was opened or we needed extra ports opened. And, once the ports were opened, we had to figure out how to use these ports in order to get those secure connections to the database. The connection from the desktop app to the database was the most difficult. We had to open up secure SSL connections but to do so we needed certain certificates on both ends (the desktop app and the database). None of us had previously worked with certificates authentication, so there was a pretty steep learning curve. Once the correct certificates were in their rightful spots the connection went fairly smoothly and we were able to send database commands from the desktop app to the database.

To conclude the constraints, our main limiting factor was our inexperience in the fields of security and external connections. Once we were able to get a better grasp on these two aspects our project was able to flow more smoothly.

### **7.3 Economic**

As far as cost goes, we did not have to spend any money on this project. The only service that we consumed was getting a virtual machine provisioned from Cal Poly.

Development time was around 3hrs/week for the first quarter and then around 5hrs/week for the second quarter. We had three members of our group so the total hours spent on this project hovers around 250 man hours.

## **7.4 Environmental**

Describe any environmental impact associated with manufacturing or use.

The main environmental impacts that we are dealing with is the energy needed to keep our data in our database as well as running the web app. There are no manufacturing environmental impacts as we did not need to manufacture any products.

## **7.5 Manufacturability**

Describe any issues or challenges associated with manufacturing.

We do not have any parts that needed to be manufactured for this project. Like we have mentioned before we did use a virtual machine to host our database and our web server. The main challenge with this virtual machine was getting access to the correct ports. For instance, we could not send data to the database because we did not have the access to the SSL port. We also could not access the virtual machine when we were not on campus for the first quarter (until the SSH port was opened up).

## **7.6 Sustainability**

Our project is relatively sustainable. We made sure that in the case that this would become a business, we could scale our project easily. In case there is growth, we could upgrade to a larger database and our old implementation would still be effective. The one potential problem that we could encounter is moving the web app off the server. We would need to connect to the database from the web app differently than our current implementation. However, we already have a connection to the database from the desktop app so we would just need to mirror that for the web app. As far as the actual movement off the server, that part would be relatively easy because Cale developed the web app on his local machine and migrated it to the server. He would just need to do the exact same thing to move the web app to another server (ie. Amazon's web hosting).

Some upgrades could be made to all facets of our project. The desktop app could be

expanded to work on different platforms (ie. OS X and Linux). The desktop app could also be used to make alterations to your account. For example, changing your address or changing your name. This could also be useful for medical professionals as well. The database could have more fields user fields to give us more information about the patients. We could add in information to let us know about previous health history. Has the patient had a heart attack, this would be extremely pertinent and could help with EKG diagnosis. Also, having a message field where doctors could leave messages for their patients (ie. ways to get better EKG results or diet alterations). The web app could use a general makeover. Making the web app more user friendly by doing case studies to figure out what it is that consumers would like. Similar to the desktop app, it would be nice if the web app allowed users to alter their database information. This however would mean that the web app would have to send and receive information from the database.

## **7.7 Ethical**

Describe ethical implications relating to the design, manufacture, use or misuse of the project.

Ethics plays a big role in our project. In our design we have to make sure that no one's medical information can get out to anyone. From the very start we need to make sure that our data is safe and secure. We also want to keep any information that the patient gives us secure. People would not use our product if we were handling all this information and not providing any security.

## **7.8 Health and Safety**

Describe any health and safety concerns associated with design, manufacture or use.

There are not any health and safety concerns with our project as it is all exists on a computer.



## **7.9 Social and Political**

Describe any social and political concerns associated with design, manufacture or use.

Our app is going to be so amazing that there will be a political uprising that will end up in our group becoming the next emperors of the United States. Other than that, no social or political concerns.

## **7.10 Development**

Describe any new tools or techniques used for either development or analysis that you learned independently during the course of your project.

The main thing that we all learned was the connections with databases, web applications, and desktop apps. Learning how to use certificates to create SSL connections between the desktop app and database took a lot of research and many a late night pulling out hairs. We also gained a lot of new information on how to use pinholes to virtual machines. We learned how to install applications on virtual machines (installing mysql). The first setup of mysql ended up crashing and burning horribly, so we also learned how not to set up applications. We learned how to create desktop applications for a windows machine. We learned how to create graphs on web pages and in general gained a better understanding of how to create web pages.

Above all, this project gave us all a better insight on how to work together as a team. There were a couple times this project where one person would not be communicative with the rest of the group and that set us back big time. We will be able to take these lessons into the workforce and will help us to become better employees and eventually better managers.