POST MORTEM REPORT FOR WIRELESS AUSCULTATION WITH DECISION SUPPORT

CARDIOVASCULAR INSTRUMENTATION, LTD.

Document Revision History		
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POST MORTEM REPORT

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1 INTRODUCTION

The CVI Wireless Auscultation Device with Decision Support is an electronic stethoscope with the ability to record heart, lung and other body sounds that doctors can use for diagnostic purposes. Auscultation is a very important diagnostic tool in the medical field and can give doctors a wealth of information in a relatively short amount of time and with minimal effort. Unfortunately, these tests can be hard to interpret as the sounds from a normal stethoscope can be quiet. The CVI Wireless Stethoscope alleviates these problems in several ways. The electronic stethoscope is very sensitive and has the ability to easily amplify the sounds with an adjustable volume control. This functionality can benefit doctors that may be losing their hearing or when administering tests to obese patients with a large amount of body tissue where a conventional stethoscope would yield low volumes. Additionally, the CVI Stethoscope is able to record and transmit results to a mobile device (an Apple iPad) to provide a visual representation of the internal body sounds. Once recorded, this data can be stored in a secure database for archival as well as allowing other doctors in different locations the ability to log into the database and interpret the data. This function is very useful in areas of the world where doctors are not readily available. In remote settlements there may only be a nurse assigned to the village or group of villages. The CVI Stethoscope is easy to use and will allow the nurse to take the test results and send them to a doctor located elsewhere. This will allow people in remote locations a chance at similar care given to people in large cities without the cost of having the doctor travel large distances. CVI prides itself in quality and ease of use. The stethoscope requires very little training and operates much like the standard equipment that nurses and doctors use every day.

2 SYSTEM OVERVIEW

2.1 Hardware Overview

The stethoscope hardware includes several basic components. The stethoscope head remains unchanged except for an electret microphone embedded in the rubber tubing. The sounds are transmitted through the head into the microphone and then passed along a wire to the amplification and filtering circuit. The circuit filters out noise and amplifies the signal to the proper level needed to pass into the microcontroller unit. The circuit also has a headphone jack and power LED mounted on the casing. The signal is passed into the Arduino microcontroller's 8 bit analog to digital converter (ADC). This ADC samples the voltage at 38.5 kHz and updates a register with a new value every 26μs. The microcontroller is programmed to take these values and pass them into an Ethernet shield connected to the Arduino board. This shield is used to interface with a small wireless router that is connected to a Wi-Fi network. The signal is passed as an 8 bit number through the shield and router to the mobile device for future conditioning and display.

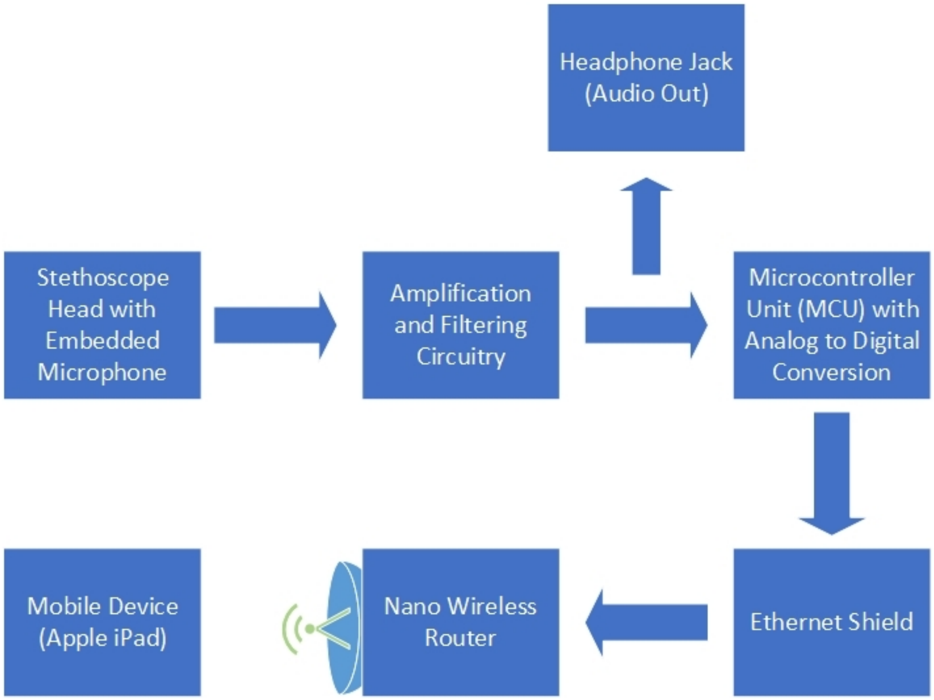

Figure 1 - Hardware Overview

The stethoscope is encased in a hard polystyrene enclosure. Inside are all components listed above as well as an 8000 mAh lithium ion battery and two 9 volt batteries. The lithium battery can power the router and microcontroller for over 10 hours of constant use and will hold a charge for over 6 months. The amplification and filtering circuit must be powered by ±9 volts and thus is powered with two 9 volt batteries in series configuration. The rubber tubing exits the case at the bottom and allows for easy use of the stethoscope. The front of the case has a power switch, power LED, volume control, headphone jack and record button. These buttons are placed such that it is easy to take readings. The stethoscope head is held with the user's left hand on the patient. The user then uses their right hand to turn on the stethoscope by flipping the switch. From this point the volume control and recording buttons are placed on the right hand side of the case to allow for easy access.

2.2 Hardware Challenges

The hardware team was successful in completing all the requirements outlined in the functional specifications with several changes from the original design specifications. Several of the problems that were encountered and their solutions will be outlined in this section.

2.2.1 Arduino Sampling Time Too Slow

The Arduino microcontroller's ADC is a 10 bit device that samples at 8000 Hz as standard or 125 μs. This sampling rate was not enough to capture audio inputs as the required rate of around 40 kHz. To solve this problem the hardware team programmed the ADC to only read the top 8 most significant bits of the ADC. This allowed the microcontroller to reduce the amount of clock cycles needed to find a new value, increasing the sampling rate to 38.5 kHz which equates to a period of 26 μs. This effectively allowed the team to use the easy-to-operate Arduino board while only losing a small amount of precision in the conversions.

2.2.2 Arduino Wifi Board Not Supported

The company that makes the Arduino board has recently released a Wi-Fi board. Unfortunately this board does not have software support currently available. A team discussion decided against spending large amounts of time starting from scratch with the Wi-Fi software. The solution was to use a supported Ethernet board coupled with a very small nano wireless router. Although this solution takes up a slightly larger amount of space it actually is significantly easier to program and costs less than half what the Wi-Fi board would. This solution, although not ideal was both easy to implement and much cheaper thus fulfilling all the requirements.

2.2.3 Overall System Size

The original functional specifications call for a case that is 130 x 100 x 70 mm. The final case that was decided for use ended up being 190 x 110 x 57 mm. This case is roughly the same volume as the original but longer and shorter. This case is actually slightly too small and is a tight fit for all the components. The main issue was that there are too many large power USB and cat 5 cables taking up room. Another issue is the size of the switches and buttons underneath the casing when attached. This was not originally considered and caused issues. Clearly upon taking the next step after prototyping the system would be to minimize the size of the case.

2.3 Software Overview

The software component of the CVI Wireless Stethoscope mainly acts as an interface between the hardware system and the health care professional administering the auscultation session. The interface is implemented for iOS applications with full support for the iPad. The software system allows the user to view the wirelessly streamed and filtered auscultation signal and also provides an automated calculation of the average heart rate. In addition to signal analysis, a database of patient, session histories and signal recordings is stored locally within the device. Account authorizations have been implemented to provide secure access to patient data.

Figure 2 describes the overview of the implemented software system, which receives user inputs and wireless signals from the hardware system. The user, once successfully signed in, can choose to analyze the auscultation signal, review past sessions of a particular patient, record the wirelessly streamed signal to the local database, or grant other authorized users of this system to view a particular patient.

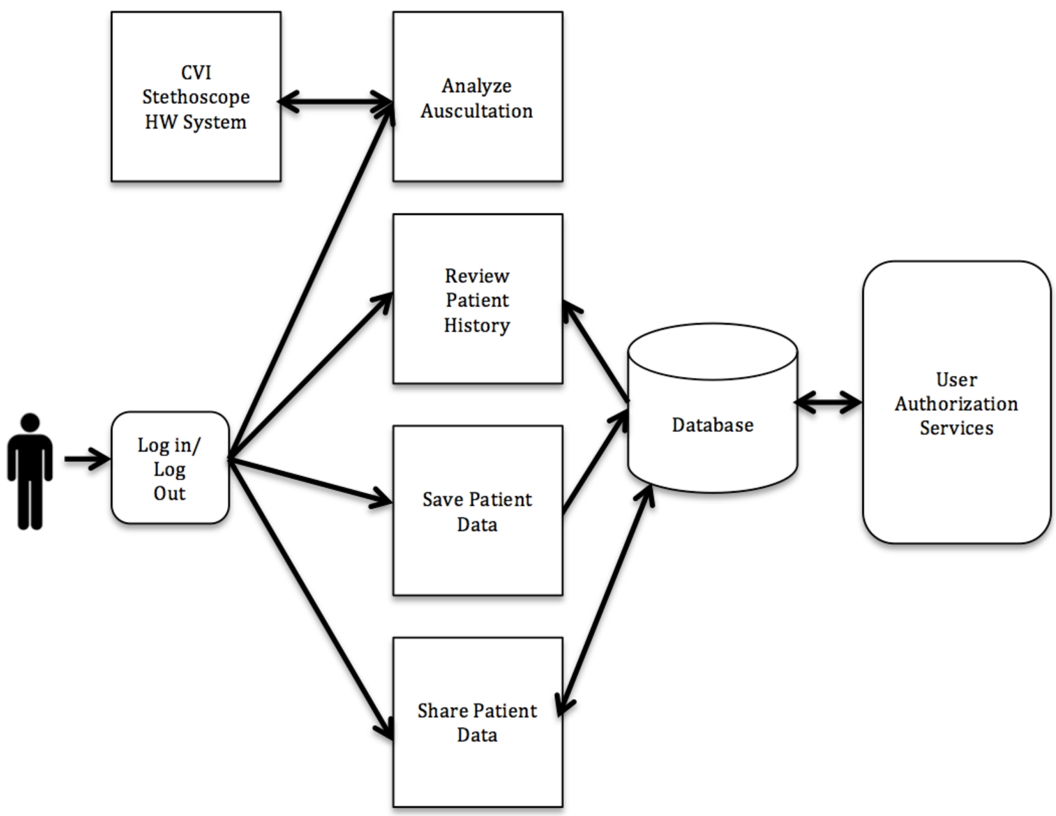

Figure 2: Software System Overview

The finalized circuit produces at signal with frequency content ranging from 0-100 Hz. Although this frequency range reflects the bandwidth of a healthy heart signal, heart murmurs are not detectable as the frequency response of heart murmurs are of high frequencies in the magnitude of kHz.

2.4 Software Challenges

The software system reflects the foundation for a basic wireless stethoscope system offering analysis support. The team was successful in delivering wireless signal communication, basic signal analysis and visual representation, and database functionalities. Although the team was able to deliver basic features that reflect the feature specifications, there are features that only partially satisfy the requirements outlined in the test plan. The following outlines several limitations and challenges encountered.

2.4.1 Low Signal Resolution and Audio

Although the Arduino offers a 10-bit resolution for streaming the wireless signal, a lower resolution of 8 bits were used instead in order to deliver real time streaming without noticeable latencies. Because a lower resolution was used, the data signal received by the iOS application is not usable for audio replaying. Instead, the live analog audio signal from the Arduino is used for listening. Although the saved audio signal cannot be used for later retrieval, the user can still listen and visualize the signal during live stream and thus aids the auscultation process by providing visual cues.

2.4.2 Limitations of Wireless Communication

Although the hardware system produces a signal with a bandwidth of 100 Hz, which mirrors the bandwidth of a healthy heart signal, and the ADC sampling rate is ample for reproducing the digital signal with minimal loss, the wireless transmission of the digital signal limited the sampling rate of the signal received by the iOS device. It was found that down sampling the digital signal from 38.5 kHz to 100 Hz resulted in reliable TCP packet delivery without packet loss or latency. However, by Nyquist-Shannon sampling theorem, this implies that the lowered sampling rate is not ample for representing the desired 100 Hz signal. This result implies that the level of analysis can only be applied to characteristics below the 50 Hz. As a result, we focused on developing an automated heart rate calculation algorithm since the average resting heart rate is less than 2 Hz.

2.4.3 Ethernet and Cloud Services

The iOS application can only communicate with one MAC address at any instance of time. Mechanisms for switching between wireless addresses will need to be implemented in order for the iOS application to connect between the Arduino and the Internet. However, the wireless connection between the Arduino is not as reliable as we wish, switching between MAC addresses will add to the complexity of the current handshaking protocol between the Arduino and thus limits our ability to communicate with other MAC addresses. Implications of this design limitation resulted in ridding our completed implementations for database storage using cloud services. Instead, the database of all patient related information is stored locally within the device. Since the data is stored and only retrievable amongst authorized users, the security of the information is still maintained and also offers the foundation for further work in uploading local files to another server. However, due to time constraints, we did not have enough time to implement this proposed mediating solution.

3 COSTS AND MATERIALS

As reported previously CVI has received full funding from the ESSS in the amount of $800.00. This amount has proved to be sufficient and no further sources of funding will be needed. Shown below in Table 1 is the initial project budget breakdown submitted in our project proposal including a contingency of roughly 20%.

Table 1: Initial Project Cost Breakdown

Part Description	Project Cost
Microcontroller (Raspberry Pi - Model B)	$35.00
USB Bluetooth Audio Transmitter	$39.99
Stethoscope	$141.95
USB Mini Microphone	$199.00
Wireless Router	$20.00
Amplification, transmission and filtering circuitry	$160.00
Noise Cancelling Headphones (borrowed)	$20.00
Contingency	$100.00
TOTAL COST	**$715**

The electronic stethoscope design was modified significantly since the initial project budget was submitted. Table 2 details all parts that have currently been purchased with bolded components being unused in the final prototype:

Table 2: Final Cost Breakdown

Part Description	Part #	Price	Shipping
Ethernet Shield	DEV-09026	$68.77	-
Wireless Router	TL-WR702N	$20.37	-
Electronic Components	DigiKey - Assorted	$62.18	-
PCB Fabrication	-	$112.78	$30.00

SD Card	AUSDH16GCL10	$11.19	-
Raspberry Pi	Model B	$55.94	-
Software License	-	$110.88	-
Soldering Equipment	Miscellaneous (solder, flux pen, heat shrink)	$54.03	-
Battery	DB-Tech 8000	$30.00	$11.00
Case	Hammond Manufacturing 1591ESBK	$20.00	-
TOTAL EXPENSES		**$587.14**	

The CVI team was lucky enough to have several components donated including the Arduino Microcontroller, Littman Cardiac Pro 3 Stethoscope, headphones and wired router. These donated items would retail at roughly $200 bringing the team right on budget if they had been needed to be purchased. In reality the team came in over $200 dollars under budget and will be returning the extra money to the ESSS.

4 SCHEDULING

Table 3 details the proposed and realized milestone dates for the electronic stethoscope design.

Table 3: Projected and Realized Milestones

Milestone	Projected Milestone Date	Realized Milestone Date
Project Planning/Proposal	January 21	January 21
Design	February 14	March 11
Coding, Development, and Unit Test	March 17	April 3
Integration and Assembly Test	March 31	April 20
Project Closure	April 3	April 23

While striving to meet all deadlines we set for ourselves, and although optimistic at the beginning of the semester, a number of milestones were modified during the course of this project as unforeseen issues arose. Due to the dependency of the software on having a working hardware device to test on, design and construction of the hardware circuitry proceeded immediately after the initial project concept was determined and agreed upon. This foresight was pivotal in our ability to deliver the product on time as the software development took longer than initially predicted. While many of the above mentioned projected milestones dates were not met, it is worth noting that we set a very early milestone for project closure. Once our final presentation date was scheduled for April 23, our project closure milestones and other internally set deadlines were rescheduled accordingly and we were able to produce our final project on time as well as on budget.

5 GROUP DYNAMICS

The CVI team was split into two main working groups, a hardware team and a software team. These teams were then further split down into individual tasks. The hardware team was made up of Andrew and Scott, while the software team included Amir, Dianna, and Kevin.

5.1 Hardware Team

The hardware team worked closely together to design the initial circuitry and then split into two hardware streams. Andrew focused on taking the circuitry design from concept through to PCB design and fabrication. Scott focused on the rest of the project including embedding the microphone, programming the Arduino, and power management. The team mostly worked together side by side and chose to meet up at least one to two times a week. There were no issues between the group members.

5.2 Software Team

The software team abstracted the software system into four sub-modules: wireless signal communication, signal processing and visualization, database supportability, utilization through a graphical user interface. The team delegated the sub-modules amongst its team members. Amir was primarily responsible for wireless communication between the Arduino and iOS application. Kevin focused on visual representation of the auscultation signal and automated signal analysis. Dianna was responsible for database support along with implementing the main graphical user interface.

Because the team was not familiar with iOS development and Objective C, the team had worked well to mutually support each other during the learning process. The team mainly worked individually but communicated progresses through meetings and through verbal progress updates. The team focused on integration of sub-systems within the last month of development to ensure the entire system was functionally compatible. The team had work well and proficiently together.

6 INDIVIDUAL LEARNING

6.1 Amir Siddiqui

Designing an innovative and creative engineering project for capstone has always felt like the holy grail of an engineering degree ever since observing my brother's project at UBC. Based on his previous experiences, the importance of creating a well-balanced team with strong group dynamics was essential to academic success and lasting friendships. The four additional group members fortunately exceeded my expectations for this criterion. Of all the possible permutations of potential group members, I could not have asked for anyone better.

Capstone is notoriously known as the most demanding course of an engineer's undergraduate degree, and without a doubt, it definitely was. Learning two new coding languages and various communication standards without any prior knowledge proved to have quite the steep learning curve. This over-ambitious attitude as experienced by the majority of capstone students makes you appreciate the sheer amount of knowledge acquired through the short time span of a mere four months. From inception to completion, it is amazing how university experience coupled with co-op experience assists in developing an innovative product. Specifically, my exposure to embedded systems on a device level at Intel set a foundation for my personal success over the past four months. Aside from all this optimism, a slew of challenges arose along the way definitely leading to some demoralizing situations. The most petrifying part of this project was not learning a new development from scratch or fiddling with communication channels for the first time, but coming up with a novel product. It was important that our design target a specific market that could benefit personal lives. After tossing useless ideas back and forth, we came up with the CVI Wireless Auscultation Device. Now that we had a product to design, it was time to get going.

Strong group dynamics, as mentioned above, were imperative to our final success in this course. Disagreements and animosity towards one another did occur from time to time, but luckily, this never became a debilitating problem. The distribution of design subsections to respective group members based on their specific degree specialization avoided any potential inefficiency. Our prudence from the beginning guaranteed minimal conflict while encouraging strong integrations. I am confident that any other team following our conflict-minimized scheduling would experience the same level of success.

Of course, there are many other aspects to our project that I wish could be implemented, but the product turned out to be pretty “cool” and useful anyway. I honestly wish we began design slightly earlier to avoid tight deadlines present at the end of the semester. Setting solid milestones that we could actually follow through upon could have improved the functionality and reliability of the product. Despite the above critiques, I am exceptionally pleased with the result and am glad it actually works on a basic level. The two things I can easily take away from this project include adding more coding languages to my repertoire, and dealing with conflict resolution correctly.

6.2 Andrew Oudijn

Coming into the capstone project this semester I was nervous and apprehensive due to the nature of the course and horror stories I heard from friends who had taken it previously. However, my nervousness was overshadowed by my excitement to be able to work with a group of hardworking individuals on a project that we were all passionate about. I had worked with most of the team members in previous courses as well as knowing most of them as friends before this course started, so when I was contacted by Amir a few months before the start of the semester and asked if I would like to join his group I jumped at the opportunity. I was extremely confident that we would be able to work together successfully as a close-knit group and produce a final product that would be a success. Now that the course is finished I am extremely proud of not only the quality of the device we have produced in such a short time but also our ability to work together effectively as a team.

The first challenge that we faced was also one of the biggest of the entire course: coming up with a project idea that we all agreed had value, a specific market, and one that could benefit human lives. In our first meeting we all agreed that we would like to pursue a project with biomedical implications as both Amir and Dianna are pursuing this area. It wasn't until sometime later that we finally came to our chosen project of a wireless electronic stethoscope which we dubbed the CVI Wireless Auscultation Device with Decision Support. This was an ambitious project due to some big unknowns including software development on the iOS platform as well as wireless communication between the device and an Apple iPad.

In an early meeting the division of labour and roles were determined and agreed upon. Scott and I would head the hardware development portion of the project due to our background of Systems Engineering, while Amir, Dianna, and Kevin would work together on the software components. Out of all group members, I worked most closely with Scott throughout this project. Initially we worked together on the preliminary design of the hardware circuitry and spent a few weeks building and tuning the circuit on a breadboard before we were satisfied with the final design. From here we branched off slightly with Scott focusing his efforts on research into the microcontroller that would convert our analog audio signal into a digital signal, as well options for wireless communication to the Apple device. While Scott was working on the difficult task of determining how the hardware would ultimately mate with the software, I began designing the PCB using the Altium Designer software. It was reasoned that moving from a breadboard prototype circuit to a PCB with surface mount components would help minimize much of the noise we were hearing through headphones. This was a daunting task as I had never worked with PCB creation software before or soldered surface mount components. I was lucky to have guidance from a friend who had worked a co-op job for a PCB design company and he was able to help me through many of the problems I came across. I am very proud of the PCB that was designed and am glad that I have learned this valuable skill.

Scott and I worked together effectively and were able to get the hardware portion of the project done with a few weeks to spare. This was imperative as it allowed the software team ample time for testing and debugging on the actual final product. Looking back, one regret I have is that I was not able to be more involved in the software side of this project. I believe that with a little more coordination between the two design teams we could have delivered a more impressive final product. For this project however, this was simply not feasible due to the short time frame of 4 months. That being said, proceeding through the entire design cycle from initial project inception and conceptual design through to having a final working prototype has given me a new appreciation for what can be accomplished with hard work and teamwork. I am extremely happy with what we have done and am glad I did not bypass this great opportunity to work with this talented group of engineers.

6.3 Dianna Yee

Over the course of this semester, I had the chance to work as part of the CVI team to create an analytical stethoscope. Having witnessed the entire course of our product from brainstorming project ideas, designing and implementing features, I gained exposure to the many stages of general project development and processes required for prototyping a working model for demonstration. Considering skills regarding general project development, I learned about the different necessary documents required to record the different stages of the product development cycle. In addition, this project heavily exercised team working skills and scheduling practices that helped guide our development. Although these skills were not new to my repertoire, being able to create a working prototype within four months definitely helped hone these skills.

Working on the software system, I was primarily responsible for the general graphical user interface and database saving capabilities. Considering the technical skills required for my contributions and having no prior experience with iOS development, I had to learned how to use Objective C and learn about the fundamentals of iOS development. In addition, I had no previous experience with database design; additional learning was required for designing efficient data access and relationship modeling.

From this project, I also learned that the integration process between sub-systems should occur as early as possible. Earlier communication between sub-systems will ensure compatibility at an earlier stage in development allowing for more time for future iterations and refinements. I have also learned that time management during the project development cycle is a crucial on an individual and team basis. Challenges may surprising arise, thus emphasizing the need for careful planning and design at the earliest time possible.

The team dynamics within our team during the semester was quite good. The delegation and completion of tasks were done well. Working amongst the other CVI team members, I got to practice revising my own implementations to reflect the other team member's valuable feedback in the timely manner. I also learned to exercise careful design such that design changes can be easily implemented without affecting other sub-systems. Lastly, I have learned a lot from the other team members when they had shared about their knowledge and implementations.

With the end of the semester approaching and reflecting upon the work and efforts put forth on this project, it was extremely fruitful to see our working prototype finally completed.

6.4 Kevin McNiece

ENSC 440 confirmed for me what my industry work experience has already led me to suspect: it is not a technical skillset or a particular specialization that imbues an engineer with employable value, but rather the ability to learn, adapt, and create reliable, original solutions to novel problems using only a broad knowledge base and creativity.

In a job interview for my last position, my then-future boss told me, "We expect you to be a jack-of-all-trades. Perhaps, in time, you'll leave us as the master of none." At the time I dismissed this as an offhanded joke, but when I was assigned data processing and representation in our group's project, I began to think back to it increasingly often. My practical experience in course work and industry was all related to hardware (specifically in large-scale communications and energy management control systems), and I had only ever completed two software courses, so being handed the unfamiliar topic of data processing and signal representation was initially intimidating.

Fortunately, my experience in equally unfamiliar settings enabled me to learn a new programming language, data processing algorithms, and a hellish version control system. I found that the basics learned in first year combined with the accumulated resources of the Internet proved more than sufficient to complete my designated tasks with relative ease. The reputation of ENSC 440 as a near-unreasonably demanding course proved at least somewhat unfounded in light of the availability of resources and the proper organization of our team.

Speaking of our team, it is hard to imagine a team that would have been better-suited to develop our product. One start-up company I worked for had in their hiring process a "beer test": before any technical questions were asked of the candidate, they would have to prove themselves interesting enough to make the employer want to have a beer with them. Our team (soberly) excelled at this, and our friendly banter created a strong yet professional team dynamic while we still boasted the technical prowess to produce a reliable product. As a result, we not only worked efficiently towards a quality result, but also enjoyed the process.

As for the results, we produced about what I had expected. Our initial proposal was ambitious, but we were ready from the start to make changes and had contingency plans in effect. The data processing algorithms were unfortunately restricted by hardware limitation on the data and user-generated noise inherent in any stethoscope. To avoid the hardware limitations, we should have made a more detailed software requirement for the data before launching into hardware design, but the stethoscope noise is unavoidable in any case. We also stripped down database functionality to meet deadlines, but in the end turned out a robust, complete product regardless.

I take away from this course a myriad of relatively inconsequential skills: a new programming language, data processing experience, communications protocols; but more importantly, I was assured that with strong fundamentals of organization, professionalism, interpersonal ability, motivation, and a basic understanding of a few simple engineering principles, the dedicated engineer, with a dedicated team, can create nearly anything he or she imagines.

6.5 Scott Greene

I knew coming into this project we would do a great job. I feel like we had a group that could really take whatever idea we decided on and run with it. I am generally an easy going person to work with and I feel choosing to work with people of a similar mind has contributed to the project running so smoothly.

In my role on the hardware team I spent my time working very closely with Andrew. We began by working closely together on the initial circuit design. It was nice to realise that everything we needed to know to design this whole circuit was stuff that we really knew from previous classes. We could easily discuss different aspects of the things we needed to use, as well as having actually used many of the different components in previous labs. We spent several weeks tuning the circuit using many different techniques we have learned in the past. From this point on we were stepping into new territory. Andrew continued working on the circuit design and fabrication while I started working on the rest of the project. I spent a huge amount of time doing research about microcontrollers, analog to digital converters, and wireless technology. The one thing that I found difficult is how each component interacts with each other and thus need to be chosen properly. When you choose an ADC you need to pay attention to the impedance of the circuit, but when you try to match the circuit impedance it then affects the amplification and filtering. The Arduino microcontroller was an intimidating prospect initially until I started programming it. It is an incredibly easy piece of hardware and software to use. There are a large amount of demo programs that can easily be adjusted and parted out. The issue with the ADC sampling frequency was one that took me a long time to figure out and I borrowed a lot of knowledge from ENSC 215.

We worked really hard on the hardware portion of this project and starting early was a key factor to this. We put a lot of time into the initial design and this allowed us to finish the hardware ahead of schedule. Finishing early allowed the software team to be able to use a finished product so they knew exactly what they had to work with. Another important factor towards the hardware portion running so smoothly was the incredible amount of research we did to completely understand what we needed to do. It was nice that we had set several levels of completion and met each level in stages. This way if a certain portion of the project did not go as planned we had something we could fall back to that still did much of what we needed. In the end we reached all of our goals and the team worked very well together. It was sometimes odd to have such a low understanding of the software as generally I like to be on top of each portion of a project. This was a learning experience for me as this format is how it is in industry. I am very happy with our product and how our team functioned this semester. I would work with each of these individuals again in a heartbeat and feel like I learned a lot about how to take something from an initial idea to the finished product in this course.

7 NEXT STEPS

This section will briefly detail the steps that would be required in order to move our design from a proof-of-concept prototype to a marketable product. At this time however no such plans have been made.

7.1 Miniaturization

While still fairly comfortable to wear around the neck, the case of the electronic stethoscope is significantly larger than was initially anticipated. This was due to a number of design modifications that were implemented as unforeseen issues arose with the design. It was initially hoped that we would be able to achieve wireless communication using a Wi-Fi shield sold as an accessory for the Arduino Uno microcontroller. However, through research we discovered that TCP (Transport Control Protocol) is not yet supported with the Wi-Fi shield. As a result we modified our design to instead utilize the Ethernet shield Arduino accessory which required a hardwired connection to a small router inside the case through a CAT6 Ethernet cable. This significantly increased the size of the case that was required to fit all components. The inclusion of a large battery pack to power the Arduino as well as the router also increased the size of the case. In order to refine our design to the point where it could be a marketable product to physicians or nurses we would need to significantly reduce the size of the case. This would involve a significant amount of effort in either software development (to include TCP functionality into the Arduino Wi-Fi shield) or research into other microcontrollers that include this functionality.

The CVI Stethoscope mobile application has been optimized for viewing on an Apple iPad screen. To supplement the miniaturization of the case that would be required to move this prototype to a marketable product we also propose creating another version of the application that would be optimized for viewing on an Apple iPhone screen. The miniaturization of these two components would make the device easier to carry and use when performing auscultation. The amount of effort required to create an iPhone version of the application would be fairly minor as only the GUI would need to be redesigned.

7.2 Audio Recording on Mobile Device

As it stands currently, our device is capable of producing a clean audio signal that is comparable to that obtained from a conventional stethoscope. However, a limitation in the Arduino ADC limited this functionality to only a real-time signal from the hardware circuitry without the ability to record audio on the mobile device for future playback. In order to get a high enough sample rate for the ADC converter we were forced to remove the two least significant bits of our signal. This reduced our resolution from 10 bits to 8 bits resulting in an audio signal of poorer quality. In addition to this, our implementation of TCP for wireless transmission of the audio signal and the overhead that accompanied it (handshaking and error checking) further reduced the quality of this signal. This would need to be remedied for the product to become marketable. This would require significant research and perhaps investment in a more robust microcontroller or more development in wireless communication.

7.3 Anomaly Detection Algorithms

The issues that restricted the recording of audio on the mobile device also negatively impacted our ability to provide heart anomaly detection algorithms on the mobile application. While we were able to successfully implement heart rate detection in beats per minute, we were not able to implement any other anomaly detection algorithms such as heart murmur detection. The reasons for this include the loss of signal resolution due to the ADC and wireless transmission as mentioned above. In addition to this, our filtering circuitry utilized a low-pass filter with a cut-off frequency of 100 Hz. This is insufficient for heart anomaly detection as many heart defects or diseases are characterized by sounds with frequencies higher than 100 Hz. In order to implement these anomaly detection algorithms, a significant amount of work would be required both in software and hardware.

8 CONCLUSION

The CVI team has met and exceeded their goals for the prototype of their Wireless Auscultation Device. The device works as intended and almost no functional or design specs were not met. The hardware was completed ahead of schedule with no major issues apart from fitting all the components into the case. The software team has gone beyond what was expected and produced a slick, easy-to-use program that works as intended. The team worked very well together with no issues that needed to be resolved. Communication between members and teams was facilitated using the WhatsApp mobile application so that each group member was up to date on everything that was being discussed. All documentation was done as a group and equally distributed as well as completed with a high degree of professionalism and quality. No future plans have been made regarding the product and it is not expected that any will. There is currently one electronic stethoscope on the market produced by 3M. This stethoscope is very expensive, but the company has a huge amount of capital and resources to reduce this price. The CVI team is very proud of what they produced and would readily work together again.

APPENDIX A – MEETING MINUTES

2013-01-03

ENSC 440 Group Meeting

Team Leader Discussions

Scott Volunteers on account of having fewest classes

Motion passes unanimously

Topic discussions

Amir – Biomed projects have potential support of more faculty members: many of them do biomed research and will express interest

Several biomed ideas:

- Concussion protection – Sensing, response, anticipation?
- Animal feeding – automated control for testing purposes
- "Do it yourself" triage
  - Interface with database, apps for iPad, etc.
  - Blood pressure readings, heart rate, temperature
  - Patient prioritization (automated)
- Medical information database
- Skin condition, etc auto-detection or remote doctor outsourcing
- iPhone heart rate monitor

Else:

- Infrared imaging – does this already exist?
- Golf ball tracking
- Home automation – power tracking, control,
- Noise cancellation, detection, replacement
-

2012-01-08
2:15 PM

Meeting with Dr. Andrew Rawicz

Purpose: To obtain feedback on current ideas from 2012-01-03 meeting

Biomed Idea

- Talk to John regarding current triage
- Well-defined scope already
- Experience triage system firsthand

Building management

- Define scope better for the project
- High costs of project?

Consider the entrepreneurial aspect – biomedical is a rapidly growing field.

<u>Data for Proposal Use</u>

$17B for 4M people. $1B increase each year
    Annual report by BC Government
$256B federally for Canada
    GoC reference?

Determine the social and environmental impacts of each project before making a finalized decision.

Based on the support from Dr. Rawicz, our group's personal preferences towards the project, and the feedback we received, our group unanimously decided to pursue the triage support system.

Dianna obtained contact information for VGH

<u>Action Items</u>

- Dianna: follow up with contact regarding an appointment at triage.
- Group meeting to be held on Thursday re: next steps.
    - Team name, logo design
    - Information required to complete proposal
    - Division of labour
    - Preliminary specification discussions

Medical Triage Program

AGENDA

January 10, 2013
11:30 to 12:30
ASB

Purpose of Meeting: To develop a list of questions for health care workers and determine next steps

Items for Discussion:

- What should we be asking health care workers about the triage process?
- What information do we need before we can develop a detailed proposal?
- What are the basic functional requirements of our design?
- Discuss division of labour for proposal due on Jan. 21.
- Team name, branding.

Medical Triage Program

MINUTES

January 10, 2013
11:30-12:30
ASB

Present: Dianna Yee (DY), Scott Greene (SG), Andrew Oudijn (AO), Kevin McNiece (KM), Amir Siddiqui (AS)

Absent: None

Purpose of Meeting: To establish questions for triage, determine next steps for project.

Minutes:

Little Pig #1 called the meeting to order at 10:30.

A. Approval of the agenda and minutes of the January 13, 2013 meeting

Agenda was approved as amended:
- Discuss funding sources
- Regular meeting times

B. Business Arising

None

C. When should we be meeting regularly?

Discussion: Early in the week is better. Thursday 2:30 is the only agreeable time.

Action: Meetings will take place after ENSC440 on Thursday.

D. What should we call ourselves?

Discussion: Amir suggests Mediacal Triage Program (MTP). Group agrees. AS suggests simple letters. SG suggests it should indicate what we do. AS and SG agree on a medical cross on the logo with small subscript explaining acronym.

Action: Ask Mike Phang for assistance in graphic design, complete draft by 17/01/12. Approval to be given for design at that time.

E. What are the fundamental requirements for our design?

Discussion: SG: A machine that takes vital information, accepts symptoms, puts into database, syncs to patient file on portable device. System prioritizes patients based on need. Database allows access to all patient information and history. Patient interface is also a concern?

DY: Set up separate station?

AO: Three sides: box, server, interface.

Action: Meet with healthcare worker and figure out what we can get. Specify interface, server format, devices.

F. What questions should we be asking of triage and health care workers?

Discussion: SG: What is the necessary vital information triage?
- Walkthrough of the current system
- What are the bottlenecks?
- What could be fixed or changed?
- What are the vital signs that would be helpful for doctors?
- What does the doctor want to see about a patient?
- How useful would anomaly identification be?
- What's **wrong** or what's **right** about the current system?

Action: Take these to a health care professional. DY to see someone this weekend. AS to join. SG is also available. DY to ask for more contact information. DY will also continue pursuing the current contacts.

G. Where can we get funding?

Discussion: Scott will handle finances, get a prelim report out. ESSS funding proposal due on Monday. Once we determine how much funding we get, revisit the issue.

Action: SG can go ahead and specify a rough estimate of hardware and cost. This will be issued to the group Friday, January, 11. AO will complete the funding proposal pending SG's budget.

H. How should we distribute labour for the proposal?

Discussion:
- Executive summary - SG
- Introduction - DY
- System Overview - AS
- Possible Design Solutions - AO
- Proposed Design Solution - AO
- Sources of Information - DY
- Budget and funding - SG
- Schedule - KM
- Team Organization – Each their own, determine roles at later meeting
- Company Profile - AS
- Conclusion - KM
- Sources and References - DY

Action: AO to secure template, each to work on individual sections. Due Jan. 17 for review and concatenation.

I. Should we get a locker?

Discussion: Yes, for safekeeping.

Action: KM to supply lock, KM to secure locker as well by emailing Fred

D. Next Meeting Date

The next meeting was arranged for January 17, 2013 at 2:30-3:30 in ASB.

E. Other Business

None.

Meeting was adjourned early at 12:20.

Medical Triage Program

AGENDA

January 13, 2013
10:30 to 11:30
IM/Video Chat

Purpose of Meeting: To review the findings of the team visiting triage

Items for Discussion:

- Is our project feasible?
- What are the findings?
- Are any better ideas available?

Medical Triage Program

MINUTES

January 10, 2013
10:30-11:30
ASB

Present: Dianna Yee (DY), Scott Greene (SG), Andrew Oudijn (AO), Kevin McNiece (KM), Amir Siddiqui (AS)

Absent: None

Purpose of Meeting: To establish questions for triage, determine next steps for project.

Minutes:

Kevin McNiece called the meeting to order at 10:30.

A. Approval of the agenda and minutes of the January 13, 2013 meeting

Agenda was approved

B. Business Arising

None

C. Is our topic feasible?

Discussion: Triage is not the problem – it's mostly waiting for results that is holding people up. Access to computers is alright. Health care workers did not approve of the system.

Action: Scrap this idea.

D. Stethoscope?

Discussion: A stethoscope is a feasible project – covers all aspects of design, within the limits of our capabilities. This would enable tele-health. The project would interface with a preliminary database that would be able to track other patient information.

Action: So far this is the group's best option. We will meet to finalize details of the project at 10:30 Monday.

E. Wireless leads?

Discussion: Leads from sensors often get tangled – can we design sensors that communicate wirelessly? This is already in development, but we might be able to make it unique.

A 440 group in 2010 has been completed already.

Action:

F. Communications?

Discussion: Communications between staff is a problem – can we interface test results, etc. to ipads or other devices an establish staff-wide communications? This is mostly software.

Action:

G. Patient data tracking?

Discussion: Idea: to put patient data in a database that can be updated by patients and accessed by medical staff

Action:

H. Blood glucose level?

Discussion: Track blood glucose levels, complete online tracking accessible by medical professionals.

Action:

I. Patient information profile?

Discussion: Put patient information from various devices into one place and make it available to doctors wirelessly

Action:

J. Next Meeting Date

The next meeting was arranged for January 17, 2013 at 2:30-3:30 in ASB.

K. Other Business
None.

Meeting was adjourned early at 12:20.

Cardiovascular Instrumentation

AGENDA

January 17, 2013
2:30 to 3:30
ASB

Purpose of Meeting: To review progress on proposal so far, move forward in design specification and delegation of functional blocks

Items for Discussion:

- Where do we stand with the current proposal?
  - What have we finished?
  - What else needs work on? (incomplete/rework)
  - Team Logo
- What aspects of the project do we want to focus on?
  - What functional blocks do we need and how do they interact?
- How are we going to delegate roles?

Cardiovascular Instrumentation

MINUTES

January 17, 2013
1:40-3:30
ASB

Present: Scott Greene (SG), Andrew Oudijn (AO), Kevin McNiece (KM), Amir Siddiqui (AS)

Absent: Dianna Yee

Purpose of Meeting: To review proposal progress so far and determine/plan for next steps for project.

Minutes:

Kevin McNiece called the meeting to order at 1:40 PM

A. Approval of the agenda and minutes of the January 13, 2013 meeting

Agenda was approved

B. Business Arising

None

C. Where do we stand?

Discussion:

- Scott on exec summary: in progress, near-completion. Group provides feedback on idea. Budget: Needs to include stethoscope. How detailed does the budget need to be? Needs to find a list of products. Talk to Ash about specific current controllers.
- Andrew: Finished company profile blurb, started existing technologies – stethoscope analysis (electronic and otherwise), not sure about possible design solutions. Possible design solutions: intermediate device, portable device, ECG. Proposed design solution – already covered in discussion.
- Amir: company profile under construction – need to define roles. Financial officer – Amir. Hardaware design coordinator – Andrew. Chief software programmer – Dianna. COO – Kevin. System overview – in progress with diagrams.
- Kevin: PM Software acquired, conclusion in progress.
- Dianna: To provide update and request help if required, assumed to be on task.

Action:

- Scott will produce preliminary budget by Saturday Noon.
- Andrew: Saturday morning – all sections
- Amir – Saturday as well
- Kevin – Get 'er done by Sat.

D. What should our logo look like?

Discussion: Mike is already designing the logo, V will be a stethoscope instead of the I.

Action: Make less penis-y

E. Division of labour

Discussion: AS, DY, KM – Software. AO, SG - Hardware

Action: Schedule individual meetings to discuss subsections

F. Next Meeting Date

The next meeting is TBD

G. Other Business
None.

Meeting was adjourned at 2:15

Cardiovascular Instrumentation

AGENDA

February 21, 2013
10:30 to 11:30
ASB Atrium

Purpose of Meeting: To provide hardware and software updates and discuss technical specifications

Items for Discussion:

- What has the hardware team accomplished?
- What is forthcoming from the hardware team?
- What has the software team accomplished?
- What is forthcoming from the software team?
- How shall we divide work on the technical specification?
- Project-level progress report
- Sustainability

Cardiovascular Instrumentation

MINUTES

January 10, 2013
10:30-11:30
ASB

Present: Dianna Yee (DY), Scott Greene (SG), Andrew Oudijn (AO), Kevin McNiece (KM), Amir Siddiqui (AS)

Absent: None

Purpose of Meeting: To update team regarding status

Minutes:

Kevin McNiece called the meeting to order at 14:06.

A. Approval of the agenda and minutes of the January 13, 2013 meeting

Agenda was approved

B. Business Arising

None

C. Hardware?

Discussion: Working amplifier, need to eliminate noise (linear only) and tune. Next step: interface to Arduino board, start programming board. Need to regulate voltage to board from 9V. Altium designer is being used by Andrew to design the PCB.

Action: Interface to board: find out resolution of Arduino ADC, make it work. Andrew and Andrew will collaborate on programming.

D. Software?

Discussion: Dianna: DB and GUI, Kevin: Data processing, Amir: comms between HW and iOS. Has GUI outline, needs to start building off of that.

Action: Begin construction of functional components from iOS interface. Amir will buy software license from existing funds.

E. Technical Specification?

Discussion: Kevin: Data processing, System Test Plan; Dianna: UI, DB; Amir: Comms interface; Andrew, Scott: do hardware together. Scott: Exec Summary, Sustainability; Andrew: Conclusion

Action: Get the above done. Yo. By the Saturday before.

J. Next Meeting Date

The next meeting was arranged for March 3, 2013 at 14:00-14:30 in ASB.

K. Other Business

None.

Meeting was adjourned early at 14:20.

Cardiovascular Instrumentation

AGENDA

March 18, 2013
10:30 to 11:30
ASB Atrium

Purpose of Meeting: To update project progress

Items for Discussion:

- Written report progress
- Individual team member updates
- Collaboration steps required

Cardiovascular Instrumentation

MINUTES

March 18, 2013
10:30-11:30
ASB

Present: Dianna Yee (DY), Scott Greene (SG), Andrew Oudijn (AO), Kevin McNiece (KM), Amir Siddiqui (AS)

Absent: None

Purpose of Meeting: To update team on progress, plan next steps

Minutes:

Kevin McNiece called the meeting to order at 10:45.

A. Approval of the agenda and minutes of the January 13, 2013 meeting

Agenda was approved

B. Business Arising

None

C. Progress Report

Discussion: Amir sent out an email to the group breaking down tasks for individuals. Refer to this email for delegation.

Action: Complete individual sections by March 30th

D. Dianna Updates?

Discussion: GUI structure is done, database work is on deck. Third party software is presenting some small complications (Dropbox API).

Action: Tidy up GUI and fix some bugs, tie in database side

D. Amir Updates

Discussion: UDP working – getting a datastream through Arduino. Working on implementing a synchronization button on the hardware.

Action: Begin construction of functional components from iOS interface. Amir will buy software license from existing funds.

D. Kevin Updates

Discussion: All data processing algorithms are in place, needs to be put into dynamic C. Will need to start preprocessing to eliminate hardware noise.

Action: Implement Dynamic C and start preprocessing data.

D. Hardware Updates

Discussion: PCB is ready to be manufactured, Arduino is easily programmed. Anticipating near completion.

Action: Fabricate PCB and begin testing.

J. Next Meeting Date

The next meeting was arranged for March 24, 2013 at 11:00-11:30 in ASB.

K. Other Business

None.

Meeting was adjourned at 11:20.