April 30, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Post Mortem for Biomedical Monitoring System

Dear Dr. Rawicz:

Please see attached *Post Mortem for Biomedical Monitoring System*, a document, which describes our results and experiences through completing the ENSC 440/305 project. The main purpose of our project was to develop a real time data acquisition system to measure and monitor heart rate and patients' cardiovascular health. The monitoring can be done via two options: USB cable or through a wireless protocol.

The report presents the functionality of our project, the problems we encountered, the incurred costs and timeline for the project development.

Biomedical Embedded Systems Technology (BEST) is a group innovative engineering students from diverse backgrounds. The team consists of Sam Sayfollahi and Alireza Rahbar (Electronics Engineers), Farzad Abasi (Computer Engineer), Parna Niksirat (Systems Engineer), and Shaghayegh Hosseinpour (Biomedical Engineer).

For any further information please feel free to contact me.

Yours truly,

Alireza Rahbar

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Enclosure: *Post Mortem for a Smart Biomedical Monitoring System*

Postmortem for: Biomedical Monitoring System

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1. Introduction:

The heart is the center of the cardiovascular system. Through the body's blood vessels, the heart pumps blood to all of the body's cells. The blood carries oxygen, which the cells need. Cardiovascular diseases are a group of problems that occur when the heart and blood vessels aren't working the way they should and affect many lives throughout the world.

One of the best ways that doctors can detect signs of cardiovascular disease is to monitor their patients for signs of abnormalities and erratic heartbeats. The electrocardiogram (ECG or EKG) is a diagnostic tool that measures and records the electrical activity of the heart in exquisite detail.

Since the beginning of January 2010, we at Biomedical Embedded Systems Technology (BEST) have been developing a prototype for a portable, real time data acquisition system that is capable of acquiring the electrocardiograph and heart rate of a patient.

This report shows the overview of the finished prototype, modification to the details outlined in our design specification, the project budget and timelines as well as suggestions for future development. At the end, each member of BEST explains the inter-personal and technical experience gained from working on the project.

2. Current State

The development phases of the BMS, as outlined in the functional specifications, were: complete the hardware of the BMS, develop the code backend software and develop the Graphical User Interface.

During the last few months, BEST team members have been working hard to complete the above phases. The current state of the project phases are:

Hardware:

- The ECG circuit has been completed and is fully operational. Initially, we ran into a problem with electrical noise which resulted in poor output quality. After redesigning the ECG circuit, we were able to resolve this issue and obtain a clear ECG graph. Additionally, we added a DC offset circuit to our system in order to account for negative graph points (due to microcontroller limitations).

- The wireless module is functional and can send data through the air. The data is transmitted serially and can be received from a distance.

- The microcontroller has been setup and interfaced with the USB daughter board, wireless module and ECG circuit.

Backend software:

- The core data acquisition software for the microcontroller has been written and fully tested. The microcontroller converts raw analog data to a digital stream of data points. These data points are used by the GUI to represent the voltage of the heart.

- The software for the wireless module is complete and allows for communication between the GUI and the microcontroller.

Front end software:

- The GUI is fully operational and features user friendly control for the system. The GUI offers the user controls for communication (serial port) setup, microcontroller configuration (to set sample rate and storage location), and real time data acquisition. All of the main controls of the BMS that can be performed using the serial port commands can also be done using the GUI.

3. Future Plans

Due to our limited time and budget, we had to leave out some details in our design. The Heart Monitoring System has potential for improvement. The following are possibilities for future work to make the device more user-friendly and practical.

3.1. PCB

The heart rate monitor prototype that was proposed was planned to be constructed on a breadboard. Although using a breadboard is a great tool for implementing and testing initial ideas, it is not intended to be used in a final product. One of the main issues is that it introduces noise to the signals, making readings inaccurate. It also causes other problems such as loose wire connections and taking up too much space.

In order to resolve these problems, the final product should be transferred into PCB. The PCB board will include ECG circuit, microcontroller, as well as the wireless module. This will reduce the size and weight of our design significantly.

3.2. Bluetooth Transmission

In this prototype, we used Xbee module for our wireless communication. Although a low-cost, low-power communication module popular among hobbyists, Bluetooth will be a better alternative.

Most laptops and computers these days can communicate with Bluetooth devices. This means by using Bluetooth, a receiver for computer will no longer be necessary, reducing the cost of the product.

The down side of using Bluetooth is that it has significantly lower range than what we are currently using. However, the benefit of Bluetooth technology is that it is so widely used that it can be connected to almost anything. Currently, most cellular phones in the market have built-in Bluetooth capabilities. After connecting our heart beat monitoring device to a cell phone, data can be easily transmitted not only to a computer, but to a hospital through a 3G network. This way, if a problem should arise, the hospital will be the first one to be notified. Finally, a GUI can be easily written for cell phones to completely remove the need of a computer.

3.3. Additional Sensor Integration

In order to be successfully used as a diagnosis tool for heart disease, we need to increase the number of electrodes that we attach to the patient’s body. In our initial design, we used three electrodes. A standard electrocardiograph machine however, has ten electrodes attached to the body. More electrodes will increase the accuracy of the readings, improving sensitivity in detecting any hear problems. This requires redesigning part of our circuitry as well as some additional programming.

3.4. Problem Detection

As engineering students we lack the knowledge to fully analyze ECG waves and interpret any abnormal rhythm. However, with help of professional medical practitioners, we can develop and implement algorithms that detect abnormalities in heart beats. This way, immediately after detecting a problem, the device will send an alarm to patient's doctor to warn them about possible heart complications.

4. Budgetary, Funding and Time Constraints

4.1. Budget

Table 1 represents the estimated cost and the actual cost of the project up to April 30th, 2010.

Table 1: Estimated Cost vs. Actual Cost

Required Materials	**Estimated Cost**	**Actual Cost**
Micro-Controller : WASP	$40	$107
Daughter board module for USB connection: USB10	$40	$66
Connector module for micro-controller and related wires	$10	Borrowed
Heart beat sensor (ECG) leads and wires	$250	Borrowed
Wireless (transmitter and receiver)	$100	$100
Shipping costs	$40	$20
Parallel to USB converter	$20	$10
ECG circuit parts	$50	$180
Total Cost	**$550**	**$483**

As the table above shows, the actual cost is less than the estimated cost. We expected to spend $250 on the ECG sensor and wires, however, Dr. Moradi generously provided us with the leads and wires. In addition, as the table indicates, the actual cost for the microcontroller was twice the amount we estimated as we bought two so that the team members could work on the software in parallel. Another difference in the table is the cost of the AD624AD which was used in the ECG circuit. As we could not find this electronic part in any Canadian store, we ordered the part form the US and the cost as shown on table 1 is almost triple what was expected.

4.2. Funding

As per the budget for the production of this prototype, different sources of funding were considered by BEST. The cost for the developing a prototype of our product is much higher than mass producing it. Therefore, the above estimated cost does not correctly reflect the final production costs.

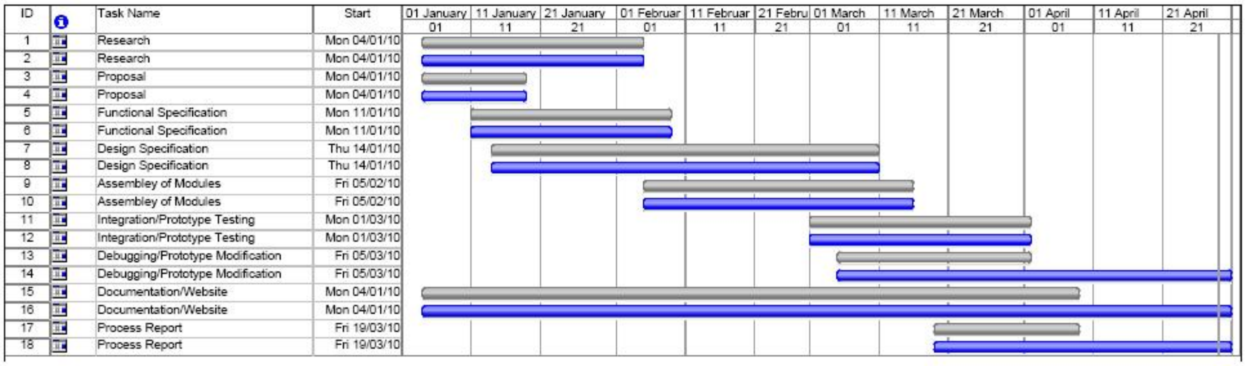
We applied for the Engineering Science Student Endowment Fund and we were funded $625. Furthermore, we applied for IEEE mini grant but we were not successful.

All financial transactions were accurately recorded and members of the group were properly reimbursed.

4.3. Schedule

Table 2 shows the estimated Gantt chart and our tentative time to accomplish various parts of the project. Fortunately, the two week break during the Olympics gave us extra time to accomplish the different tasks of the project and we were ahead of all the deadlines except for the last one which forced us to postpone the demo time.

Table 2: Gantt chart



ID	Task Name	Start
1	Research	Mon 04/01/10
2	Research	Mon 04/01/10
3	Proposal	Mon 04/01/10
4	Proposal	Mon 04/01/10
5	Functional Specification	Mon 11/01/10
6	Functional Specification	Mon 11/01/10
7	Design Specification	Thu 14/01/10
8	Design Specification	Thu 14/01/10
9	Assembley of Modules	Fri 05/02/10
10	Assembley of Modules	Fri 05/02/10
11	Integration/Prototype Testing	Mon 01/03/10
12	Integration/Prototype Testing	Mon 01/03/10
13	Debugging/Prototype Modification	Fri 05/03/10
14	Debugging/Prototype Modification	Fri 05/03/10
15	Documentation/Website	Mon 04/01/10
16	Documentation/Website	Mon 04/01/10
17	Process Report	Fri 19/03/10
18	Process Report	Fri 19/03/10

5. Inter-Personal and Technical Experiences

Alireza Rahbar

From a technical perspective, I have gained so much fundamental knowledge of programming in C and C#. I spent a great amount of time learning C# in conjunction with the Microsoft .Net platform. I learned a lot about RS232 protocol and how to create a communication port using GUI. In designing the GUI, I tried to follow the standard features you can find in almost every program in order to make the GUI as user-friendly as possible.

Other than software, I was also exposed to different circuit design ideas and components which I never had the chance to work with previously. The best part of the project for me was the opportunity to integrate the technical skills that I have learned over the past 4 years. It was an interesting experience to use a type of filter that I learned about in third year and combine it with an amplifier stage that I was introduced to in my second year. Suddenly, all those mathematical equations became more appealing.

Overall the Capstone Project has taught me several lessons; these lessons are not limited to an academic nature, but extend to the interpersonal realm as well. Project management, team work and communication were a significant part of this great experience. I had the opportunity to work in a wonderful group and I consider this project a great success.

Farzad Abasi

During the course of this project I have learned the steps required in designing an embedded, real time system. I had to adapt my traditional knowledge of programming and learn how to write code for a project that had very limited recourses (both CPU power and memory) and one that did not have an operating system. To achieve this, my code had to be both efficient and expandable.

I also learned how to work together in a team with four other members. All the team members had their own strengths and weaknesses which added to the unique dynamic of BEST. We worked closely as a group to achieve our goals.

The biggest hurdle we faced throughout this project was the electrical noise issue with our ECG circuit. This problem caused many wasted hours of unnecessary debugging which could have been better spent on other aspects of the project. We overcame this hurdle through persistence and help of the professors.

ENSC 440 was by far the most interesting and practical course I have ever taken throughout my career as a student. I particularly like how the course blended topics of both hardware and software. The skills I learned in this course have prepared me for my future career goals.

Parna Niksirat

As I started to work on this project, I thought it would be difficult to work with a group of people with different backgrounds, ideas and interests. As we started to generate ideas and make progress, I realized the importance of a team work.

We designed different types of analog digital circuits and analyzed them to acquire the best performance. In every design of ECG measurement circuit, we faced a great amount of noise which was difficult to filter. We learned how to minimize and avoid the noise to some extent. In designing the stages, I became more familiar, confident and analytical in the circuit design. The more we got in to trouble, the more I understood the concept behind the design. One of the benefits of working in a team where each member has a unique strength, is if one cannot see the problem the other may figure it out. This can smooth out the flow of the project and prevent further frustration.

I also got to work with a Atmel Embedded processor and XBee wireless communication. I learned to program in C# which was very similar to C that I learned in the first year. The great thing was, three of us were working together on the programming side which I think was very rewarding. Each person had a different approach to the problem. As a result, we got introduced to a different solution from another perspective. Then in our meetings we discussed to choose the best solution to our problem.

In order to meet our goal, we had to learn about and research different devices available in the market. After we had done research, ordered our parts, and started working on the system, we understood how little we knew about the product we had chosen. I believe with more knowledge and information about the devices available in the market, we could be more efficient and productive. By doing this project we increased our knowledge about different amplifiers, AD devices, microcontrollers and wireless communication devices and their functionality.

I learned in this project that planning ahead and setting deadlines are necessary steps to success. By working in a team, we can minimize the time we had to spend troubleshooting a circuit design, system communication issues or a software program. As we got close to the final demo, and the pressure to finalize the project increased, I understood the importance of the support of my team members. The things I appreciated the most about my team members was their flexibility, understanding of one another and sense of humor.

Shaghayegh Hosseinpour

When I decided to take these two courses in January, which was my first semester in SFU, I didn't have a clear idea of what these courses are about and what I should be expecting. I was expecting just another course in the university. But at the end I realized that these courses were very different than any other course I had taken. Moreover, I got better understanding of the theories that I had studied in my undergraduate courses.

My main contribution to this project was in the designing and development of the biomedical parts as my background is in biomedical engineering. I also learned many good things about analogue circuits in this project. Since the ECG signal is very noisy, I learned a lot about noises and filters. We made some different configurations for the ECG circuit and we learned a lot from each of them.

One of the most important attributes I learned from this course is the importance of teamwork. I must say I am pretty pleased with dedication and work ethics of my team. Although we all had individual responsibilities, we all helped each other find solutions to problems when needed and collaboratively worked on certain areas together.

To conclude, I found the contents of this course and project to be most practical towards my career as an engineer.

Sam Seyfollahi

The last 16 weeks changed the way I look at engineering, now I have a better understanding of what I have learned during the past 4 years. Ensc 440 gave me a chance to apply all the theoretical knowledge that I have gained from my math, physics and engineering courses, and Ensc 305 has taught me the importance of documentation. The functional specification and the design specification were the basis of our project and saved us a lot of time in design specific decision making.

From a technical point of view, I was working on the ECG circuit and we had to design many configurations to decrease the noise almost from every thing, so it was a chance for me to work with multi stage circuit and learn how to analyse them. I also leant so many things about shielding and filtering 60 Hz noise.

Having finished these two courses, I feel much more confident in my self facing new challenges and I learned in order to find a solution for a problem, you need to approach it from different ways and consider all the aspects.

6. Conclusion

Biomedical Embedded System Technology has created a prototype wireless monitoring system that is used for screening and diagnosis of heart diseases. This system is easy and convenient to use in the house or fitness centre and can be used for remote real time monitoring. The patient either can be monitored remotely by the doctor, or the data acquired by the system can be transferred through the use of USB cable at a later time. After completion of the first prototype, BEST is encouraged to optimize the design and make it more convenient for the patient and medical personals. During the design process BEST set some goals and standards to achieve the optimal result. After working on the system for months, BEST realized that the design can be improved by altering the device as well as doing some research or surveys on the product.