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December 18, 2003

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

Re: Sonitus Solutions Post Mortem.

Dear Dr. Rawicz,

The attached document, *Sonitus Solutions Post Mortem,* describes the implementation and design strategies of our product. As well, we also state the deviations between our design plans to the present implementation methodology. After we discuss the future plans of the product, the document concludes in discussion of the experiences gained from the project.

Sonitrac, our product, is a 3D Ultrasonic Motion Tracking System. Its primary targeted application is for research usage. Sonitus is composed of six highly motivated and resourceful individuals: Alan Chuang, Kenneth Fong, Henry Lin, Warren Lee, Edward Loo and Richard Sheng. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (604) 771-9719 or by e-mail at sonitus-340@sfu.ca.

Sincerely,

Richard Sheng
President
Sonitus Solutions

Enclosure: Design Specifications of the 3D Movement Tracking System

Sonitus Solutions Post Mortem

Project Team: Alan Chuang
Kenneth Fong
Warren Lee
Henry Lin
Edward Loo
Richard Sheng

Submitted To: Andrew Rawicz
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1. Introduction

Lesson number 1, capacitors are our friends, noise is our enemy. This document is Sonitus Solution's Post Mortem, in other words, we shall examine the present state of the system, compare it to the past, and look towards the future. Sonitrac is a 3D motion tracking system that uses ultrasonic technology in order to triangulate the location of specific points on the user's body. Thus, Sonitrac will be able to determine the posture and movements of the user in real-time. Our software uses this data to display a model of the person in real-time, as well as plot the data for analysis.

2. Present Status of Sonitus Solutions

Sonitus Solutions has chosen to use the acoustic technology for Sonitrac, which consists of a base station, a mobile unit, a receiver array matrix, and a PC software user interface. The receiver array matrix is composed of receivers attached on a rigid frame that defines the allowable user movement space. Receivers detect ultrasonic waves emitted from the transmitters of the mobile unit attached at various locations on the user. The base station will then provide the elapsed time of the detected sound waves to the PC software, which will pin-point the exact coordinates of each transmitter channel. The software user interface will then display correspondent orthogonal 2D images of the user body, thus creating a 3D model.

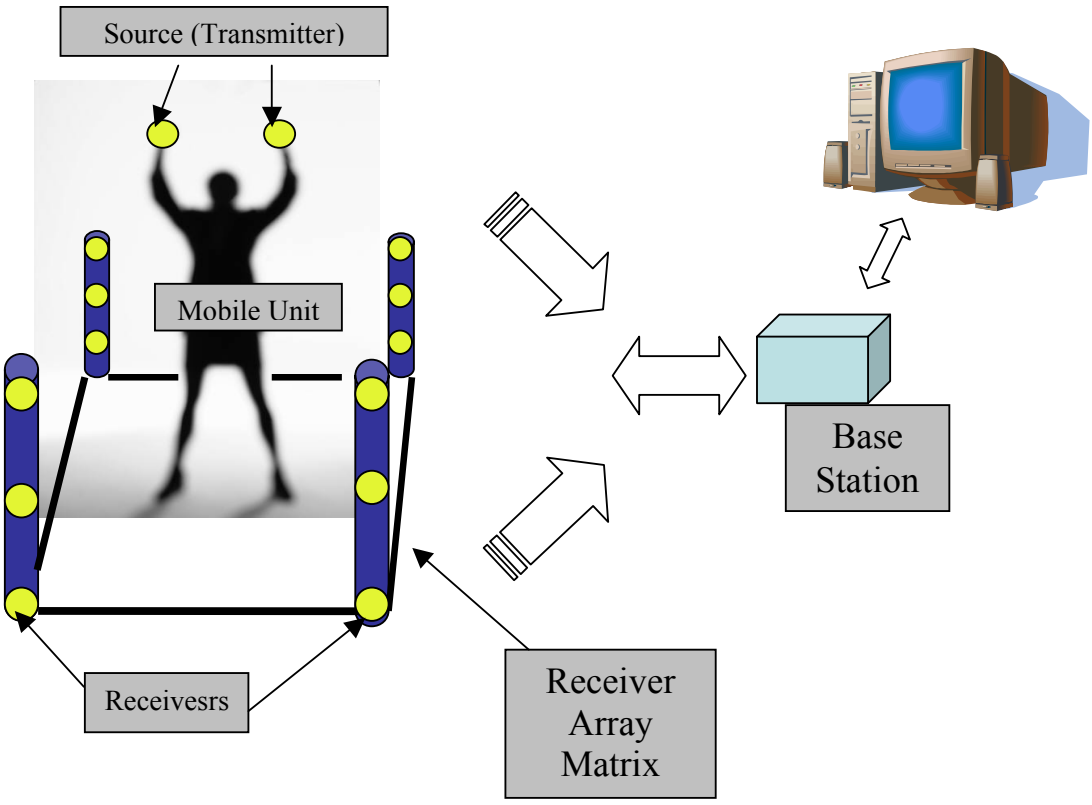

Figure 1: System Overview

The Receiver Array Matrix consists of a collection of ultrasonic receivers and a receiver module circuitry. Four poles are set up around the user and each pole has three receivers attached to it. Each receiver is wire-connected to the receiver module. Signal obtained from the receivers are amplified and registered by the receiver module. At last, the receiver module outputs the signal to the base station microcontroller.

The Mobile Unit consists of a PIC18F242 microcontroller, a RF Receiver Module, Transducer selection circuitry and a body suit. The function of the Mobile Unit is to receive the RF Data from the Base Station, interpret the data, and output the correct signal to the correct ultrasonic transducer located on the body suit.

The Base Station is designed to serve as 1) the power source to RAM and itself, 2) the communication medium between hardware and software, and 3) the central control unit of the hardware module.

The graphical user interface is an event driven interface based on a PC computer with the computer monitor as the output display medium. The user interface is comprised of various windows as described in the following sections. The design of the software is completed using Microsoft Visual C++ 6.0, using the Microsoft Foundation Class for GUI development.

Interfacing the software application with the hardware is accomplished through the use of the serial port of a PC computer. The code's purpose is to manipulate the serial port and reading from the port's buffer to obtain information from the hardware.

3. Implementation Deviation from Design

Most of the actual hardware and software implementation went as planned, but of course, modifications had to be made. We will discuss this in terms of hardware, firmware, and software.

First of all, as we mentioned, capacitors are our friends. We had to put in many more additional coupling caps on the power in order to filter out noise, and stabilize our system. Some traces had to be cut, and jumpers put in because the layout was changed. But the core design including the FPGA and the amplification circuitry has proven to be quite efficient.

Firmware was modified in terms of the communication protocol. Initially, a header byte and a footer byte were to be sent via serial communication with the computer. Due to simplification, currently only a header byte is sent out. Minor modifications were also implemented so that the system would ignore false data, and correctly capture 3 to 4 time difference values.

Finally, software has changed in terms of the parameters, to reflect time and cost constraints. The space that is visually represented has been lowered, and a second triangulation algorithm had to be implemented in order to handle 3 sets of time difference values.

The accuracy of our system is now 0.20m, compared to 0.01m as stated in our functional specifications. This is due to the high sensitivity of our triangulation algorithm. Although the accuracy is lower than what was earlier specified, we would like to note that the deviation is significantly smaller. Time captures from various sensors only vary by a few nanoseconds. Also, please note that the system performance can be greatly improved with a higher budget, and more time. We were limited to sampling at about 10ms due to having to time multiplex in order to determine the sensors. However, if we had the funding, we would implement the system using frequency multiplexing, which would allow us to process multiple channels in parallel, thus increasing the sampling rate.

4. Future Plans

The individuals of this team all have separate plans for the future, some are heading to Japan to do coop, and others are going on coop locally and/or starting their undergraduate thesis. Thus, any future plans for this project will be put on hold. The following list composes of the items that will be implemented in the future:

- The system should be able to update the coordinates of each transmitter modules at a rate of 1 KHz.
- Software will use OpenGL or Direct3D to implement a 3D drawing of the user
- The pause button located on the Mobile Unit allows the user to pause the system. Once this button is pressed again, the system will continue running.
- 2D positional graphs can be obtained on selected channels, in which velocity and acceleration graphs can be derived and displayed.
- Display character's size will be proportional to the actual size of the user.
- The system should remain functional between the air pressure range from 0.9 to 1.1 atm
- The base station should automatically be powered by a 9V backup battery if regular outlet power is disconnected.
- A LED will be implemented to indicate when the base station is powered by the back-up battery.
- The 9V battery will be rechargeable within the mobile unit by attaching it to the base station.

5. Budget

Table 1 contains the estimated cost and the actual cost of the project as of Dec 13th, 2003.

Material	Estimated Cost	Actual Cost
Sensors	$480	$78
Microcontrollers	$50	Free
Miscellaneous Components	$150	$500
Wireless Transmitters/Receivers	$70	$185
Batteries	$30	$48
Prototyping/PCB	$150	Free

Cables & Wires	$20	$40
Enclosures	$50	$160
Contingency	$100	$109
Total	$1100	$1120

The reasons for the overspending mainly due to the purchase of back-up components such as capacitors, RF modules and enclosures. The first set of RF modules purchased did not work properly therefore we had to purchase another set of RF modules. Because of the noise problem, large capacitors are purchased to eliminate noise. We have utilized many free services and free samples such as PCB manufacturing and microcontroller samples to the best of our ability.

6. Individual Contributions

Alan Chuang

After together working on this project with my other five other group members for nearly eight months, I have developed my interpersonal as well as communication skills. I learnt how crucial cooperation is while involving in a major project. Although there are few bumps along the way, we still put it together and made the bond even stronger. Regardless of the mark we got, working with my group members has been extremely worthwhile.

On the technical side, I have strengthened my skills in assembly language programming as well as circuit designing and debugging. I have also familiarized with the procedures to follow while dealing with major projects and the interaction between software and hardware.

Kenneth Fong

This 340 semester has been a unique experience for me. The project has been full of challenges, and I have been pushed in ways I never imagined. The project has also been a learning experience for me.

I learned some new skills which I am certain will be useful in the future.
This 340 group has been very interesting to work with. The group has a very powerful skill set and this has helped to create an amazing system at the end.

Warren Lee

For the duration of this project, I have learned many things. These things include social skills, life skills, and technical skills. My project team was composed of exceptional individuals who were not only intelligent and innovative, but also supportive and caring. It was an honor working with them on this complex project. In all, it was truly an overwhelming experience.

For this project, I belonged to the software division due to my skills in software programming. I was able to experience programming in Visual C++ and MFC. I also learned serial interfacing and protocols on the software level. In addition, I was exposed to PIC assembly language and VHDL in my occasional encounters with the hardware division. Although there were countless

days and nights spent staring non-stop at a computer screen, it was a true pleasure to be able to work on various aspects of software engineering and interfacing it with hardware. I have learned now that following proper design procedures and strategies for producing software instead of going straight to coding is much more efficient and effective.

With respect to team dynamics, our group did encounter some obstacles. I learned that not speaking out when problems arise will lead to more problems. Problems within a group should be addressed when they arise and solutions should be brainstormed and decided upon by the group as soon as possible. Also, keeping things to oneself is not a solution. I also learned how to be more open and understanding towards team members. To be able to be a team requires team members to be supportive, understanding, and trusting of each other. I was lucky enough to experience this within my team.

Henry Lin

It has been an honour and great pleasure for me to work with the members in Sonitus. In the past 8 months and more, we strived and fought together for a common goal, and all survived through this experience full of sweat and laughter. I could not believe how much time and effort each individual of Sonitus was willing to sacrifice and how much support they offered to me throughout these days. To me, they are also the teachers in this project course, and they taught me a lot more than the course itself offered.

Edward Loo

In the past 4 months, I felt like we've, as a group, grown up a lot. Personally, I now know what it takes to tackle such a large project. Drive, determination, and the willingness to sacrifice sleep and leisure activities are all aspects that allowed us to get this far in our project.

Working with these people, which I have great respect for, have made this semester quite an experience. In terms of hardware, all the work was done to perfection. This may have caused some problems later such that the software team did not have as much time to test their code as they would have liked.

For the most part, this group worked well together. They always looked for an opportunity to help others and kept the environment a great place to work in.

Richard Sheng

It has been an honour to work with this team. Through the semester, we came together and worked hard together for a common goal. Personally, I'm walking away with more knowledge than just the practical software knowledge that I have gained. I'm also walking away with the knowledge that team dynamics is truly important for the success of a team, as well as knowing clearly who your customer is. It's not enough that you have a product, but it must be of use to someone. Having a clear understanding of the market, as well as who we are selling to, and what expansion strategies we had were our definite weakness. But this project was extremely

technically complex, and having it actually work in this short time frame definitely makes us confident about our ability as engineers.

7. Conclusion

The best way to sum up our feelings towards this project would be a quote from Edward Loo - "At least now, we can say we truly experienced 340". This past semester, has been one of the best experiences of our lives. We have gained a myriad of technical experience from this project. The following list composes a sample of what we have learnt:

- Hardware design - power circuitry, FPGA, amplification with noise rejection circuitry, RF, ultrasonic transmitters and receivers, etc.
- Firmware design - algorithm used to capture time differences, synchronization, timers, etc.
- Software design - Visual C++ with MFC for GUI, serial port manipulation, protocols, etc.