April 16th, 2007

Mr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440/305 Post-Mortem

Dear Mr. One,

Please find the attached document, *U-Nexus Inc Post-Mortem Analysis,* outlining the design progress for our prototype device. Our final project was able to successfully monitor four seats using IR sensors with a two second delay. We also had four seats which used switches to demonstrate flexibility in our seat tracking implementation.

Along with technical status of the project, we also present views of each team member regarding the general team dynamics, and their personal opinions regarding this project. Each member will discuss their personal and technical developments within the past four months. Lastly, each member will discuss valuable skills which we acquire from this project.

U-Nexus Inc consists of four senior-level undergraduate students in the electronics option. Team members consist of Danny Chan, Gordon Lee, Bo Wang and Eric Wang. Please do not hesitate to contact us if you have any concerns, we can be reached at ensc-unexus@sfu.ca.

Best Regards,

Eric Wang

Eric Wang
CEO
U-Nexus Inc

Enclosure: *U-NEXUS Post-Mortem Analysis*

ENSC 305/440 Post-Mortem:

Theater Ushering System

Project Team: Danny Chan
Gordon Lee
Bo Wang
Eric Wang

Contact Person: Eric Wang
ensc-unexus@sfu.ca

Submitted to: Mr. Lakshman One – ENSC 440
Mr. Steve Whitmore – ENSC 305

Issued date: April 16th, 2007

Revision: 1.0

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1. Introduction

The Theater Ushering System is a device specifically designed for movie theater industry, used to provide convenience and interaction to moviegoers. One of the major tasks of the systems is to provide seating information on display panel prior to entrance of a movie screen. Moviegoers can gather location of vacant seats before entrance, thus save the daunting tasks of seat finding. A second major task is for the system display panel to have additional features such as movie trailers and advertisements capabilities. The system uses wireless communication protocols for transmitting seating information to the display panel, thus minimizing the changes introduced to the infrastructure.

The project will be divided up into stages, where a working prototype will be completed during mid April 2007. Engineering prototype with embedded system is targeted for August 2007 and the manufacturing model is targeted for February of 2008.

2. Current State of the Device

2.1. TUS in General

In general, the current state of the system is exactly where we wanted to be after four months. The system is able to monitor seats with delay of two seconds, while displaying on an aesthetic interface. Wireless network is reliable and is properly maintained by our automatic house keeping designs. Future add-ons and additional devices can still be used, thus future development is still viable.

2.2. Acquisition Unit

Acquisition unit monitors the status of the seats and updates the seating information to Beacon. The Beacon then transmits the information to coordinator for display. The basic concept behind this unit is the application of Parallel-In-Serial-Out shift register, which converts parallel input line into a single data output line.

By this approach, our design would support monitoring unlimited seats theoretically with constant wire needed. This also gives us an advantage of identical circuitry so that each acquisition unit circuit shares the same layout. This is much preferred in the industry because it provides an easy deployment and maintenance. The actual prototype we built is shown in Figure 2-1.

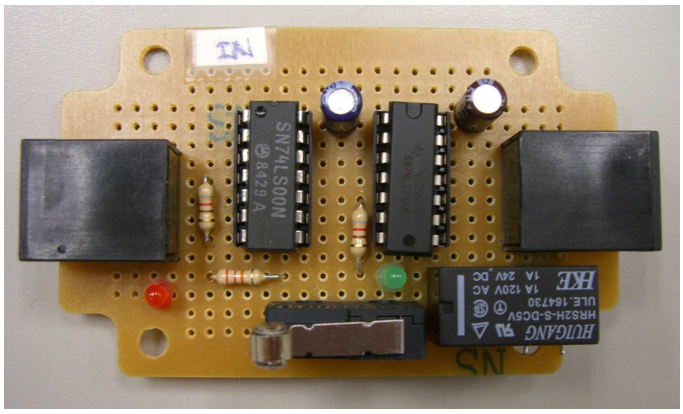
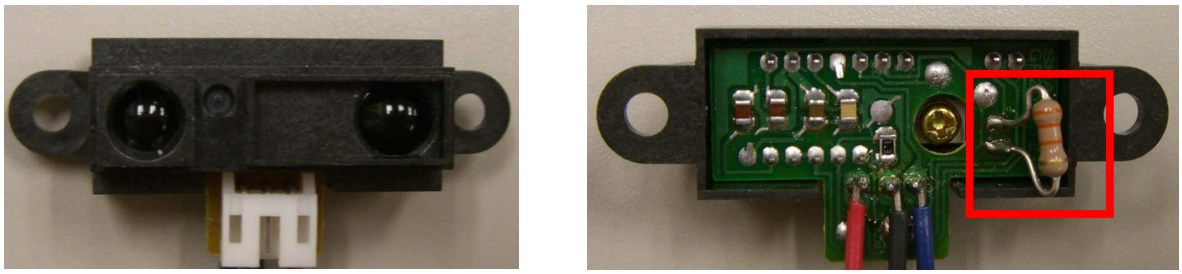


Figure 2-1: Overall Layout for AU

To detect the seat status, we proposed two solutions, using limiting switch and IR sensor. Limiting switch is cheap and has no power consumption; but some mechanical modification to the chair is required. On the other hand, IR sensor would not physically change the chair, which is preferred in this case. We chose SHARP GP2D15 IR sensor for its simplicity and accuracy. The detection distance of IR sensor is preset to 24±3cm. With some modification, we changed the IR sensor detection distance to 45±3cm. The sensor is shown in Figure 2-2.



Front **Back**

Figure 2-2: Modified SHARP GP2D15 IR Sensor

The concept of changing the detection distance is to change the reference voltage of the embedded Schmitt Trigger. The modification is circled red in Figure 2-2, where we replaced the original feedback resistor of 51kΩ to 33kΩ.

2.3. Wireless Network

The current state of our wireless networking worked as expected. We were able to implement the entire network layer and the application layer according to our design. In additional, our wireless network was able to perform automatic network formation, automatically manage device join/leave, manage data communication and packet scheduling to avoid packet collision. The coordinator sends out query packet every second, and our system were able to obtain the seat's occupancy information from the acquisition and deliver the information back to the processing unit for interface to display. Right now, we have verified our wireless communication system

with one coordinator communicates wirelessly with two beacons, and result worked out nicely. Three devices were able to form the network by itself, and transmit packets accordingly.

2.4. Processing Unit / User Interface

A laptop computer is used as both processing unit and display unit, as the design for working prototype intended. For the user interface, two variants are created. The 1st interface was designed for display placed outside of the entrance of the theater. The 2nd interface was designed for displaying on the theater screen. The first interface consisted of a main display screen which displays seating status of the theater and sections which displays advertisements, movie trailers, along with movie show times.

The 2nd interface has the same functions as the 1st, but items displayed on screen are semi-transparent. The control panel can be hidden with a click of button, and it displays movie trailer in full screen. Therefore, some of the functions such as advertisements and movie show times displays are discarded in 2nd variant.

3. Deviation of the Device

3.1. TUS in General

The completed prototype system has almost every feature that we had envisioned in our proposal. We had not yet encountered any major design changes except perhaps algorithmic changes. However, these changes are relatively minor and do not impact performance in any ways. We describe the deviation in more details in each section of the system in the following.

3.2. Acquisition Unit

Deviation of the acquisition unit is realized by clearly specifying the design requirements.

Requirement #1: Automatically detecting seat number.

Since we want to detect the number of seats automatically, we need to reset the acquisition unit for every request. A reset circuit is required. Initial reset circuit design is based on RC circuit which is shown in Figure 3-2.

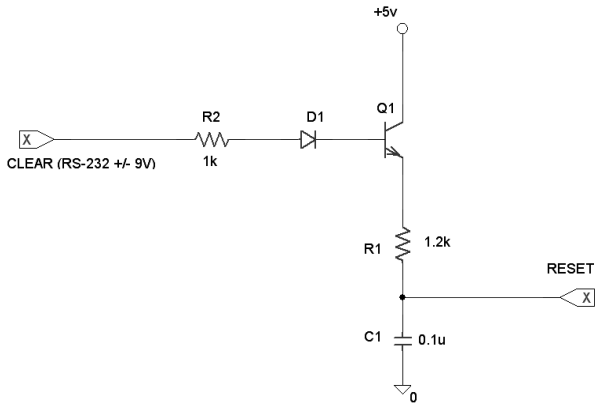


Figure 3-1: Original Analog Reset Circuit

Unfortunately this design did not perform as desired since the capacitor is never fully discharged so that the circuit cannot be reset correctly. The waveform of the output reset circuit is shown in Figure 3-3.

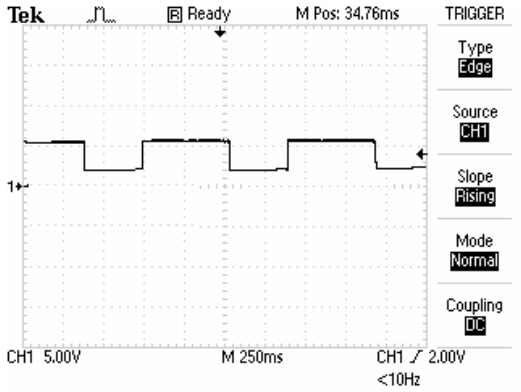


Figure 3-2: Reset Waveform from Original Analog Reset Circuit

To overcome this problem, we changed the analog reset circuit to digital reset circuit by replacing the RC section by a Schmitt Trigger. The newly designed circuitry is shown in Figure 3-3.

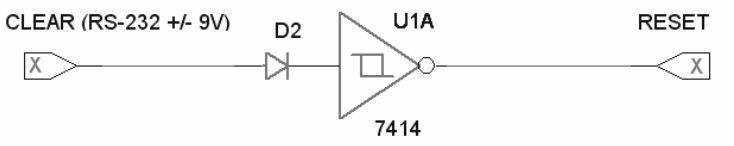


Figure 3-3: Fixed Digital Reset Circuit

With two other control lines, all three control lines have a noticeable startup time. This is because when MCU is powering up, all output pint is set to high. Figure 3-4 shows the behavior of the digital reset circuit.

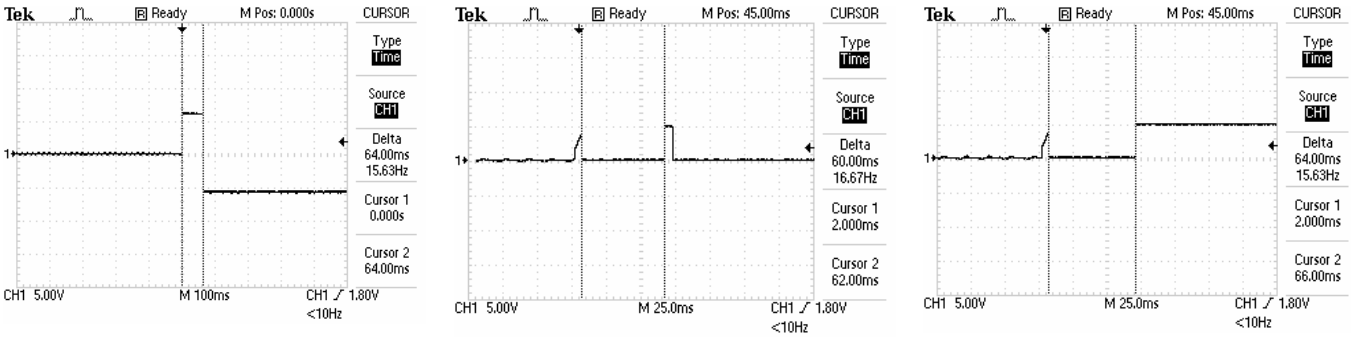


Figure 3-4: Start-up Waveform for Control Signals

As one can see, all output pin is set to high when powering up. It will then take about 60 to 64ms to initialize the output pin. In other word, during the first 64ms, incorrect commands will be sent to acquisition unit because we expect CLEAR/CLOCK/SHIFT signal to be LOW during idling. To overcome this problem, we modified our hardware firmware so to ignore data if the control signals are incorrect and no data would then be transmitted.

Requirement #2: Smart Connectivity.

There is a single-side double-pole relay on each board. This relay helps routing data either to next board or back to Beacon. When next board is plugged in, relay is triggered and will route the data to next board, otherwise, the relay will route the data to Beacon via Data Out line.

3.3. Wireless Network

TUS WPAN development has not deviated very much according to our original plan as state in functional and design specification. We have achieved all the functionality as planned. However, there are some minor deviations on the selection of some design parameters. We have altered some values to obtain a more robust, and stable network. In addition, we have added housekeeping features to increase the ease of maintenance of the network.

These features included allow the devices to make correct decision to connect to or disconnect from network during failure. In other words, if a Beacon station has not reply to the coordinator announcement packet five times in a row. Coordinator will treat the Beacon as a dead device, and delete it from its Beacon list. For Beacon stations, if Beacon has not receive Coordinator Announcement Packet for a duration of five seconds. It will automatically disconnect from the network. The five seconds parameter means that either Coordinator has been powered off, or it is not in proper operating mode. In summary, wireless communication performs as we desired, and modifications were made to make TUS WPAN more stable, robust, while still easy to maintain.

3.4. Processing Unit / User Interface

The Processing Unit development did not deviate from our original plan stated in our design specification. However, due to the fact that many high resource elements are used in both variant of user interfaces, higher hardware performance requirements must be considered when selecting processing unit. Specifically, more RAM will improve the system greatly.

For the user interfaces, the 1st variant did not deviate much from our designs in design specification. We have fully implemented a functional Windows program in C# which will read and decode the data from the serial port and use those data to update the seating status on screen. We also implemented other functions such as display of movie trailers, advertisements, and movie show times. The only superficial difference comparing to our original design is the placement of advertisements and additional control panels. The additional control panels are added for debugging purposes.

The 2nd variant interface is an improved version that contains additional features. It is designed to be displayed on full screen which semi-transparent items such as control panels and seat information. Since the interface displays the movie trailer on full screen and thus other features such as advertisements are discarded.

4. Future Plan

4.1. TUS in General

Embedded System

The current system operates on a traditional notebook. To ensure portability and reduced costs on hardware, we hope to adopt the current setup onto an embedded system. By using embedded system, we can effectively reduce component costs along with a more aesthetic pleasing look.

Power Connection

Currently, our AU runs on the battery. However in the future one should build a power bridge circuit which that the AU and Beacon obtain the power form the stair power Led line.

Additional Add-On Devices

As mentioned previously, we hope to have the capability to have additional buttons on each seat to implement promotional materials. For example, large screen trivia can be played where moviegoers can win small prizes.

Central Master Display

One of the features that we hope to have is to have a central display which displays the occupancy number or seating availability of all theaters after a movie has started. This feature enables moviegoer to make decision on their movie choices prior to ticket purchase.

4.2. Acquisition Unit

Increasing Seat Detection

Future improvement includes increasing number of seat detection. The current prototype uses 1A rating voltage regulator. Since each IR sensor constantly draws 30 to 50mA of current, the current maximum number of seat detection is 16. As signal lines get longer, we might need to add additional buffer and lower the CLOCK speed to guarantee accurate detection.

Device Power-saving Mode

A future feature includes adding an additional power-saving control line. By doing this, we can shut down the acquisition unit completely to save power. However, we must then need to consider the startup time of the IR sensors in our design.

Extended Real-life Testing

Since our user is open public, a thorough real-life testing must be conducted. We must consider all possible conditions in order to minimize the failure of the system.

Minor Bug Fix

The current prototype circuit uses older generation ICs, and their performance is not as good as expected. One bug currently exists in the system is that D-Flip-Flop is not shifting data to next stage correctly under certain conditions. As Mr. Lucky One suggested, other newer ICs should be considered, such as ABT and HC packaging.

4.3. Wireless Network

Test Stability of Larger Network

Currently, the WPAN has successfully connected up to three Beacons, and are capable to deliver correct packet information. For future plan, we must test the stability of the network by introducing more devices. Since most of the design parameter can be changed in software, one should also make modifications to obtain optimal results.

Device Sleep Mode

Another future plan includes putting the Beacon into sleep mode while it is not in a network to reduce the power consumption required by these devices.

Rang Extension

Range extension refers to extending the wireless connectivity. It is similar to have an access point to increase the rage of the WPAN operation. One should keep in mind that the level of difficulty increases with respect to the level of the devices or the operating range. This future plan might not be suitable to for the theatre due to the dimension of a room; however infrastructure such as parking lot or sport arena are more likely to utilize this modification.

4.4. Processing Unit / User Interface

Front End for Operator Configuration

Currently in order to configure the user interface for aspects such as movie trailers, movie show times, and advertisements, operators have to modify the initialization file manually. The information on the initialization file contains the locations and number of movie trailers and advertisements. In future, we plan to create additional interface panels which provide front ends for operators to configure the user interface directly. For example, the program has a tab in the program which operators can access configuration options.

Improved Interface

In the future, we also have plans to improve the user interface by incorporating the following:

- Improving graphical representations for seats and theater layout
- More control options such as adjusting baud rate for serial port
- Changing the colors for each status of seats to better contrast

- Able to switch to full screen mode with trailers playing in the background and objects on screen remains semi-transparent
- Additional interactive functions such as opinion polling

Platform Independence

The current user interface will run in Windows Platform with .NET Framework. The 1st interface uses the .NET Framework 2.0 while the 2nd interface utilizes .NET Framework 3.0. In future, we plan to implement these programs without platform and programming framework restrictions so that we do not always have to resort to Microsoft Windows.

Automatic Data Acquisition

In future, we plan to improve the interface program so it can automatically acquire data and execute processes including the following,

- Scanning for movie trailers and advertisement in current directories or memory space
- Generating initialization files if none exists
- Stream the movie trailers from central server thus eliminating the need for large storage on processing unit

5. Budgetary and Time Constraints

In this section, we discuss our project budgets and timeline in detail. Although we experienced some technical issues, we remain optimistic in solving them on time.

5.1. Budget

As seen in Table 5-1, the proposed budget was in the range of $1500 due to inclusion of large screen display and wireless design kit. However, after careful consideration, we decided to demo the project using traditional PC desktop system and therefore reduced the budget significantly. We were also very lucky to have been able to get free wireless design kit from one of the co-op employer, there effectively saved another $500. In the end, we spent just little over one tenth of the proposed budget and majority of those costs is due to infra red sensor switches. Other costs are used for items such as circuit components, PCBs and connectors.

Table 5-1: Budget Comparison

Equipment	Estimated Cost	Actual Cost
Data Acquisition Microcontroller	$10.00	$0
Sensors for Seat Monitor (set of 8)	$20.00	$100
Wireless Transmitter/Receiver Kit	$500.00	$0
PC Desktop System/ Flat Panel Display (19 inch)	$750.00	$0
Miscellaneous	$220.00	$60
Total	**$1500.00**	**$160**

Overall, we seemed to have overestimated the budget by allocating funds in sections which were not essential, while neglected other parts. For example, we should have simply ignored the large screen display in the budget and spend more time on estimating the costs used for sensors.

5.2. Time

Figure 5-1 shows the Gantt chart and timeline for this project where blue represents the proposed schedule while green represents the actual schedule. Note that we are typically very close to the desired duration on major milestones with the exception of system integration. Due to graduation requirements, we must demo our project prior to 20th; therefore in order to avoid conflicts with other commitments, we decided to move the demo date to April 10th instead of the original proposed of April 22nd.

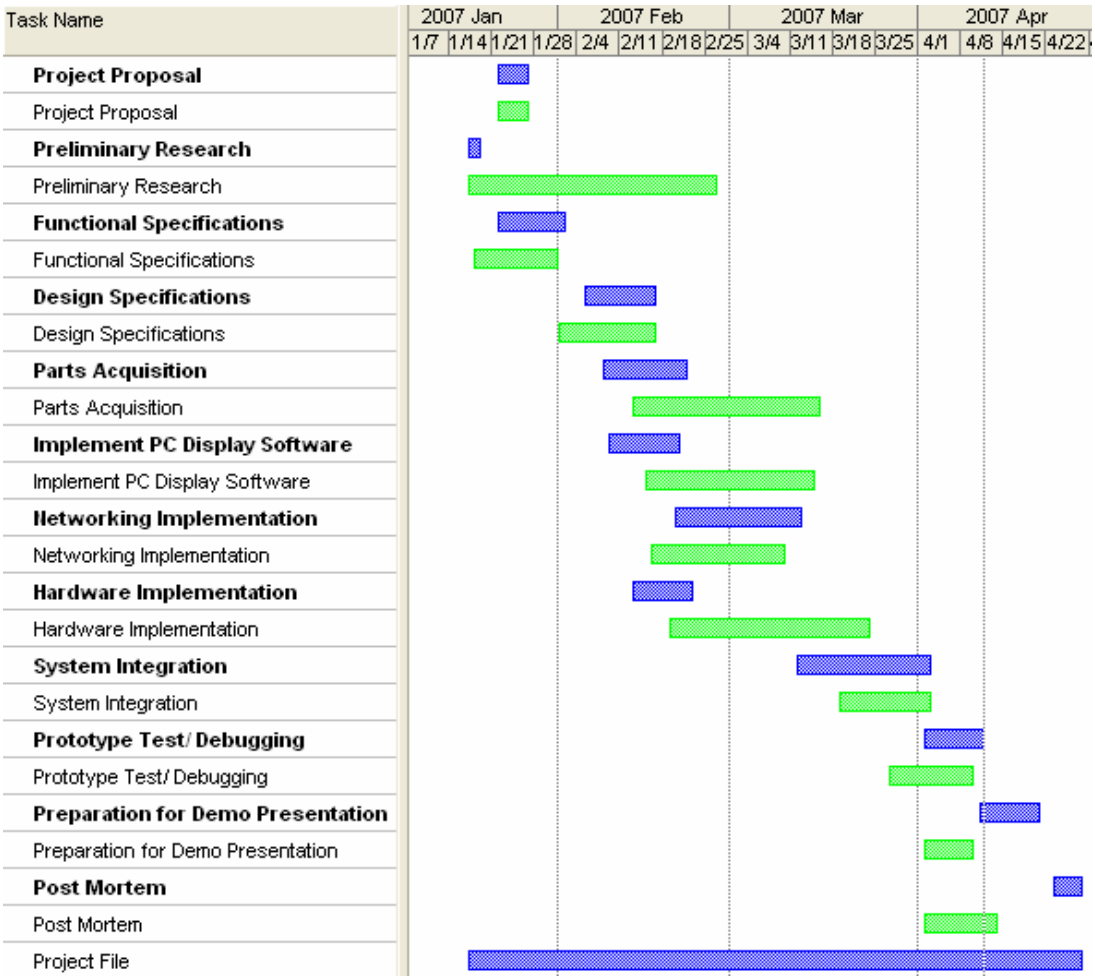


Figure 5-1: Gantt chart

We believe that because our dedication and adherence to the strict deadline, we were able to avoid a lot of headaches and sleepless nights. We anticipated problems in each stage thus when we constructed the original timeline, we incorporated an overhead of almost 50%. This overhead accounts for any extra times that might be spent on certain section. Because of all the work we put in, we were able to successfully present our project on April 10th 2007. Although the system had a bug, we were confident that we can solve it if we had more time. However, it was a group decision that we should do a design freeze and demo the project in a state that we were comfortable of; rather than debugging to the last minute and risk of introducing additional bugs.

One issue with the timeline was that we failed to incorporate enough time for research. In fact, we were actually behind schedule when we performed the oral progress report since we spent so much time researching on various topics. For example, we had to spend enormous amount of time researching IEEE 802.15.4 protocols, RS232 protocols, and many other programming languages. However, by spending time researching and planning, our implementation progressed much smoother.

6. Inter-Personal and Technical Experiences

6.1. Danny Chan

Before U-NEXUS was formed, all four of us already have ideas of the kind of projects. After many meetings and research on the feasibilities, we decided on an idea for a wireless application for movie theaters, especially a system application which displays seats occupancy on screen. The reason for choosing the above is because when we were in movie theaters, we felt that sometimes the theaters do not provide enough attraction and comfort in addition with movie. Especially when the theater is almost full and some audiences are forced to sit in the front where it is hard to enjoy a movie. As a result, we decided to create the Theater Ushering System, which provides seating information for audiences before they enter the theater. The project is a challenge for me because I only have theoretical knowledge on fundamental basics in wireless communications.

During the design process, we spent a lot of time on planning phase. Personally, I think we spent approximately 60% or more out of total project time on the planning stage. The details such as wireless communication protocols, hardware specifications, and program developments are carefully planned out. As a result, during the development process, we are able to minimize the problems on implementation because we foresaw most of them. It is fortunate we do not have to pull the infamous “all-nighters” which is often regarded as a necessary process in the development of major projects. I learned that through planning before hand, makes a huge difference.

In the technical area, I was charged with the task of creating user interface program. Our final user interface program was created with Visual C# because compare to MFC, it is much easier to create Windows applications with Visual C#. Fortunately Visual C# has built-in library for serial port communications, so not much time was wasted on learning this aspect. I actually have no experience with creating Windows applications with C#. Therefore, after this project, I learned a great deal on Windows application programming along with wireless communication protocol. In addition, I also explored some programming aspect for creating fancier applications by using DirectShow Library and .NET Framework 3.0. The latter item was used to create the 2nd interface program, which involved semi-transparent interfaces items.

The team dynamic is truly great and it was truly a blast working with them. I actually learned a great deal on wireless communications protocol from Gordon, many programming and organization skills from Eric, and hardware from Bo. Despite this, there may still be some minor disagreements on various technical aspects, we always calmly try to evaluate alternate solutions or drop the idea if it takes longer time to implement. Overall, I was actually very pleasant in working with my team members, they brings their own specialties to the project and able to excel in process. I truly learned a lot from my team members in technical, logistical, and social aspects.

6.2. Gordon Lee

For the past 13 weeks, it was a memorable experience working with our team members. I have learned to work with different group members. As a team, individual members have their own

needs and schedules. It is important that we understand each other and we should always be transparent to one another and be responsible in the area where you are responsible for. It is fun to work as a team, and I believe that having a good group dynamics is vital. This course ends my SFU career, I was proud that three other group members and I could successfully finish the capstone project in time.

From a technical perspective, I have strengthened my knowledge in areas such as building, debugging circuit boards, writing application in .NET framework with C# and developing RF wireless network on the IEEE 802.15.4 telecommunication protocol. As for hardware, I have learned from my group member a lot. I have learned different ways of debugging circuit board and strengthen my knowledge with low level device port programming. For software development, I have learned to use the .NET framework, and MS C# to build a windows form application for our first interface design. This process enables to learn the functionalities in VS2005 and the window application programming. In additional, we used XAML and DirectShow Library and .NET Framework 3.0 to build a fancier looking interface, which was a really nice experience for me. As for the RF wireless networking development, I have strengthened my understanding with the IEEE 802.15.4 protocol and proved my concept with developing a private wireless networking environment, where devices can exchange data accordingly. I was very happy with this achievement. Another memorable thing is that this project enables me to see and experience with a product development cycle typically from a simple concept to a working prototype. I found that the process is always challenging, but having a clear goal, and maintaining the consistency over comes all the challenges.

As a group we had an excellent way of writing and reviewing our documents. Normally, one of the group members will setup the entire document template, and this is done almost four weeks before the actual due date; hence we have sufficient time for reviewing. In addition, we assigned the sections according to the field of expertise to obtain the optimal documents. Moreover, we have a web-based CVS to keep track all our documents and codes. This web-based CVS applications increase ease of inter-communication between group members and reduce the hassle of passing emails around. In addition, this application enables us to share equal responsibility to the project which it's very nice and useful.

I am glad that I was able to complete this course according to our schedule. I believe that having a clear vision or goal for a project is critical, typically for a start up company. I enjoyed my project, and I enjoyed working with my team members.

6.3. Bo Wang

This project has been a great experience to me in working in a development team. During the past 13 weeks within the team, I learned a lot of technical skills in hardware design along with implementation and communication skills as a team member. A team can be more productive than individual, so that team skills is essential in this project. Our team has been in a great momentum, and each one has shown their interests in this project with lots of efforts put in. Our CEO, Eric, is responsible for managing the team besides his tasks, which brings lots of energy to the team.

In our project, we roughly divide the project into two major parts, software and hardware. Eric and Danny are responsible of the software part, while Gordon and I are responsible of the hardware part. This is a not an absolute divide of the project, rather this is just a guideline for each individual. By this guideline, each of us can works on the area where his specialty is. In more detailed tasks; Danny is responsible of development of computer user interface. Eric is responsible of interface design and market research. Gordon worked on the wireless network and he also helped a lot on documentation. I primarily worked on development of data acquisition unit.

In technical areas, I learned about development process and understood the transition from schematics to implementation, and then to a final product. For consumer products, lots of consideration should be carried out in order to build an excellent product, while keep the design as simple as possible. In our developing process, there was a delay in acquisition unit due to the number circuit board we planned to build. The delay primarily results from debugging and integration process. Due to the automatically seat number detection feature, a reset circuits was required. To achieve this goal, three versions of designs had been built, from a RC analog resetting to a final version of digital Schmitt Trigger resetting. All the design drawings are included in our project file. The Sharp IR sensor we purchased also caused minor delay because the sensor did not meet our design requirement. Although the datasheet clearly said detection distance is adjustable, neither the datasheet nor Sharp website provided the adjusting information. I basically traced the IR sensor circuitry and replaced some component so that we have a correct detection range.

During this semester, I was also doing a co-op term at VTech. This semester became the busiest time I have ever had. Although I sacrificed most of my personal time, the experience that I gained is priceless. Managing the time and stress has been a key to me. I worked on this project after work and weekends, which usually meant spending many long nights at school. There were also other teams worked extra hours, so I got a chance to know about other team's interesting projects and how others realizing their ideas.

I am glad we successfully finished our project except for some minor bugs. We believed that the bug is due to the selection of chips. Because of low funding, we used general purpose chips, which will give incorrect result under some conditions. In future work, we will upgrade our hardware by selecting more advanced chips. New technology, such as 1-Wire™ as Mr. Lucky One suggested, could be invested in the future. This project has been a great experience to me and I enjoyed working with my team members. Each of us has shown his passion and effort in developing something new and interesting. I want to thank everyone for their hard work in this project.

6.4. Eric Wang

After the never ending journey at Simon Fraser University, I have finally conquered the unimaginable engineering science program. With that in mind, I can leave this school with pride and my head high. I am especially proud that I and three other fine individuals were able to complete the capstone project with minimal damage to our health.

The last thirteen weeks of has been extremely hectic as I tackled the capstone project with additional courses and a co-op term. The reason for such suicidal action is strictly financial, for I needed money to pay for school. If I had to make that choice again, I would certainly think hard about it. But fortunately, my CTO, Gordon Lee, was able to ease the burden and step up at the right moment. Team dynamic between each other did not pose major problems as we all know each other previously. However, it would have been nice that other individuals stepped up with more effort. Even with my busy schedule, I believed that my effort and contribution to this project is still significant. When it comes to due dates for submission, typically Gordon and I worked on majority of the documents. Danny and Bo supplemented with additional sections when requested. We held meetings at least once per week, but usually we discuss issues over Skype, a VOIP phone application on internet. Conflicts are almost non existent until near the end of the term when progress was not as fast we had hoped. Our project was indeed very ambitious, and our deadline required strict dedication. In the end, we managed to meet the deadline with few conflicts.

From a technical perspective, this project required us to use all that we have learned from first year to fourth year, and at the same time be exposed to new technologies out there. For example, for my personal part, I was able to deal with wireless technology using IEEE standard. Understanding such protocol is indeed very useful as these skills are easily extensible onto other IEEE protocol development. Even though the protocols are different, the approach remains the same. From the software perspective, I was able to work with Danny Chan on using Microsoft C#, which is one of the leading software frameworks currently available. The experience was indeed very nice, as I was able to deal with such professional development tool.

From a personal perspective, I learned first hand on what it takes to have a successful start-up. I also realized the amount of work required just to have a working prototype product and that dedication must be required in order to a complete product. I found that planning is the most important stage and that is where most of the time should be spent on. By spending vast majority of time on planning and designing, our implementation went much smoother and our integration went was a lot less painful. Lastly, I learned what qualities I should look for when working in teams or even a startup environment. I believe there should a balance between work and play, however, in a startup environment; work will always come before play. Of course, the same statement is not true as you start to age and advance into your career, at that time, you must review and adjust your priorities accordingly.

7. Conclusion

This document discusses the result of our semester long product development cycle and all aspects surrounding the project. We discussed issues such as the system developed, future works, budget, timelines and our thoughts. We were able to apply our technical skills which we acquired in our university years along with proper product development procedures. This course is indeed very valuable and allows us to understand our maturity in dealing with technical problems.