InnoDimension Enterprise
Simon Fraser University
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April 30, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
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Re: ENSC 370 Project – *SpotU Process Report*

Dear Dr. Rawicz,

The attached document, *SpotU Process Report*, outlines the process we went through, the problems we encountered, and the learning experience we gained while designing and implementing the SpotU system. Our project was an automatic stage spotlight that will constantly maintain its focus on a particular performer by determining the location of this performer through transmitters and receivers.

This document lists the prototype's current state, changes in functionality and design, and future developments. We also discuss major problems we encountered and the interpersonal and technical experience we gained from this group project.

InnoDimension Enterprise is set up by five highly motivated Engineering Undergraduate students from Simon Fraser University: Ada Pang, Joyce Wong, Mei Chan, Sherla Cheung, and Victoria Chen. If you have any questions or concerns about the project, please feel free to contact us through e-mail at inno-d@sfu.ca or contact Mei Chan at (604) 436-2349.

Sincerely,

Victoria Chen, President
InnoDimension Enterprise

Enclosure: ENSC 370 Project – *SpotU Process Report*

InnoDimension Enterprise

SpotU
Process Report

Submitted to Andrew Rawicz
School of Engineering Science
Simon Fraser University

Steve Whitmore
School of Engineering Science
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Submitted by InnoDimension Enterprise
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Date April 30, 1999

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1. Introduction

InnoDimension has been working on designing and implementing an automatic follow spot. The project was divided into five parts for our five members. Joyce Wong was in charge of the ultrasound sensor circuitry. Sherla Cheung worked on the communication between the stage and the light. Ada Pang was responsible for programming the microcontroller. Mei Chan dealt with the motor and power circuitry, as well as financial matters. Victoria Chen was responsible for the mechanical structure, packaging, and documentation. This report outlines our progress and details our learning experience during the past sixteen weeks.

2. Current State

For a general system overview and detailed functionality and design of each subsystem, please refer to our *SpotU Functional Specifications* and *SpotU Design Specification.* Currently, our SpotU prototype is capable of tracking movement in one dimension. On our first SpotU demonstration on April 19, 1999, we demonstrated our mechanical system, ultrasound circuits, and RF data communication modules. Our second demonstration illustrated that our design works for one dimension and can be easily expanded into two or three dimensions.

The system has a small delay caused by the response time of the motor. However, given the diameter of the light poll, the performer should still be covered by the light poll when using real spotlight. The range of the ultrasound sensors is three meters maximum; therefore, the theater dimension was reduced to three meters by three meters.

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3. Changes

The basic functions of the prototype SpotU system have not been changed; however, we down scaled the system to one dimension tracking for our second demonstration. The subsystem designs followed the designs detailed in our design spec. Major changes had to be made before our second demo due to limit time and resources. The following paragraph outlines the problems and the changes made.

Locator and Receiver Unit

The ultrasound sensors were too directional and the maximum range was only three meters. More transmitters were needed for the two receivers at the opposite side of the stage to receive the stopping pulses. We tried using six transmitters in parallel; however, the power from the transformer was not enough to drive six transmitters and the effective range decreased to less than half meter. The potentiometer value was toned to increase sensitivity of the ultrasound receiver. Since one of the ultrasound receivers was not stable, we down scaled our system to one dimension utilizing one ultrasound receiver and one ultrasound transmitter.

Control Unit

Timer

Duty cycle of the triggering pulse was changed from 1-1000 to 1-100 so that the low to high transition would be clear to the ultrasound receiver.

A/D and D/A conversion

Feedback control was moved to the motor amplifier; thus, analog to digital conversion used for the feedback input from the potentiometer to the microcontroller was not needed. As for the D/A circuit, only minor adjustments to the resistor values were made.

Microcontroller

We tried to move all calculations to the MAX7000 chip; however, it wasn't capable of handling the calculation required. Since the counter program in MAX7000 wasn't producing proper output, we decided to move the counter program to the PIC. The digital to analog conversion code in the PIC program was modified to give proper output to the motor. Lookup table was added for mapping displacement to motor control voltage. Feedback control was moved to the motor amplifier.

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4. Future Developments

4.1 SpotU

A second year SFU engineering student, Eric Keung, has always wanted to build an automatic spotlight. He will be taking ENSC370 in January 2000, and his group might be interested in continuing this project. They can work on expanding the prototype to a three-dimension model or adding additional features that are listed in our functional specification.

4.2 Signal Acquisition and Conditioning Stage

For two dimensions, two ultrasound receivers are required to track the position of the performer. From the two timings, the microcontroller calculates the x and y coordinates of the performer using triangulation. The two timings gives two distances for the ultrasound signal to travel, the two distances are like two radii of two circles. The intersection of the two circles gives the location of the performer. Figure 1 shows one of the intersections of the two circles. Since the ultrasound receivers are located at the front corners of the stage, the other intersection will be off the stage and need not be considered.

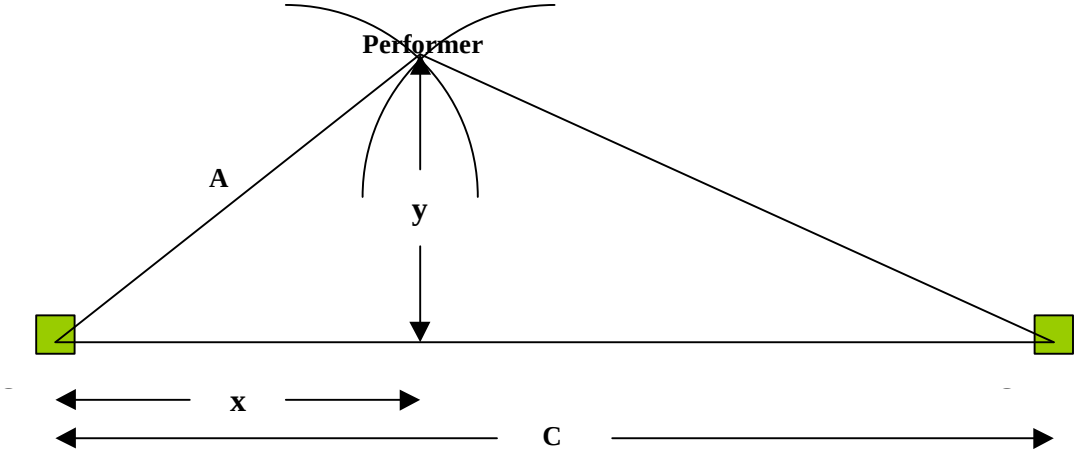

Figure 1: Locating the Performer

From the above concept, three sensors are needed to track position in three-dimension. Two spheres intersects and gives two arcs and the third sensor on the ceiling of the stage gives a circle or a sphere to intersect with the arcs to give the position of the performer. With three receivers, more transmitters may be needed to cover all directions. Transistors can be added to the locator circuit to increase the current when more transmitters are added. The addition of transmitters may require a more complex noise filter at the receiver side.

The period of the timing pulse can be reduced to increase accuracy; however, the minimum period allowed depends on the capacity of the microcontroller. For better result, a more suitable sensor should replace the ultrasound sensor. Ultrasound sensors are too directional and signals can be easily blocked.

4.2 Signal Processing

For three dimensions, the microcontroller needs more input pins. The PIC17 microcontroller is picked for our two-dimensional design and does not have enough input pins. Our microcontroller supports neither trig functions nor floating point data manipulation; thus accuracy is reduced. This problem can be solved by implementing a look-up table or by using a more complex microcontroller.

4.3 Mechanical Control System

The mechanical system was designed for testing the integration of the circuits and for demonstration purposes. Because motors, drivers, and other mechanical parts are fairly expensive, we decided to build our mechanical parts from available parts in the lab. The best motor we found rotates smoothly; however, it does not turn slow enough for the light to turn at small angles. Therefore, a belt and pulley system was designed with a 5:1 turn ratio to drive the light. If a high torque-low speed geared motor was used instead, the belt and pulley system can be eliminated. The motor we used has a fairly slow response time; thus, if the performer moves move back and forth rapidly, the light will be lagging. A motor with faster response time could be used to decrease error.

Other feedback systems can be added to SpotU. For instance, a sensor on the locator to tell if the light is actually shining on the performer would also increase the performance. The motor amplifier can be configured to control the motor with current or voltage and can be configured to use analog or digital potentiometer feedback. It can also use tachometer or encoder feedback. Depending on the feedback device used, the amplifier can be in position or velocity feedback mode. Cascading feedback sensors and amplifiers to give both position and velocity feedback control would increase the accuracy of the system dramatically.

The supporting mechanism for supporting the load, which is the light, needs to be scaled to support a spotlight. It will be better to built the mechanical structure using steel instead of aluminum to give stronger support and to prevent damages. However, the design can remain unchanged.

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5. Problems

5.1 Technical Problems

None of our group member had experience in building an engineering project. We lacked knowledge on systems and components available on the market. We also did not have a good direction on where to search for information. A considerable amount of time was spent on researching for different types of components. Only one member knew how to solder. Therefore, soldering the sockets and surface mounting the RF components took us a long time. None of us had any knowledge and experience with mechanics; thus, designing and implementing the mechanical parts took longer then we planed. To summarize, we lacked a group member who had the sufficient knowledge and experience to guide the group on technical issues.

For the same reason, design took more effort than expected. We designed our system based on the limited knowledge and experience we had. Every time we found or heard about another component, we were tempted to change our design. We started designing early but we could not settle on one approach. While writing the design spec and trying to explain things in great details, many details and links that we never thought about appeared. The deadline for the design spec made us realize our limitation and pushed us to seek help from professors and friends. Lack of knowledge and experience also made it extremely difficult to implement, integrate, and debug.

Wood and aluminum were used to build the mechanical structure. Steel would give better support and reliability; however, we were not skilled enough to work with steel. If wood and aluminum parts are reassembled many times, the holes will get larger and the parts will not hole together as tight.

For the components that cannot be bought off-shelf, we should have borrowed some more from our friends for backup. For example, we accidentally blew one of the RF receivers the night before our first demo and it was too late to call up people and ask to borrow theirs. Again, since we lack experience, we should have double-checked our connections carefully before we fed any signal to our circuits.

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5.2 Time and Budgetary Constraints

For the same reason, because we were inexperienced and because we did not have enough knowledge, every process took longer than needed. If we could begin all over again, we would have reduced our course load this semester and devote the time to this project. We also had problem keeping up with our schedules. Since all subsystems are interrelated, if one member did not meet the deadline, progress on other parts would all be delayed. We should have a person responsible for making sure that everything went in the right order and that all deadlines were met to increase efficiency.

Budget had always been our concern. Since we had limited funding, we tried to get most of our components from old projects, professors, and friends. Therefore, we were not using the best quality components to implement our project and this affects the performance of the system. The mechanical structure was build from old project parts; therefore, the design was based on the best components we could found instead using the most suitable components and materials on the market.

5.3 Group Dynamics

Our group had group dynamics problem since the very beginning; however, we did not realize the significance of good group dynamics and did not deal with it early enough. We realized that lack of communication and misunderstanding really affected our progress towards the end of our design stage. We had a meeting and we talked things over; however, it already affected our progress significantly since most interfaces between subsystems were missing.

Other then communication problems, all five of us had different objectives, goals, and values. How people see, approach, and value things are developed over the years and cannot be changed within this short period. These fundamental differences not only cause misunderstanding and discourage communication, but also made it impossible for the team to set a common goal. Trying to solve this problem was an extremely time consuming process and at the end we decided to give up and focus on our parts as much as each of us is willing and capable of committing.

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6. Personal Learning Experience

6.1 Victoria Chen

As the documentation girl, I have said everything I can possibly come up with in the previous sections of this document; so I'll use this section to express my appreciation towards all the people who had assisted me in the past sixteen weeks. And I have also learned that living my life up at SFU is actually not as painful as I thought; after a while, I felt at home. And the machine shop is a pretty nice place to release some stress ☺.

On top of valuable technical and interpersonal experience which everyone gained from this course, I have also learned how fragile as well as how valuable friendship is. It is hard working as a team when we have five different goals. However, we managed to go through all the misunderstanding and conflict and remain as good friends. For the past ten days, I had friends who come up during their spare time to help me with my project or just to give me some mental support. I don't think I could have survived my second demo without their help and support.

Gary Houghton guided me on designing the SpotU mechanical structure. He also helped me with some parts that required the usage of machines that he doesn't feel safe giving me permission to work on. Sharam Payandeh and Patrick Leung lent us many components and equipment. Celina Tinio gave me some information on ultrasound sensors and their circuits. Gary Chu and Tim Norman helped me understanding and debugging our PIC program as well as reading the understandable motor amplifier spec. Shahram's grad students lent me their motor control books which was way more helpful than the amplifier spec. William Chan helped me with soldering; having someone checking the connections with me saved a lot of time. He also drove me to Future Active and Main Street Electronics several times when I was too stressed to drive. Versatile Innovation, Smart Sense Innovations, and Vincent Yen from RainWorks were really patient in helping me with little problems. I would like to take this opportunity to thanks them for their help and support. I would also like to thank all my other friends who have been calling me or visiting me; they kept me alive and awake. Also like to thank my mom and my sisters for spending hours preparing food for everyone up here during those ten days.

6.2 Sherla Cheung

During the course of the 370 project, I've acquired the experience of participating in an engineering group project. I've improved my problem solving skills. I've encountered difficulties throughout the project, both technically and dynamically; but I've learned how to work as a group and find out the solutions. Technically, I've learned about different positioning methods and mechanisms, how to source and obtain components, perform efficient research. My knowledge on electronic components and equipment is broadened, especially in RF and programmable integrated circuits. I have also improved my circuit layout and soldering skills. My part can be improved if I had started earlier so that I could have more time in terms of testing and researching. Also, I could have anticipated the requirements of my part in more details if I had communicate with other group members more frequently and thus had a more thorough understanding of the entire system. If I had an opportunity to do the project again, I would start much earlier and reduce my course load, so that I can afford to dedicate more time, effort and energy from the start of the project, instead of pushing it after my final exams.

6.3 Mei Chan

The SpotU project has been a great learning experience for me, both technically and inter-personally. From the technical perspective, I gained knowledge in the bahaviour of motors. I also furthered my knowledge in the areas of motor amplifier and using a potentiometer. I learned that detailed research and careful planning helps tremendously in the design process.

A more valuable experience is the inter-personal skills I have acquired during the past thirteen weeks. Having to work together with four other members requires patience and constant communications between the group members. I learned to express myself in the group as well as listening to others' opinions. I also learned to be more considerate. There are often times that scarifications have to be made in order to move the project forward and keep a positive team dynamics. These experiences will aid me greatly in the future.

If there's anything to be changed for our project, I would choose a topic way before this semester starts and keep firm deadlines. I feel that by doing so we would have more success in our project. I would also like to see a more organized group structure and more communication between the group members so that each of us can have a better idea on the overall progress of the project. Also, a group member with more experience and knowledge would save us a huge amount of time.

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6.4 Ada Pang

For myself, these past 13 weeks have been a great learning adventure. The experience that I have gained through the ENSC370 course is not taught in any courses or obtained through any co-op terms. The process of developing, integrating, and testing a product is very interesting. Having these hands-on experiences, I now have more insights towards the product development cycle.

Being in charge of the microcontroller part of the project, I grew to enjoy low level programming. The microcontroller is considered the brain of the system. Its activities and outputs govern the way that the system runs. Taken on the full responsibility of the microcontroller, I became familiar with the overall system architecture. I learnt the importance of interactions between different subsystems and have become keen in error detection and bug-fixings.

Apart from technical knowledge, I also gain valuable personal experiences. Teamwork is very essential when it comes to group projects. I learnt to work well with other team members, and be attentive when others are expressing their opinions. Often times, the person involved is too concentrating on working on a particular task that important things might have been neglected. Other group members are always great peers to provide important reminders and ensure that the progress is proceeding in the right direction.

I find that ENSC 370 is an excellent course. The skills that I have gained from this course are invaluable towards my future career as an engineer. I'd like to take this opportunity to thank all the professors and peers who have provided me with many advice and tremendous support.

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6.5 Joyce Wong

This project had brought me some very valuable knowledge and experience than I ever thought I would get from a project course. In search of a solution to our tracking problem for the SpotU system, I came across with the GPS solution which is used world wide for global positioning of an object using radio frequency. Due to our limited resources and knowledge, we solve our tracking problem by capturing the basic concept of GPS but using ultrasonic waves instead of radio frequency. Although our SpotU system is not performing at the optimal standard that we wished it can, the pleasure of knowing that we are in the right direction to solve the tracking problem is already a great achievement in my own standards. Since I was responsible for the ultrasonic part of the SpotU system, I had learned a deal about ultrasonic wave including its theory and possible applications. The most important thing that I learned from this course is to always give all you have and never give up. Through out the whole project, I realized that our lack of experience, knowledge and resources are some of the key factors that limited our ability to deliver a top performance project. However, the more we pushed ourselves forward the more we learned and the more we achieved. At the end, I found that we gained a lot more than we ever believed we could and that we had redefined our own boundaries. The greatest accomplishment of this project is knowing that no matter how difficult the environment is, we can always over come obstacles and learned something useful and valuable along the way.

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