Flame Extinguishing Intelligent System

April 23, 2010

Dr. Andrew Rawicz
School of Engineering Science
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Re: ENSC 440 Post Mortem for FlexiSys

Dear Dr. Rawicz,

Attach is our document, "FlexiSys Post-Mortem Report", which describes the entire process and the steps taken by our team as we developed our product. Our automatic fire extinguishing system addresses the need for an intelligent system to combat fires and provide an additional blanket of safety for small buildings.

Our process report outlines the technical progress we have achieved, the changes to our project, and future plans for our product. We have also included an outline of the non-technical issues such as the budget, group dynamics, nontangible benefits, and difficulties in developing our product.

FlexiSys is composed of four engineering students from Simon Fraser University: Kelvin Ho, Luke Dang, Peter Zheng, and Ken Zheng. If you have any questions or require further information, please contact me by phone or email.

Sincerely,

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604.780.3392

Post-Mortem Report

For a Flame Extinguishing Intelligent System

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Submitted to: Dr. Andrew Rawicz – ENSC 440
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1. Introduction

The inception of our product began in January 2010, when the four members of our team began brainstorming ideas for a project. Over a span of thirteen weeks, we created a product that was able to detect a fire and then proceed to extinguish it. We were able to meet the functional specifications that were described for our proof of concept method and we completed a successful demonstration to our peers. There is, however, plenty of room for improvements – necessary if we wish to push this product to the market. With this said, the events that occurred over the thirteen weeks and the amount of experience we gained were extremely valuable.

2. Current State of the Project

Currently, we are in the state where we can build a prototype, as shown by our working model for the demonstration. Our model follows the block diagram as shown in Figure 1 and has enough functionality to be considered a proof of concept. Unfortunately, some minor functions did not get included in the working model. For example, the system was not tested to see if still could operate at over 300 degrees Celsius, the system was not optimized to be power saving, the system was supposed to be noiseless, and other minor functionalities. As we wanted to demonstrate a proof of concept, all major functionalities such as detecting and spraying water to the fire in any location were met.

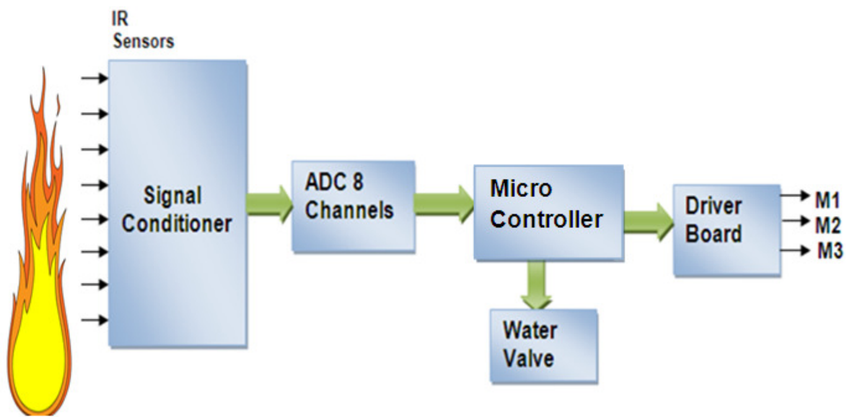

Figure 1: Block Diagram for the Fire Fighting System

3. Original Design Deviation

Our current design is not optimized for the consumer market. Alternative prototypes were optimized for the consumer market. Our actual system does not have much deviation from the original design. However, few modifications were made to fit with our budget and time issues.

3.1 Hardware – Mechanical Design

System mechanical overall design and actual models are displayed in Figure 2 and Figure 3 below:

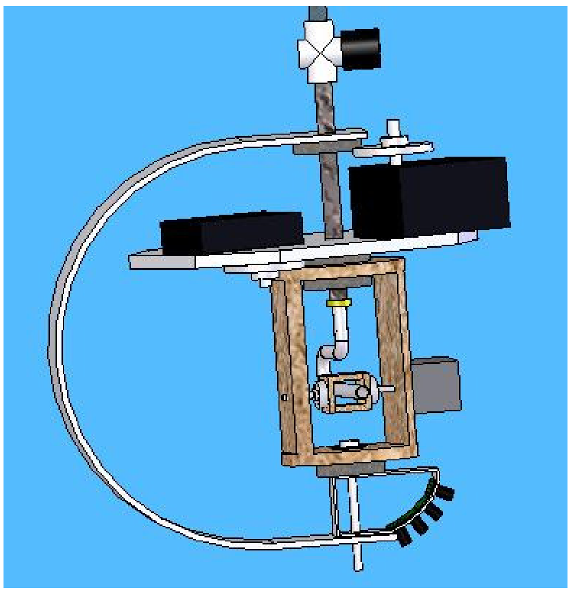

Figure 2: Original system design

Figure 3: Overall system: working model

From the figures, there are mainly 3 units in the system, the sensors, the water casing and the water hosing.

The sensors cover a range of 25^o to 65^o below the horizontal. The sensor stack holds the sensors together and in the right angle. Each sensor has a field of vision of 10^o over 12 meters. The motor to rotate the stack sensors is attached on the base at the top of the casing. To translate the motor rotation, the right angle bracket is used. As a result, when the motor rotates, the motion is translated to the bracket which in turn is translated to the sensor stack.

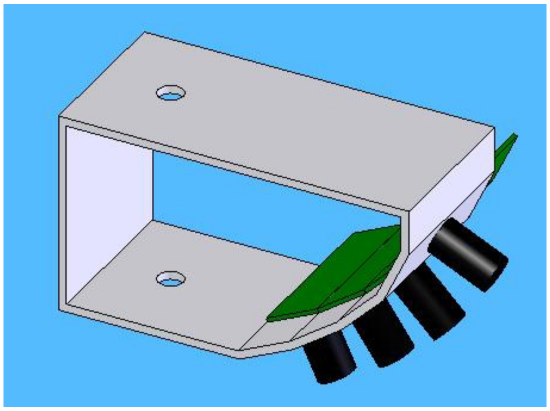
Figure 4: Original sensor stack with sensors

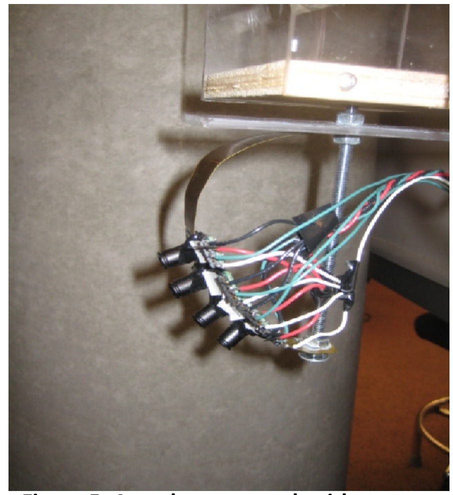
Figure 5: Actual sensor stack with sensors

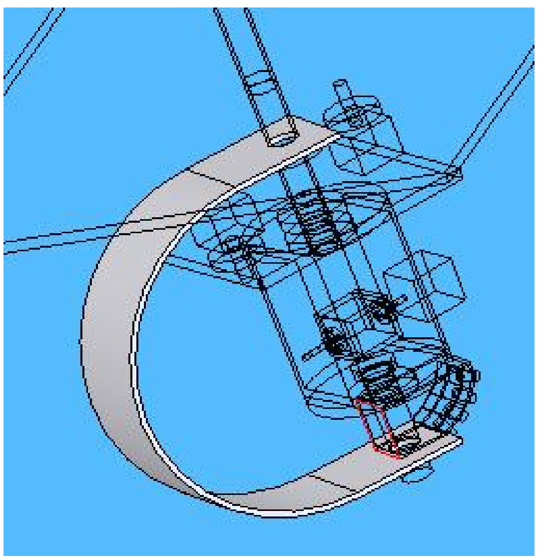
Figure 6: Original C-bracket

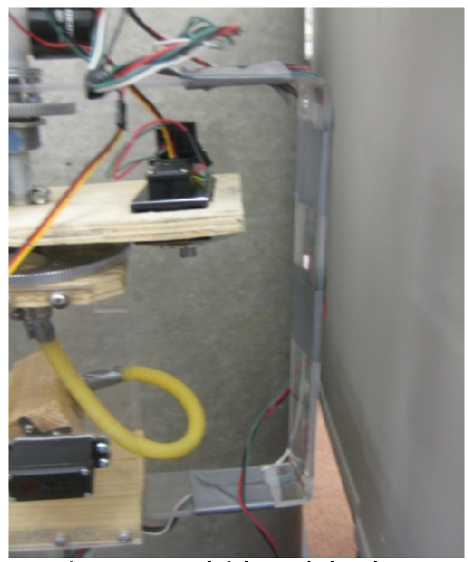
Figure 7: Actual right angle brackets

The water casing provides the left and right motion for the water hose. The design did not vary from the CAD design except that the shape is square instead of circular.

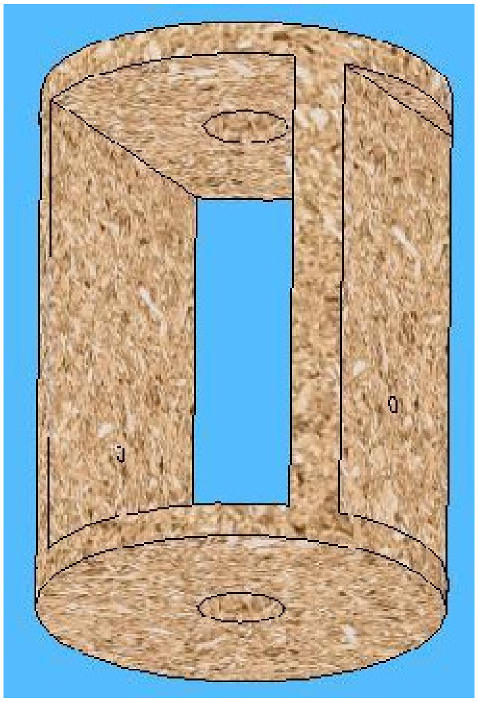

Figure 8: Water Casing Design

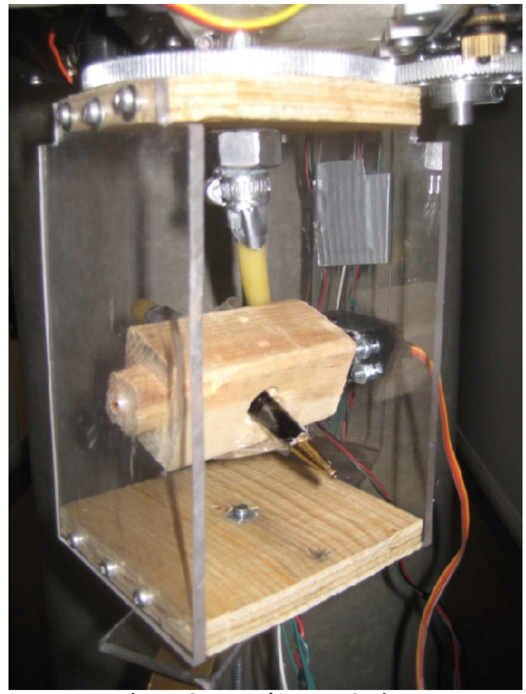

Figure 9: Actual Water Casing

The water hose casing is different than our previous design. Originally, we wanted to build a box to hold the hose. However, we did not use a garden hose so as a result, we had to improvise and drilled a hole big enough for our water hose inside a wooden block.

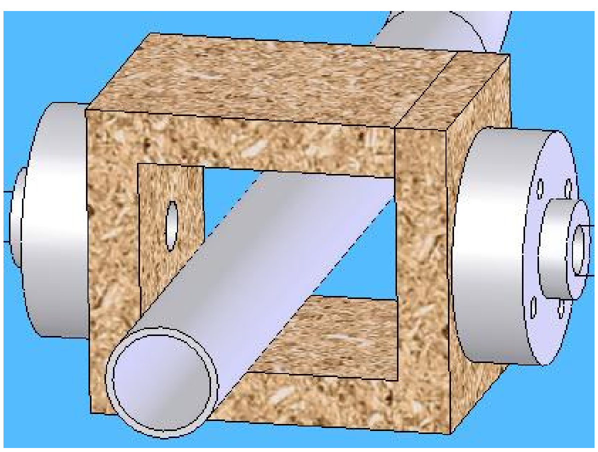

Figure 10: Original hose casing and hose

Figure 11: Actual hose casing with modified hose end

There were other minor changes from the original design since we could not find material and equipments that could help realize our design.

3.2 Software – Microcontroller Interface

Arduino is a microcontroller development board chosen for this project. A lot of research and group discussion were centered on a suitable microcontroller. We all agreed as a group that Arduino has much more online knowledge support compared to other microcontrollers. This assisted us tremendously during the project.

As shown in Figure 12 below, our original plan was to use one Arduino Duemilanove for the whole project. While developing the software for the fire extinguishing system, we came across a serious bug in the NewSoftSerial library that was used to configure general digital I/O pins to perform serial communication with our sensors. This library kept on sending out interrupts that would stop our communication with the motors. We had contacted the Arduino developers regarding this issue and had given several attempts to fix the bug ourselves. Nevertheless, we figured a solution for project prototype - to use two separate Arduino boards, one for sensor interface and the other for motors and valves. I^2C communication was used to exchange data between boards, as displayed in Figure 13 below.

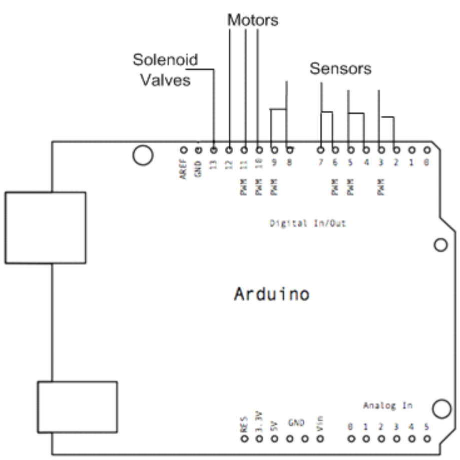

Figure 12: Original microcontroller interface

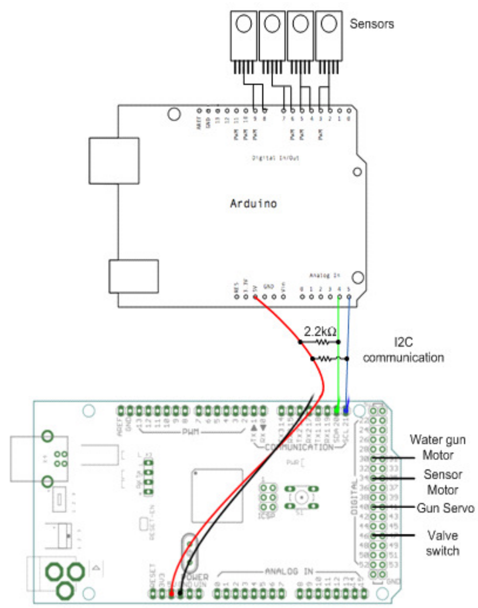

Figure 13: Actual microcontroller interface

3.3 Detection of fire

The fire detection system comprised of the sensors mounted on the sensor stack and was connected with the c bracket, resembling our original design. Sensors chosen were Parallax's MLX90614 and they performed well for this project. The wavelength pass band of this sensor is from 5.5 to 14 µm. The differences are in the bracket and the sensor stack. The sensor stack was not built due to difficulties getting the angles between each sensor right. We were not able to find a machine that could bend the plexiglass sheet with such accuracy. The other difference is the bracket. Instead of the C bracket, we made a right angle bracket as it allowed for more space efficiency.

3.4 Spraying water to the fire

Our original design was to use an open ended hose and let the water pressure dictate the distance that the water will travel. However, after testing the design, we found that the distance was too short. In our model, we used the tip of a pen to provide a larger pressure which resulted in a longer range.

4. Future plans

Flexisys provides an alternative solution to water sprinklers in areas such as computer labs, living rooms and electronics rooms. To make the system more appealing, we have the following suggestions for future developments:

4.1 Mechanical System

Better gears: Either buy customized gears with standard tooth dimension and customized bore diameter or use standard gears. The current working model used customized gears re-bored with a drilling machine. The resulting gear is good enough for the proof of concept but it has dimension errors.

Bearings: Using axial and ball bearings would reduce friction and the noise from the system while reducing power consumption for the servo motors.

Determine torque: With the kinematic analysis, the torque requirement would be more accurate. The motor selection would be more suitable for the design.

Better material: Using lightweight material would make our system more portable and easy to install. Moreover, the system interacts with water and fire, so it would be beneficial to use material that is good against corrosion and has a high melting point.

4.2 Battery Power System

Beside solenoid valves, the rest of our system is powered through Arduino board which is powered by a USB connection. Future improvements can introduce battery for these boards to make system more portable.

4.3 Microcontroller

The microcontroller we are using for our proof of concept is more powerful than what is needed. Once the power is determined, a more efficient microcontroller could be used instead to reduce cost.

5. Budget

Table 1 below contains the estimate and the cost of the project as of April 23, 2010.

Table 1: FlexiSys project cost summary

Required materials	Estimated cost	Actual cost
Motor Driver	56.64	0
Motors	158.22	536.2
ADC	16.42	0
Microcontroller	100	74.32
Water Pipe	50	90
Electronics	50	20
IR sensors	107.48	312
Water pumps	50	0
Casing material	50	0
Contingency	95.814	255.79
Total	734.574	1288.31
ESSS funding		-500
Total after funding		788.31

Our actual cost is almost double of the estimated cost. Originally, we were thinking to buy step motors and use circuits with H-Bridges to drive them. However, upon testing the motors, we found that the nema-17 step motor did not provided enough torque for the system and the nema-23 required too much current that the current H-Bridge we had could not handle. Other materials included the calliper to measure the diameter of the pipes correctly, couplers, fastener, aluminum tube, voltage regulator, diodes, PCB, headers, and other minor electronics components. After testing different designs for the motors and electronics, we found some of the materials not suitable for our project. Moreover, a few components were purchase for alternative designs in case the current model did not work. That resulted in the contingency fund increasing unexpectedly.

6. Timeline

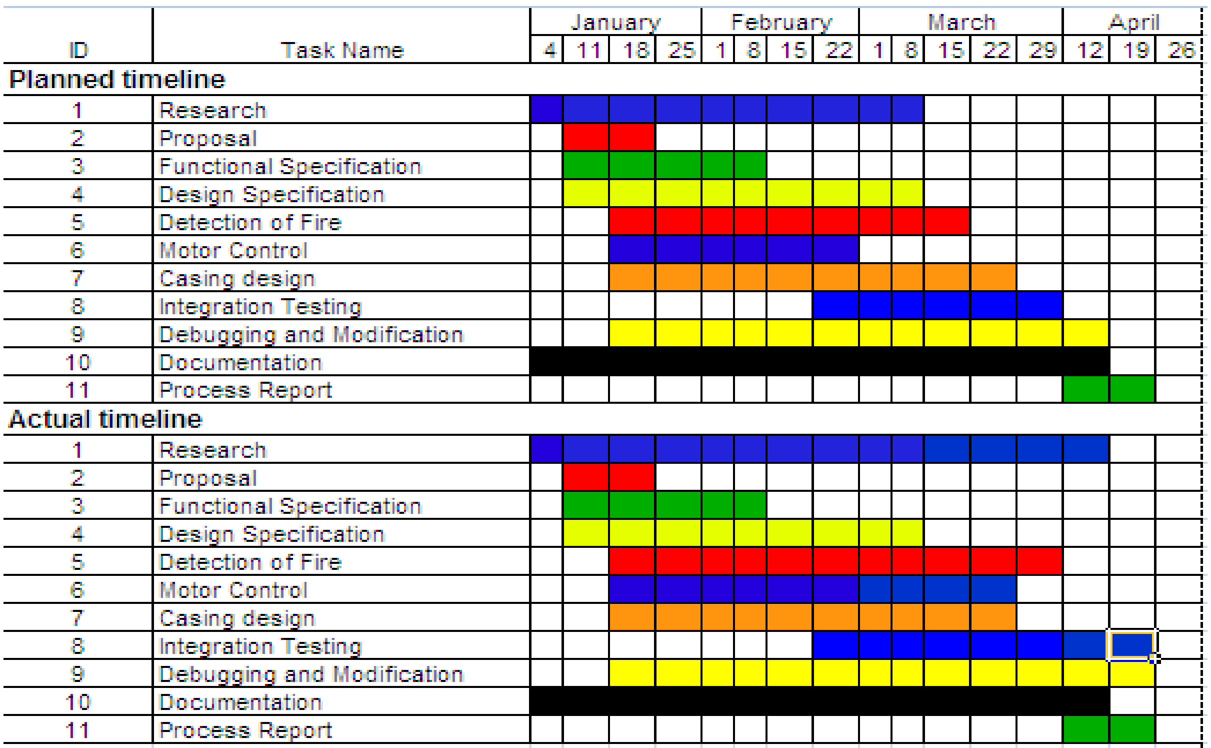

Figure 14: Gantt chart of our planned and actual timeline

Documentations were usually on time as seen in the Gantt chart in Figure 14 above. Fire detection required more time than expected due to firmware issues related to the internal clock cycle. Moreover, the integration of hardware and software was extremely time consuming. The main problem was due to our parts not being of standard size.

Our debugging time and integration time were almost as expected. We knew from the beginning that we would encounter problems at this stage so we thought about solutions for possible problems that we might encounter ahead of time. We spent a lot of time calibrating the angle between the hose gun and the sensors and every time moved the system, calibration has to be done again. On the day of the demo, we still had calibration issues. We managed to calibrate the system for when the sensors go in the counter clock wise direction before the demo and this was the decisive move because during our demo, we were able to show to the professors and the guests that our concepts indeed worked.

Researching time extended past the planned timeline because we were looking for alternative solutions. As soon as one of us hit a wall, we split the group into helping figure out the problem and researching into alternative solutions in case there problem could not be fixed. Moreover, we were also looking into other designs so we needed additional information for other designs.

7. Individual Reflections

7.1 Kelvin Ho

Over the last four months, I've gained an immense amount of technical and non-technical experience by working together in this project. Some of the technical skills that I have learnt are microcontroller programming, mechanical and motor design, hardware interfacing, and most importantly, sourcing for our parts. As I specialize in computer engineering, I had little to bring to the table in terms of initial system design. During the first month, I was heavily absorbing new material and at the same time, researching different and unique software solutions for our project. As our project was coming to a conclusion, my skills were able to be applied – a lot of coding and debugging time was invested.

More importantly, I believe, is the non-technical skills that I have learnt from this project teamwork. Technical skills can always be learnt at any time, thanks to the internet and the massive amount of help and information, but teamwork cannot be learnt like so. Group dynamics were important, as we all came from different engineering specializations: Ken and Luke are both Electronics Engineers, Peter is a System Engineer, and I was a Computer Engineer. Although there was friction from time to time between members, nothing escalated out of hand and problems were always resolved instantly. Maintaining harmony within the group was crucial, as we could not work in such a hostile environment.

Taking a glance back, there are a few things that might have helped with the project: Ordering parts earlier would have sped up the integration of our project. Splitting up the project work to our specialities would have increased efficiency. Regardless of these improvements, I have thoroughly enjoyed the time we spent as a group and I look forward to what the future has for the bonds that were formed from this project.

7.2 Luke Dang

I had been looking forward to take ENSC440 for a long time. I had heard lots of rumours both good and bad about the course, the workload as well as the teamwork dynamic. For the past four months, ENSC440 had been a big part of my life. I think this course was an incredible opportunity for undergrad students to learn various technical as well as non-technical skills.

I started this semester knowing nothing about microcontroller interfacing, mechanical design or motors controlling. The project pressure required me to gain these knowledge fast and put them into application. With Arduino programming, I acquired valuable experience with microcontroller, serial communication, I^2C protocol and motors control. Besides software, I obtained important skills in hardware/mechanical designs, implementation. These will definitely help me significantly later in my future career.

Besides technical skills, I had an incredible experience working in team dynamic. I faced conflicts with other team members but learned to solve these conflicts effectively. I developed my interpersonal skills significantly. Also, various skills such as resource gathering, communication skills, technical writing were improved as well.

I had put a lot of time and effort into the project and I did not regret them at all. Through the course, I had gained appreciation for electronic system designs and wish to pursue more into this area. If only this course give a longer time than 4 months, and less documentation, I could have focus on design, build a much more sophisticated project and enjoy it even more.

7.3 Peter Chuan Zheng

From an overall perspective, I learned that design is an iterative process. I went back and forth between the SolidWorks design, the functional specification and the design specification. Also, even though we had one design in mind, I still researched for alternative designs in case the first one did not work because for the same functional specification, there are many alternative to meet the specification; or if some parts of the first design did not work, we could borrow subsection from the other designs. I learned that having many designs is better than one design. Having alternative designs will help understand more the final product.

I realized that unlike software, mechanical engineering designs require the most time, just to check if parts could work together. Buying parts could take weeks due to shipping and manufacturing. Manufacturing, assembling and altering parts also take time because sometimes, you need specialized machines that require certain learning curve before they can be operated. Moreover, other machines might not be available right away and need to be reserve ahead before you can use them.

From a mechanical perspective, I have learned how to use turret machines, rapid prototype machines, more advanced SolidWorks technique, learned about mechanicals components selection and mechanical suppliers.

Working in this group allows me to see the strengths of being a Systems Engineer. I was able to put to use all the knowledge in mechanical, electronics and software. Moreover, since we are from different engineering background, I learned how to work with them. Conflicts are the result of misunderstanding and through ENSC 440, I have learn how to solve them. If I had known the course would require so much work, I would have taken fewer courses so that I could put more effort into building a better working model even though we just wanted something to prove a concept. I enjoyed working in this team and learning what I learned.

7.2 Ken Zheng

Before taking ENSC 440, I had heard many classmates saying how different and how valuable this course was, and I often doubted what they said. After 13 weeks, I have to say that I totally agree with them. Usually, all the labs and projects we do at SFU are set out by the professors. Basic steps are written on papers; all the necessary parts are ordered by the professors. More important, what we are doing is always related to the course we are taking currently. If something in the lab that we don't know how to do, we can usually figure it out by looking at the textbooks or lecture notes. This is totally different for ENSC 440. It is just because of this difference, I have learned an enormous amount of technical and non-technical knowledge.

My major is Electronics Engineering, and I like to learn things on analog and digital circuit design, but my programming skills are not excellent. Some of the technical skills I learn during this course are microcontroller programming, hardware and software integration, servo motor control, and especially mechanical design. I have never learned and done any mechanical design during my life time. When working on the project, I have learnt how to operate drilling machines, electrical saw machines and how to assemble all the parts together.

Besides learning all the technical skills, I also learnt a lot of non-technical ones. For example, after this course, I find it out where to buy electronic components, bearings, gears, motors and more importantly how to use the powerful internet to find what I need. Probably, I can learn all the skills mentioned above without working with my team members, but for sure there is one thing that I won't be able to learn alone, which is teamwork. In our group, all the members are good students. We all study hard and we all are confident about what we are doing. It is just because of this, some problems arise. Sometimes, we all have different ideas for doing one task, and we all believe that we have the best idea of doing the job and try to persuade others to follow his idea, then arguments occur. However, we understand our goal is to get the job done, and we usually come to an agreement at the end. In order to keep up our relationship after fighting, we sometimes dine out together so that we can be released a bit from the anxious atmosphere.

In all, this course is challenging by rewarding. I have learned a lot of skills that other courses can't offer, and I believe I can go on to use the knowledge in my future life.

8. Conclusion

FlexiSys started four months ago with a simple drawing of how an intelligent fire extinguishing system should be. With guideline from the course on making proposal, functional and design specifications, we gained better understanding of our own design. After countless hours of work both individually and together, we completed a working model that can prove our concept. As a very first developed model, there are still a lot of area which the system can be improved. However, this first model reflected our hardwork as well as suffering throughout the course and we are extremely proud of it.

9. Reference

[1] Melexis.com, *IR MLX90614 Infrared Thermometer Datasheet*, 2008. [Online]. Available: http://www.melexis.com/Assets/IR_sensor_thermometer_MLX90614_Datasheet_5152.aspx. [Accessed: April 20, 2010]

[2] Arduino.cc, *Arduino Mega*, 2009. [Online]. Available: http://arduino.cc/en/Main/ArduinoBoardMega?action=diff. [Accessed: March 08, 2010]

[3] Arduiniana.org, *NewSoftSerial*, 2010. [Online]. Available: http://arduiniana.org/libraries/NewSoftSerial/. [Accessed: March 05, 2010]