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April 20, 2009

Patrick Leung
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Re: ENSC 440 Project Smart Crutch Process Report

Dear Mr. Leung,

The attached document, *Smart Crutch Process Report,* discusses our team's effort on implementing the Smart Crutch Project. The Smart Crutch is an assistive device which prevents or helps users during falls using 3 stages of intervention namely, the warning stage, the fall prevention stage and the alarm stage.

The following document outlines the current state of the device, the future plans for the device, the deviations from our original design and the group's budget and time management details during the project implementation. Lastly, we also discussed the group dynamics, interpersonal relations and technical knowledge gained from implementing the project.

ASA Concepts consists of 5 dedicated and motivated engineering students. ASA Concepts' members include systems engineers Ben Lush, Amir Sadeghi and Chien-Wen Lin who designed the sensors and mechanical components and electronics engineers James Guerra and Ming-Cheng Lin who designed the software and hardware components of the project. If you any further questions, please contact me through email, ensc440-asaconcepts@sfu.ca.

Yours truly,

Ming-Cheng Lin
CEO and President
ASA Concepts

Enclosure: ENSC 440 Smart Crutch Process Report

Process Report for the Smart Crutch

Project Team: Ming Cheng Lin
James Guerra
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Steve Whitmore – ENSC 305

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Date Submitted: April 20, 2009

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Introduction

With the last 13 weeks of intense work, ASA Concepts has finally brought good news to all the crutch users around the globe who are afraid of walking on the slippery or the icy roads. With this pair of high tech crutches which ASA Concepts developed, the crutch users will be informed or helped whenever a potential slip might occur or has already occurred. The product is put together by five brilliant individuals: James Guerra, Ming-Cheng Lin, Chien-Wen Lin, Amir Sadeghi, and Ben Lush. This document will illustrate the current state of the finished product, any variation from the original design, possible future design improvement, the development budget and time allocation, and individual feedback from the members.

Current State of the Device

The Smart Crutch has 3 stages of prevention and assistance for the user before and after a slip. The three stages includes the warning stage where the user is notified in case a slippery surface is detected; the fall-prevention stage in case the crutches detect that the user is falling backwards; and the alarm stage to notify other people that the user has fallen. There are two sensors used on the crutch which includes the friction sensor which detects the slipperiness of the ground and the 3g axis accelerometer which detects the angle of the crutch with respect to the ground. An ATMega16A microcontroller monitors the state of the crutch and turns on a fall prevention mechanism deployed using a motor in case a fall is detected. Buzzers are also turned on in cases a slippery ground is detected for the warning stage while a periodic RF pulse is sent to a remote alarm system which also uses buzzers to notify other people in case the crutch is detected to have been fallen on the ground. The following figure shows the overall system diagram of the Smart Crutch.

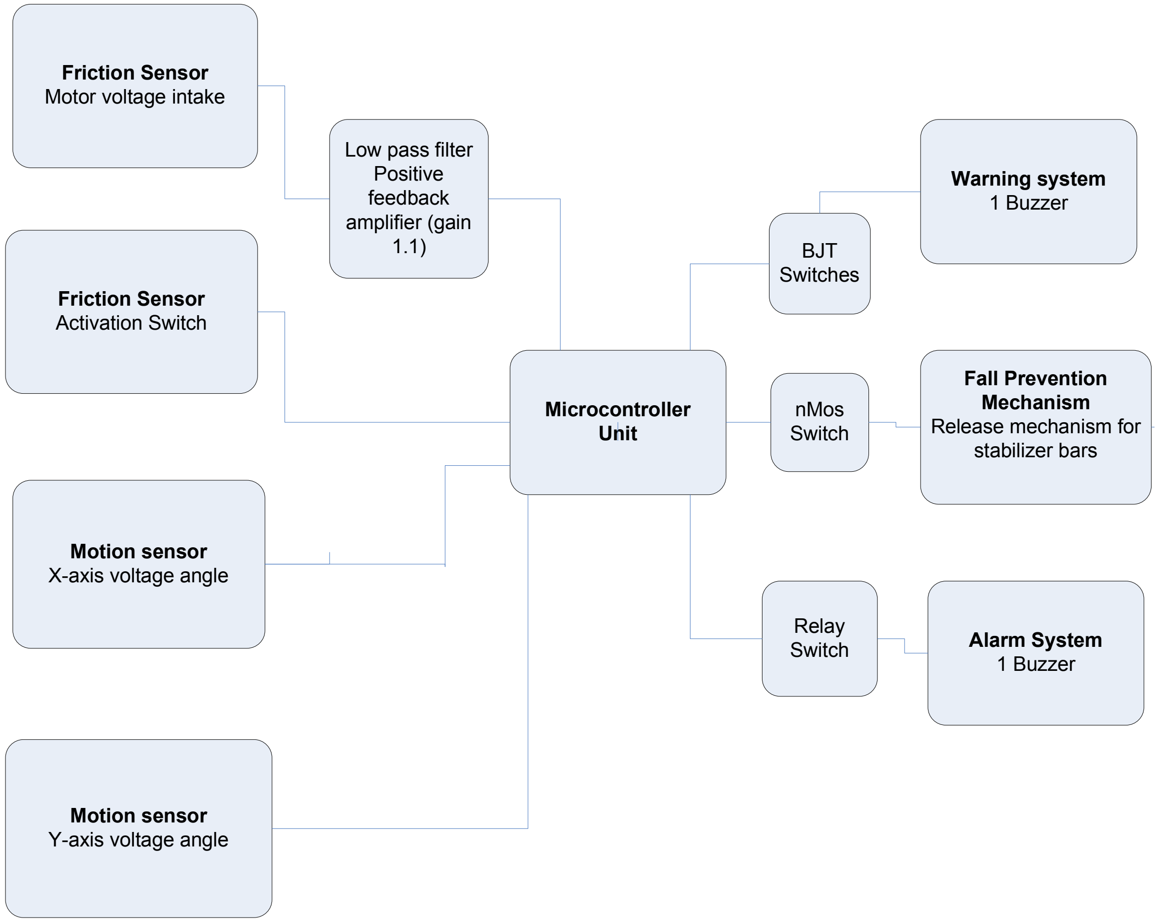

Figure 1: Overall System Diagram

The friction sensor attached at the bottom of the crutch consists of gear motor (GM14a) and a rotating wheel mounted on a springed shaft that adjusts itself once the protruded portion of the shaft touches the ground. The mounted wheel barely touches the ground and constantly rotates to detect the slipperiness of the ground. The voltage drop across a 15 ohm resistor in series with the gear motor is monitored to read the current fluctuations required by the motor. The signal is then conditioned using a positive feedback amplifier for buffering and low pass filter for taking out unnecessary high frequency noise.

Different switches were used to turn on different mechanism of the Smart Crutch. The simple BJT switches were used for the buzzers of the alarm system. A cleaner switch, the nMOS switch was used for turning on the gear motor that rotates the cam that releases the fall prevention mechanism. Lastly a relay switch was used in the remote alarm system to remove noise obtained by the RF receiver.

The fall prevention mechanism deploys when a cam rotates and releases the hook that holds the fall prevention system upright. The one way gear upon the release of the fall prevention system prevents the mechanism from going back upright to its original position. The whole mechanism however can be manually reset by pulling a lever attach to a string which pulls the stabilizer bars back right up.

Only two axises of the 3g accelerometer was used. The forward motion of the crutch used the Y-axis angle of the accelerometer which monitored the forward and backward angle of the crutch with respect to the ground. The sideward motion of the crutch used the X-axis of the accelerometer which monitored the sideward angle of the crutch with respect to the ground. Only the Y-axis angle is used in determining if the angle of the crutch with respect to the ground is sufficient as the crutch initially touches the ground. Both the X and Y axis angles were used in determining if the crutch has fallen on the ground.

Several experiments were made to determine the relationship between the angle between the crutch on the ground, the weight of the user and the slipperiness of the ground. A linear relationship was approximated that shows that more angle is required between the crutch and the ground as more slipperiness of the ground is detected. Also as the weight of the user increases more angle between the crutch and the ground. An operating procedure is then formulated where a warning system (buzzers turning on) is activated if the required angle is not met for a given weight of the user and the detected slipperiness of the ground. When a decrease in angle of roughly 10 degrees is detected while on the warning stage, a fall is considered and the fall prevention mechanism is deployed. The user can then manually reset the fall prevention mechanism later on. Lastly, when the crutch are detected to be almost parallel with the ground, i.e. crutches are <30 or >150 degrees with respect to the ground, the user is considered to have fallen and an RF pulse is sent to the RF alarm system to activate the alarm.

Deviations from the Original Design

Friction Sensor

The developed friction sensor operates as it was expected. However, due to none uniformly rotation of the wheel connected to the motor, the value of the friction fed to the system was not as accurate as it was expected. Therefore, a number of actions were taken in order to overcome the errors. Since the rotation of the wheel is not one hundred percent uniform, some parts of the wheel require more current to spin on the specific friction and some other parts require less.

Firstly, the number of success samples achieved from the microcontroller to activate the warning system had to be increased in order to include more circumferences of the wheel. This modification made the friction sensors data more reliable. However, it slows down the detection of the friction which is still less than human reaction time and therefore acceptable. This modification helps the controller to have a better approximation of the friction. Secondly, the use of a high pass filter helped the controller to reduce the noise and get more accurate samples of the friction.

On the other hand, the mechanics of the friction sensor turned out to be fairly close to the expected design except that the use of a pin under the motor inside the shaft was necessary in order to reduce the force exerted on the wheel. This action made the mobile part of the design to oscillate smoother. Due to the use of the pin under the motor, the assumption was made that the user only uses the crutch in the suggested angle. This issue can be resolved using a manufactured bearing system that makes the mobile part to oscillate smoother without use of the pin. The details of this concept will be discussed in the future plan section.

Activation Switch

The current state of the activation switch is completely different than what we expected and proposed in the proposal. The proposed design was originally implemented, used and tested. However, the reliability of the design was very low. One of the issues was that the push button as the activation switch under the pad was under a great force that resulted in breaking the switch frequently. The second issue was that the location of the switch under the pad made the switch to not be activated the whole time that the crutch is grounded. Therefore, Close to the end of system implementation, the activation switch was completely redesigned using a short circuit. Instead of placing a push button under the pad, there was placed two pieces of conductors on the mobile and fixed parts of the sensor. As the crutch hits the ground, the mobile part starts to move up and short the two conductors. As a result of the short circuit, the controller would know that the crutch is currently on the ground. Not only this new design solved the issue of breaking push buttons frequently but also it solves the problem of the push button location. Regardless of the position of the pad on the ground, the activation switch is on and stays on until the crutch looses contact with ground.

Fall Prevention Mechanism

The fall prevention portrays the correct concept of functionality. However, it is not suffice for users due to its material build up, bulkiness, and other small technicalities. Many bolts screws and scrap aluminum are jetting out from the main body and can be hazardous.

Firstly, since the one-way gear is composed of aluminum, the teeth and overall gear were required to be excessively large in order to compensate for strength. Even still aluminum is tensile and becomes warn down over time. Thus once the teeth were cut out it would function but after time the teeth would grind down and bend and the slip back prevention would not function properly every time.

Secondly, the release motor that releases the prevention arm for swinging down was not opening the trapping mechanism at a constant rate. This is due to the natural influences effecting the amount a motor can spin given a period determined by a digital microcontroller. We were unable to approximate perfectly the turning period every rotation. We came very close however. Thus sometimes it would release fast, then later slow, then fast again. This problem did not affect the releasing ability, more the reaction time.

Last, the prevention bar was composed of two aluminum bars parallel and a sawed off crutch head in between. It was a barbaric approach, but never the less turned out visually appealing. This did not turn out to be very practical though. This is because the head would always hit the ground on an angle and the increased friction would be very small. Also the head too was made from aluminum and we fear that over time it would weaken and break, resulting in perhaps a more serious injury.

On the flip side, the slider concept for transferring energy from a spring to the rotation of the fall prevention bar was a success and eventually led into the concept of how to produce a pull back resetting mechanism. This concept was strong, fast, easy to replicate and was very fitting based on the materials we had. Other versions of the slider and how to deal with the small technicalities will be discussed later in the section of future plans.

System Features

Other system features as proposed in the design documents where also not met due to time constraints. The power idle mode where the microcontroller would be turned off and the gear motor of the friction sensor was not implemented because of lack of testing and lack of switch controlled by the microcontroller that turns off the friction sensor. Also the turn-off feature for the buzzers of the alarm and warning system using a user's push button was not implemented because somehow the interrupts service routines used to mange the push button operation interferes with the normal program operation of the microcontroller and causes the whole system to stop.

Future Plans

Friction Sensor

There are three ways to improve the friction sensor. First, since the friction sensor is placed under the crutch, there is a large force that is being applied to it constantly which makes it to depreciate quickly. In order to manufacture a better friction sensor that depreciate not as fast, the motor and the wheel has to be in a smaller size. Using a smaller motor allows us to fit the motor inside the mobile shaft that fits itself in the pipe. Fitting the motor inside the shaft, we can run the cam connected to the motor outside the closed shaft to spin the wheel. On the other hand the wheel has to be made with metal to eliminate quick depreciation. Furthermore, it has to be manufactured in a smaller size and has to be placed as close to the pad as possible. Having all the parts smaller lets the friction sensor to be more compact. It also increases the safety of the crutch. Moreover, the spring inside the shaft that assists the mobile part of the sensor to oscillate needs to be mounded on a solid shaft itself to eliminate vibration and to be protected from excess forces.

Secondly, since the design is mostly used for wet and snowy surfaces, the friction sensor needs to be water proof. The closed shaft that will hold the motor inside and all the wirings need to be sealed to be protected from getting wet.

Finally, a bearing system has to be designed for the shaft inside the pipe which is the most important to eliminate the push pin under the motor. Eliminating the push pin allows the pad to be in its original shape and not cut at the bottom. One of the important features of the rubber pad through research is that it creates a virtual vacuum which protects it from slipping. Therefore having the shape of the pad as its original is a big advantage to safety. The bearing system inside the pipe helps the shaft to slide up and down the shaft with only a little force exerted on the wheel itself and therefore, the use of the push pin would be unnecessary and the wheel can be placed on the ground at any angle. Figure-2 shows the current design of the sensor using the pin and the future design assuming that the shaft is installed on a bearing.

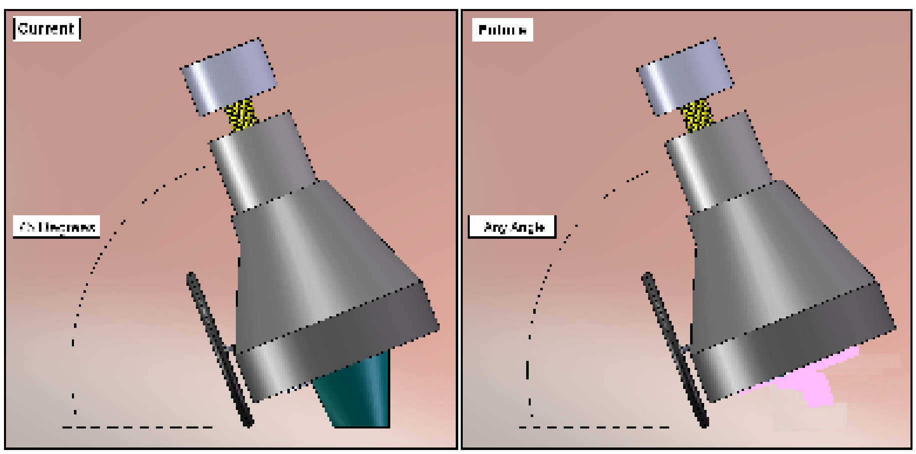

Figure 2: Friction Sensor (Current Design vs. Future Design)

Activation Switch

The activation switch is now in a good position in terms of reliability. However also as a future plan to make it water proof and less depreciable, same design of the short circuited switch has to be used except that it needs to be placed inside the pipe closer to the spring. This way the activation switch would not touch the ground in any circumstances, therefore it would be water proof and less depreciable. Figure-2 shows the future switch design. One side of the short circuit switch is placed on the fixed pipe of the crutch and the other side moves with the mobile part.

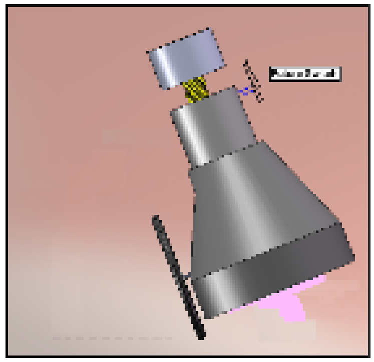

Figure 3: Future Design of the Activation Switch

Fall Prevention Mechanism

There are three ways to improve the crutch. First is containing the whole body inside an enclosure, second is producing an angled slider, and last is to make the fall prevention bar out of steel or titanium.

Putting the whole body inside an enclosure is vital for the future development of the crutch because it will not only reduce the crutch catching on cloth materials or cutting the user but also improve the style and overall feel of the crutch. It also adds the bonus function of water resistance. It may even help with adapting the crutch to alternate crutch styles that don't have the three poles as in the shoulder crutch. This can be accomplished by creating a new slider device using smaller and thinner bars and using less motors.

The new slider concept is also important for it would allow the crutch to increase it angle of fall prevention from linearly forward to up to 45 degrees in each direction. This new slider may also be able to contain the releasing mechanism and the one way gear in an area less than 3 inches long. A drastic improvement containing the one way gear, releasing and pull back mechanism, and the angled slider would reduce bulging parts, space consumption and weight allowing for more vital parts to have the freedom of occupying space.

Casting the prevention bar out of steel or titanium would account for higher strength durability and lower size. Although weight may be increased in this area, the benefits far outweigh the disadvantages. Steel is a great material to work with and should help reduce the overall cost.

RF Communications

Currently, both crutches have no idea what the other crutch is doing in terms of its current friction detection result and angular position. A future improvement would be to apply RF communication between the crutches for data exchange. Moreover, the user won't need to enter their weight twice in both crutches if RF communications scheme between crutches is established.

With the current design of the Smart Crutches, only one pair of RF transmitter and receiver is used for emergency alarm system. For the future plan, we would like to add the RF ID feature such that each pair of crutches will be assigned with its distinctive ID number. At the same time, we would like to complicate the RF receiver design so that it can receiver multiple signals from different pair of crutches. The RF receiver can decode the message by the RF ID and then determine which pair of crutches has fallen. With this advanced RF receiver design the Smart Crutches can be widely used inside a hospital with many crutches users.

System Operation

More system features can be added to the crutch which includes the unattained system features as described above. The features include ability of users to turn of the alarm and warning buzzers using the push buttons and the power saving feature that automatically turns off the friction sensor motor and sets the microcontroller into idle state when the crutch is not in use for a few minutes. Also, more complicated data analysis by the microcontroller based on the readings from the accelerometer can be used to identify how the crutch is exactly positioned with respect to the ground and detect possible slipping or falling positions of the users other than backward slipping motion. With these, investigations and research on how the users slip more needs to be done.

Budget and Time Constraints

Budget

The budget for the Smart Crutch is summarized in the following tables. Our total expenditure was for the crutches were $**668.50** but the actual cost incurred for the whole project was $**900.**

Part number	Description	Quantity	Unit Price	Total Price
TM162ADA7	2 lines* 16 LCD module	2	$ 30.00	$ 60.00
7805	5V regulator	2	$ 1.00	$ 2.00
2n7000	N-Mosfet	2	$ 0.50	$ 1.00
TXA1	434MHz RF transmitter	2	$ 3.00	$ 6.00
2n3904	NPN transistor	2	$ 0.50	$ 1.00
ADXL330	Tripple Axis Accelerometer	2	$ -	$ -
74LS30	8 input NAND Gate	2	$ -	$ -
74LS148	8 to 3 encoder	2	$ -	$ -
Atmega16A	Microcontroller	2	$ 15.00	$ 30.00
LM358	Op-amp	2	$ 1.00	$ 2.00
GM14a	DC Motor	4	$ 20.00	$ 80.00

	Piezo Buzzer	2	$ 3.00	$ 6.00
	Red Push Buttons	8	$ 3.00	$ 24.00
	Black Push Buttons	4	$ 1.00	$ 4.00
	PCB	2	$ 10.00	$ 20.00
	Resistor	40	$ -	$ -
	Capacitor	20	$ -	$ -
1n4001	Diode	4	$ -	$ -
	LEDs	4	$ 0.25	$ 1.00
	8.4V Ni-Cd Battery(1.8A-h)	2	$ 35.00	$ 70.00
	Battery Charger	1	$ 65.00	$ 65.00
STK500	Atmel Microcontroll development board	1	$ 150.00	$150.00
	Underarm Crutch	2	$ 35.00	$ 70.00
	Packaging Case	2	$ 10.00	$ 20.00
	Large Spring	2	$ 10.00	$ 20.00
	Robber Pad	2	$ 4.00	$ 8.00
	Aluminum Bar	2	$ 5.00	$ 10.00
	Bolt/Nut/Screw	30	$ 0.25	$ 7.50

Table 1: Bill of materials for Smart Crutch

Part number	**Description**	**Quantity**	**Unit Price**	**Total Prizce**
RF408	434MHz RF receiver	1	$ 2.00	$ 2.00
78L05	5V voltage regulator	1	$ 1.00	$ 1.00
2n7000	N-MOSFET	1	$ 0.50	$ 0.50
HRS1H	5V relay chip	1	$ 2.50	$ 2.50
	DC Buzzer	1	$ 3.00	$ 3.00
	LED	5	$ 0.40	$ 2.00
1n4001	Diode	2	$ -	$ -
	Resistor	2	$ -	$ -
	Capacitor	3	$ -	$ -

Table 2: Bill of materials for Remote Alarm System

Person	Spent
Amir	$200.00
Kyle	
Stan	$300.00
James	$200.00
Ben	$200.00
Total	$900.00

Table 3: Actual expenditure of each member

The extra cost obtained from the actual expenditure was from equipment bought, extra parts obtained, travel and shipping expenses.

Timeline

The following figure illustrates the projected and actual timeline for our project development. Notice that research and individual module development was took more time than expected because we have to be constantly sensitive to new ideas that we can use for better performance of our project. Integration and testing although started earlier never really finished until the latest because sometimes unexpectedly components fail.

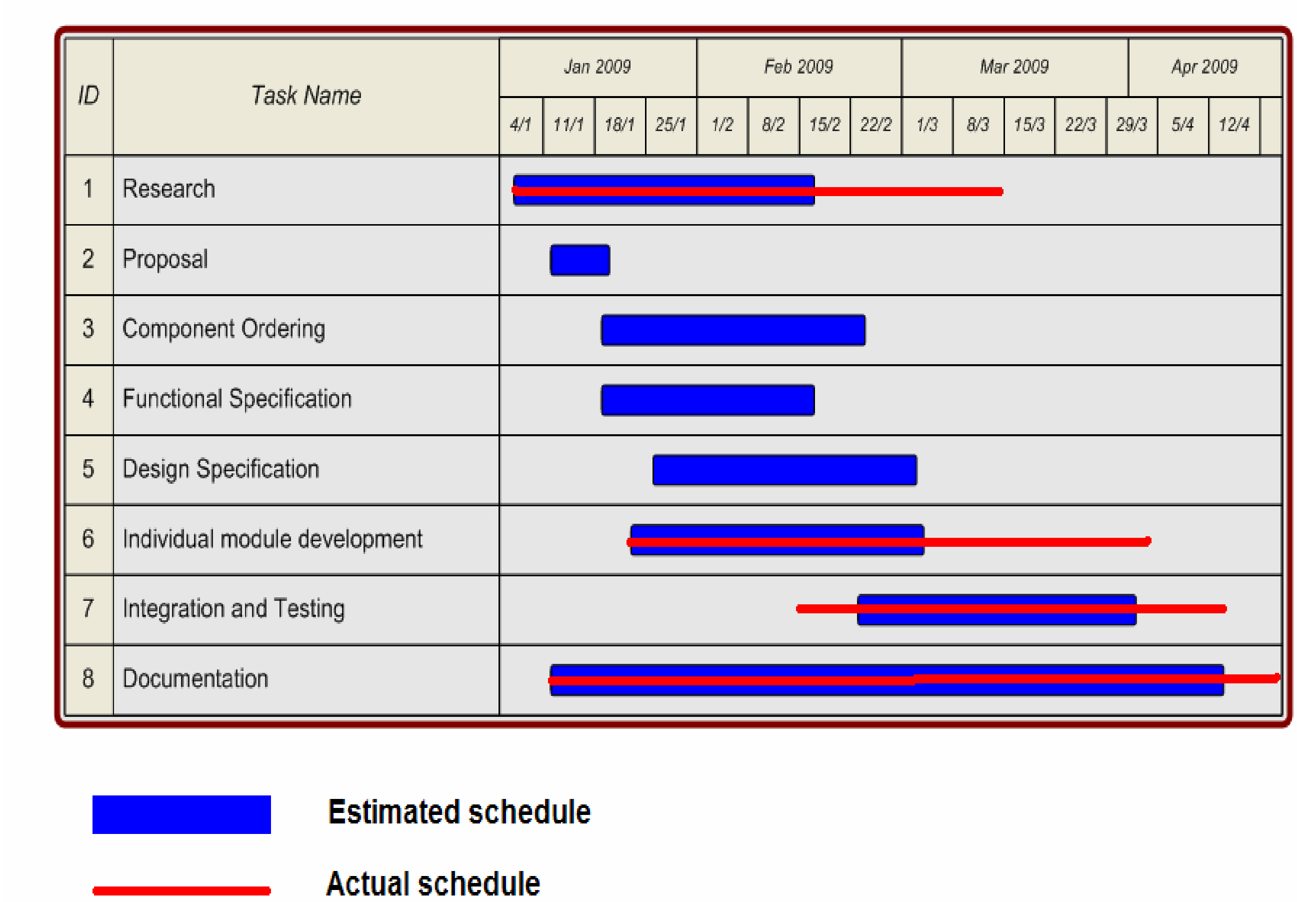

Figure 4: Timeline for the Smart Crutch Project

Interpersonal Assessment and Technical Experiences

Amir Sadeghi

Initially when I found this amazing team to work with, I did not have the chance to choose the project I wanted to work on since they already had their idea and they were only looking for two more members to start working with. However, when I heard about the project I realized that I really like the idea. What I liked about designing a smart crutch was that it involved mechanics, physics, electronics and a lot more. It also required the knowledge of sensors, control and a lot of hands on.

In this term I spent a lot of time working on the sensors specially the friction sensor that was developed from scratch. Even tough the friction sensor itself was only a small part of the project, it required a lot of different ideas to be developed and it required a lot of research and work done. Then I also spent a lot of time trying to figure out the physics and the right algorithms of processing the information to properly control the actuators at the right time. Besides all these, I spent lots of time integrating the whole system. As a result of having many parts and components, putting everything together and getting them to work properly was a challenging job.

What I liked the most about the project was that we had to come up with many different ideas for almost all aspects of it. There was not a roadmap to follow. So we had to go through a lot of napkin ideas and start to develop them. What was interesting and really enjoyable at the end was being able to see what we had in mind from no start was working even tough smart crutch was not the best marketable product at the end.

I learned a lot in this past four month both from the people I was working with and the project itself. I learned a lot about team dynamics, how to deal with partners in a team, how to listen to others and how to convince others with my ideas. Most of all I learned how to develop my own idea with the use of everyone else’s help.

I learned how to fill up the gap between theory and practice. I realized how important the answers to a page of calculations can be when it is suppose to affect every little part of the project. What I learned the most was to think out of the box. I learned how to properly research and use every little resource to achieve the goal. Moreover I learned how to get the different parts of the project done in parallel which is very important in every engineering project. I learned to focus on integration or hardware while I was waiting for motors to get shipped or waiting for the mechanics of the system to finalize.

I would like to thank all my group members. I would like to thank them for all their helps in every little time and for their understanding of each others pressure and stress. I am also very thankful to Patrik, Steve, Jamie and Jason for their highly informative information about the process and every little detail.

Ming Cheng Lin

During the first week of the class in semester, I was not able to stand up because of the leg injury when I helped push a neighbor’s car which was stuck in snow. Back then we did not have a good project idea and was still looking for at least one more member to form a valid group. By the end of the first week, it is amazing that we met other two talented members and also how we came up with this project idea from my personal injury.

I feel thankful that I take this course because it not only broadens my academic knowledge but also utilizes all academic trainings and coop experiences that I have accumulated. Five of us are all equipped with different specialty and I spent most of my time developing the hardware design of the Smart Crutch. I develop two hardware modules: one for the microcontroller which is mounted on the crutch and the other one for the RF remote alarm system. The first month I worked on the RF remote alarm system and it has been challenging for me to filter out the noise on the data input port of the receiver. In the end, I used a relay chip and a set of RC low pass filter to filter out the noise. I was quite happy that one of my work projects with relay chip in my coop would help me for the RF receiver design.

The hardware design for the microcontroller board was also challenging to me. I have never experienced designed such a big system circuitry including user interface, power circuitry, motor control, and LCD control. Therefore, I was not comfortable in the beginning. I spent a long time researching the internet resources as well as asking Professor Patrick questions to get the tips of designing an efficient and useful system circuitry. From this experience, I have learned how to design a stable power circuitry by using big capacitors. I also learned that how to make my signals noiseless with certain choices of RC network. I have done all three of my coops as a hardware engineer. Thus, I was happy that my soldering skills that I learned from coop could help me make the prototype board.

Finally, I have to thank all my group members for their hard work throughout this tough semester. I think we had a good dynamic within the team and each one of us plays an important role in the individual part. I also want to thank Patrick for his timely support on this project. He has helped us in solving many tough problems in our hardware design which saves an incredible amount of time. One example is his suggestion on placing a capacitor in parallel with all the motors to get rid of the transient voltage which results in random freezing of the system.

Chien-Wen Lin

At the beginning of this semester, I was worried and frustrated about choosing the topic and team member's shorted issue, especially after the first 305 lecture. Fortunately, it turned out we found a project we will like to work hard on and the best team members to work together. In this project, our team member has their own specialty on their focus and cooperated and helped each other all the time.

In the team, I worked as a system engineer who focused on the sensor part of our device and also help software guys, James, on communication and testing. Based on the knowledge on 387, I started to find the sensors we can used to meet our project requirement. For our project, the most difficult part is the friction sensor. We needed that sensor for sure but there is no such device on the market yet. Therefore, it took us some time to find some devices to fit our need and we ended up using motor for our best solution. I also cooperated with software guys on the commutation between the micro controller and the sensors. I was surprised that how many troubles we can face even we thought the concept was easy, and I have learned a lots base on this experience. I really want to appreciate Professor Patrick's support. He helps us a lot on how to clear out the problem and how to fix and try in different ways. That is not something we learned a lots on the book.

Besides all the technical learning through this course, I learned a lot on pressure management and team work. As I mentioned at the beginning, I was under great pressure. After that, the true is that it was getting worse. For example, there are many deadlines to meet or we are still fixing the sensor the day before the demo. I learned how to control it and trust on myself and teammate. For my team work experience, this is my first to work in a big team and with all separated job. The communication became important and I learned how to manage and help each others to get the work done.

Finally, I really appreciated all the helps from Prof, TAs, and Lab staff to help our team finish the job, and also helps all the efforts all our teammate to put into the project and got it done.

Ben Lush

When I first started 440 I has no idea what to expect. I had a bunch of drawings, some plans, and only one partner. Yet I trusted that if I kept seeking to succeed in this course that things would work together. After meeting with Steve and listening to his encouraging rebuke I set off to email and talk around with my class mates. I never expected to gain these great partners that from the start cooperated and stuck together to the very end. So we set off and I was able to gain experience beyond the scope of that which I had previously learned from Ensc courses, experience in mechanics, electronics, kinesiology, and goal setting. I was happy to be focused on the fall prevention mechanism because all my life I wanted to make my drawings come to life, and this project helped me breathe life into these concepts.

As stated previously my focus was on the fall prevention device, although I had to keep in mind each of my partners activities, my part was relatively separated from others work. All I had to do was reduce the space I consumed as much as possible, so that the sensors and electronics could fit properly. The hardest part was to come up with the concept of how to stop the prevention bar from moving backwards after it made contact with the ground. I probably spent a good week thinking of new concepts. But as time went on things literally fell into place, occasionally I would be looking for a part and it would be in the scrap bin and in one case already drilled to the exact measurement I needed! The challenge for me was not physical instead it was about always keeping my mind fresh and focused.

James Guerra

As I started the 440 course, I was immediately overwhelmed with the amount of expectations that our professor have on us. My group actually didn't come up with our project until the first week of this semester. I was very optimistic though when we finalized the members of the group wherein we took two new members, Amir Sadeghi and Ben Lush. Immediately upon knowing their profiles, I became very optimistic about the promising result that our project may have. One thing I've realized during the project development was that having an earlier integration time doesn't really mean finishing early. It just means more time is allotted for integration. The project may not work splendidly, but a working concept must at least be shown during the demo.

Throughout the course of the project development, my software skills helped me a lot in creating the program required for our project. Initially, I tested on Atmel's development board STK500. With the help of Stan Lin who is the group's hardware support, I was able to tests features that we will use in our project like buzzers, LEDs, switches and analog-to-digital converters while using the development board. Eventually, when the final circuit board for the project was fabricated, I was able to tests using the actual components.

My co-op experience in software development also helped me a lot for this project. The skill in writing test scripts in Python for obtaining sensor data from the microcontroller through the UART came from my coop experience. Also, the resources such as the interrupts, timer and analog-to-digital converters in the microcontroller was also tediously studied and learned for their proper use.

Most importantly, we could have not realized this project if it weren't for the expertise of my group members in their individual fields. Ben and Amir for instance, for me, is unparalleled in their mechanical design abilities while Stan is the authority for any signal conditioning or hardware circuitry needed for the project. Kyle is an all around person for the team and helped me a lot in understanding the accelerometers we used in our project. Overall, I wouldn't have anything else change in our group in terms its members and the group dynamics.