POST MORTEM REPORT

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1. INTRODUCTION

Since January 2006, Safe Sense Technologies has been working hard to show that it is possible to come up with a clever system that would to move the person away from danger in a tipping situation and also provide substantial and effective pressure relief for wheel chair users who have limited upper body mobility.

This document will provide information regarding our proof of concept model that was finished on April 1, 2008. This document includes system over view of the proof of concept model, problem that has been encountered during the development, comparison of estimate and actual budget and timeline, experiences that each team member of the group had through out the project.

1.1 INTENDED AUDIENCE

This document is intended to be a description of the progress and alternative ways that may enhance the overall performance of the system. Its audience is primarily course instructors/professors for evaluating the performance of our project. It will be also used by engineers within safe Sense technologies for future development.

2. CURRENT SYSTEM STATE

The Wheelchair Stability and Pressure Relief system which we designed during this semester is currently fully functional and meeting all of the functional requirements set out at the beginning of the term.

There are three modes of operation which may be turned on or off via the user interface located by the right knee of the user. These modes are: Pressure Relief Mode, Wheelchair Stability Mode, and Manual Control Mode.

2.1 PRESSURE RELIEF MODE

This mode of operation provides pressure relief to the seat of the user promoting blood circulation and preventing the development of pressure sores. The system provides pressure relief by moving the users upper body left and right in a controlled manner. A pressure relief timer implemented within the microcontroller software provides signals to the motor controller corresponding to suggested pressure relief timings. One example of pressure relief timings would be to move the user slowly to the left, hold in the left position for two minutes, then slowly move the user back to the middle neutral position. Alternating sides left and right at an interval of every fifteen minutes provides unobtrusive pressure relief and inhibits the development of pressure sores.

A PI motor controller was implemented in software code sending signals to a 20A H Bridge circuit which then delivered power from a 12V battery to the motor. The motor is a 12V 20A motor capable of 100lbs of lifting force. The force from the back of the motor is transferred to the user via ropes and pulleys which attach to a chest harness that slides on a rail located on the front of the seat.

2.2 Wheelchair Stability Mode

This mode of operation senses a potentially dangerous situation and corrects the upper body position of the user to pull them to a safer position which would either prevent the fall or at the very least prevent the injury resulting from a fall.

A single-axis inclinometer mounted on the wheelchair provides a sense of orientation to the microcontroller. Based on this tilt angle, danger is detected. In order to correct the body position, the motor moves at a speed proportional to the tilting speed of the chair. A faster tipping scenario leads to faster response of the motor while a gradual tilt leads to a slow movement of the motor and thus the body.

2.3 Manual Control Mode

A small selector switch was placed on the user interface of the system which allowed the user to move their upper body left or right accordingly. As the selector switch is moved left or right away from its center position, an interrupt is sent to the microcontroller which in turn signals the motor controller to move the user left or right accordingly. Again, a PI controller is utilized in order to move each user at the same speed independent of the load on the motor.

3. Future Developments

Our company is very interested in developing this product further and searching for business opportunities related to the product. During the development of the product this semester we found some possible future developments which we would be able to incorporate in to the product given an increased period of time to work on it. Below are some of these ideas.

- Lateral supports
    - We hope to replace the chest harness with lateral supports mounted on the rail
    - This feature would be less obtrusive to the user and more visually pleasing
    - The transfer of force is much more efficient and thus less battery power would be needed as well
- Customization
    - Adjustable pressure relief timing
    - Variable speed control
- Acceleration control
    - Take in to account centripetal acceleration
    - Acceleration dependant motor control
- Safety improvements
    - Pressure sensors on the harness/lateral
    - Ensure that the motor controller is not placing an unsafe amount of force on the user
    - Muscle Spasm detection, detect and prevent injury from muscle spasm
- User interface

  - Sip-n-puff (ideal for quadriplegic people)
  - Replace the existing switches with more accessible technology
- Mechanical structure
  - Fully encase the system to prevent interference and possible injury from moving parts

4. PROBLEMS ENCOUNTERED

We are quite happy with the progress that we were able to make on this product as a team given the three month time period in which we worked on it. As with all projects there were some bumps along the road which we were able to come to speedy resolutions and get on with the development of our project.

4.1 TRADEOFFS

A reoccurring theme in this project was the tradeoffs between certain features on the product. One example would be response time vs. noise rejection. This occurred in both our inclinometer sensor as well as our motor position feedback sensor. We were faced with a tradeoff between eliminating noise effectively enough so that the signal was usable and responding fast enough so that the entire system was effective. Much time was spent on finding the golden middle point of this tradeoff so that we could sufficiently meet both needs.

4.2 UNFAITHFUL SUPPLIERS

While sourcing our parts, we ran in to a problem with one supplier which led to a heated argument costing valuable project time and expensive long-distance charges. We first ordered our string-potentiometer from SRP control systems located in Mississauga, Ontario in mid February. They promised on the phone a two week delivery date and charged us a very expensive shipping cost of $55 for overnight shipping option. We noticed that they use UPS to ship across the country and that UPS's cost for overnight shipping was only $39 for the weight of the part that we required. Seeing that they were already marking up the shipping cost made us a bit weary to do business with them but we continued anyways.

Two weeks later, we gave SRP a phone call to inquire on the status of our order. They informed us that it would be another 1-2 weeks. Needless to say, this would be devastating to a project as we were already half way in to the semester. We were very displeased and gave them the option of either cancelling our order free of charge or expediting our product to us as soon as possible. They said that they would do neither and if we wanted to cancel, they would charge us a 30% restocking fee. Since the cost of the product was over $200, this would be a significant cost to our budget. Several phone calls later we were on a conference call with the president of the company, the sales manager, as well as the original salesperson who promised our 2 week delivery. The call quickly became heated as threats were given by both our company and theirs in hopes that the other would back down from their stance. The call ended with us cancelling our order and telling them that it would be in their best interest not to charge us a re-stocking fee.

As of this date, we have not yet seen a charge from SRP Control systems on our credit card statement. We learned a valuable lesson about suppliers and what power they hold over our progress. Although an oral contract was formed during our first call which implied that we would get our product within two weeks, the oral contract was clearly worth the paper it was written on. Following this incident we contacted another supplier and were more diligent in our order tracking as we asked for tracking numbers and specific dates to go along with our order.

4.3 MICROCONTROLLER PECULIARITIES

We used the Atmel AVR Butterfly Microcontroller to implement the software control and signal processing for our system. This microcontroller is extremely easy to use, very inexpensive, and has many great features which suit a large range of potential projects. There were, however, several problems with the microcontroller which we ran in to. These problems are listed below.

- AVR has released two different versions of the butterfly without release notes or documentation of the differences
- Many ports have multiple uses – for example, we had to pry off the piezo speaker which came with the board because it was connected to the PWM output signal creating very high pitch sounds
- ADC reference voltage was unreliable - an optional 1.1V regulated reference voltage was used instead

5. TIMELINE

Setting up a Microsoft groove account and mailing list provided efficient ways of communication. The Microsoft groove program provided a convenient centralized place to store different versions of documents, datasheets of electronic parts, microcontroller codes and so on. Our main goal was to be as efficient and productive as possible to be able to finish the project on time.

Throughout the project we tried to follow our timeline very strictly. However there were two changes that were made to our original timeline. These deviations are shown in the figure below. The blue bars show the proposed timeline for each task and the red arrows illustrate how we to followed them. As you can see from the figure below, we started the integration part sooner than the time we were suppose to start and finished it sooner than expected. Since our team was working together almost every day, we managed to integrate each other's part as soon as they were finished. We tried to integrate all finished part by the end of the day so that we don't have any problems at the end.

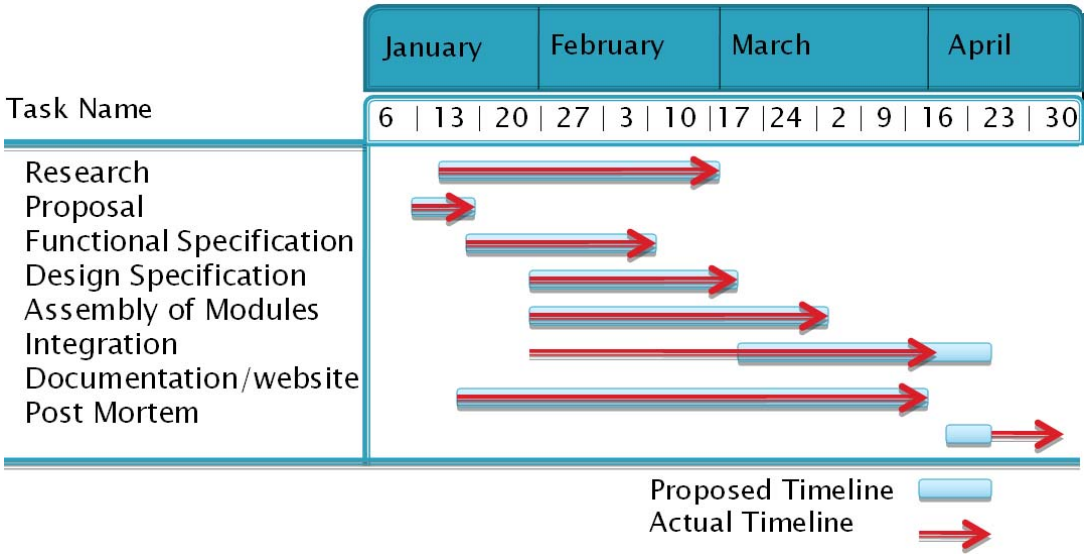

FIGURE 1: COMPARISON BETWEAN PRPOPSED AND ACTUAL TIMELINE

6. BUDGET

The table below illustrates the components that have been used on the system along with their prices. The total cost of the system added up to $1064.87.

TABLE 1: PRODUCT COST

Component	Price
AVR Microcontroller 3	38.85
Rack and Pinion/DC Motor	303.62
H Bridge	160.15
Inclinometer	65.91
Linear Encoder	257.41
12V-Battery	50.40
Circuit Components	50.78
Hardware (Cases/Pulleys/Glue/etc)	55.65
Chest harness	44.1
Rope (Aluminum rope/Kite rope)	38
Total Product Cost	**$1064.87**

However there were $598.54 additional costs during the development of the system that included tools and equipment, parts that we didn't end up using on our final system, restocking fee, travel and long distance calls.

Adding the product cost to addition cost, the actual budget came to $1,663.41.

Additional Cost + Product Cost = Actual Cost

1064.87 + 598.54 =1663.41

The proposed Budget was $1603 which is very close to our actual cost.

This project was fully funded by ESSEF and Whighton Fund. The total granted Fund to Safe Sense Technologies was $1790.

7. Group Dynamics

Being a group of three, we decided to work closely with each other and integrate different pieces as we progress through the project. To have an efficient integration, we had to have full knowledge of other team members' progress on a daily basis. We managed our schedule to work in the lab at the same time. Every team member was partially involved in other team members' tasks to provide useful feedback and finish tasks quicker.

We held meetings on a weekly basis to discuss alternative solutions for the tasks to be done. After reaching an agreement, every person would take a task based on a general guideline: Jamie was focused on the software, Shadi was focused on the hardware, and Arash was focused on the interface between the two.

We never left a team member doing a task alien to other team members. Our main objective was for everyone to learn; therefore we tried to explain what we learned doing a task in our meetings. Having enough background knowledge about each other's progress, we were able to help out one another and finish tasks quicker and more efficiently.

We avoided arguments and tension in the group by respecting each other ideas. We approached problems with a same mind set; one person would propose a solution and others would improve that. Most of our solutions have everyone's ideas embedded in it.

8. What we would have done differently

Looking back on the past three months and the progress that we have made during this time, it is hard for us to find actions or choices which, if given the chance, we would do differently. Two aspects of our project however could have improved our progress even further if they were done differently. These two aspects were the data extraction from our micro controller and the physical structure of our wheelchair.

8.1 Microcontroller Data Extraction

In preparation of our final presentation we began to explore the serial pc connection feature that was available on our microcontroller. We previously neglected to investigate this feature as it seemed to be very complex and would take up considerable development time. As it turned out, the PC connection feature was very easy to implement and provided us with extremely useful insight in to how the motor controller worked. In hindsight, we definitely

should have implemented the PC connection feature much earlier in our project. With this feature we were able to stream data from the microcontroller to our PC and then plot the results on the screen. Zooming in to a timescale of the order of 0.01s allowed us to see things that were unable to be seen by the human eye. For instance, change in effect of sampling rate on our motor controller or change in effect of filtering techniques. Throughout the project we simply looked at the motor and tried to tell what changes were beneficial and which were detrimental. The use of this PC connection would have been very useful in finding the ideal midpoint of the tradeoffs talked about in previous sections.

8.2 Structure of Wheelchair

One feature of our current wheelchair structure is two vertical metal bars which are placed upright on either side of the user. These bars prevented us from developing a more efficient and effective system with the use of lateral supports. The vertical bars would block the path of travel of the lateral support thus limiting its movement to a very small and ineffective displacement. If given the chance, our team agrees that requesting a different wheelchair structure from our supplier would be beneficial to our final project. A structure which allows lateral supports to move with greater displacement would allow for a more effective transfer of force to the body.

9. Individual Descriptions

9.1 Jamie Westell

My contributions to the team were primarily on the software design of the system as well as construction on the chair. Within the software implementation I focused on the sensor data input using the analog to digital converter on the microcontroller. I worked with Arash on many aspects of the code and collaborated with him for ideas and methods of solving different problems that arose. Filtering signals and sampling times were among the most problematic issues which we tackled together in an iterative approach.

I am very happy with the progress that our team was able to make during these last three months. I have been very lucky to be in a group with such hard workers. Many nights throughout the semester we would work until very late hours and rarely did a group member say that he or she had to leave early from a meeting or development session. Usually, the decision to pack up and go home would be made once a milestone was reached.

The beginning of the semester was met with dire warnings of groups containing only three members. The warnings were of some concern to me as I did not want conflict with my team members to inhibit the progress of the project. Gladly, I am able to report that there were many more points in the semester when we were all laughing together at something rather than coming to any sort of conflict with each other. Our team worked remarkably well together and any problem which arose in the project was met with all of us eager to provide a solution. Differences in opinions were resolved by everyone explaining how they looked at the problem

as well as a proposed solution. The solution which was settled on was usually a combination of everyone's thoughts and ideas.

I am very proud of my team and the progress that we were able to make during this semester. I look forward to developing our product in the future and working with my team members for some time to come.

9.2 SHADI SHIRAZI

This project offered me a lot of learning experiences; it was very interesting and fun to work in a group on a project of this size. I am glad that after 4 months of hard work we were able to build a system that we could be proud of. I enjoyed working with my team members every day. We had a great team and great result which made this project an unforgettable experience for me.

As a group, we were keep updating each other on our task, and helping each others to solve our problems faster. This method was very effective since not only it helped us to be on a same page all the time but also it helped us to save a lot of time in integrating each other's part. I believed that integration becomes very simpler in group of 3, since it is easier to be involved in each other's tasks and make integration easier at the end.

On a technical side, I gained a lot of experience on different types of sensors and actuator. I did many researches on choosing the most suitable and affordable control devices. As an example, I searched a lot to find a suitable H bridge that would supply up to 20 Amp of current to the motor and also allow very fast current switching to be able to control the motor by Pulse Width Modulation signal generated from microcontroller. I also contributed in mounting circuitry, making the hardware and witting software interrupt. From my past course I learned the PID controller in theory, but implementing it in a real project and making it work was a very big experience.

I can say I had the best team and the most interesting project this semester and I will never forget the good times I had with my team members.

9.3 ARASH JAMALIAN

I have worked both on the software and hardware part of the project. I worked closely with Jamie to write the software for interrupts, DC motor PID control, pressure relief algorithm, and stability algorithm. I also helped Shadi with mounting the circuitry, user interface board, and the rail on the wheelchair.

In this project, I had a chance to implement the theories I learned in ENSC 387, and ENSC 383 on the system and understand the limitations of PID control and DC motor models in practice. I learned a lot about the challenges of discrete time control and time varying dynamical systems. I also got a lot of experience in real time programming and interrupts. On the mechanical side, I learned a lot about efficient force transfer, DC motor torque and speed characteristics, and rack and pinion dynamics.

I always tried to be an effective team player by correlating everyone's tasks and providing useful feedback. I tried to be patient and listen carefully to other ideas and take them into consideration. My main contribution as a team player was to make sure everyone is on the same page and is happy with the decisions made.

I am quite satisfied with the progress we made in the past four months. When I started this project in January, my main objective was to finish the semester with a practical and useful solution for wheelchair users. My group has done an outstanding job to achieve this.

10 CONCLUSION

We were able to start from scratch and develop a practical solution for wheelchair users. The prototype already has most of the requirements of a finished product and can be presented as a strong proof of concept. There is a lot of potential for this product to enter the market and be helpful in eliminating pressure sores and tipping accidents.

We plan to attend the Solutions Exhibition at GF strong and meet potential buyers of our product. Ian Denison, physiotherapist at GF Strong, is quite happy with our design and will introduce us to people who might be interested in marketing this product.

Our recommendation to other groups is to believe in their ideas and insist on implementing them. The ideal prototype in our opinion is the one which best represents every team member's contribution.