Sense Solutions
School of Engineering Science, Simon Fraser University
8888 University Drive, Burnaby, BC, V6A 1S6
ensc440-sensesolutions@sfu.ca

December 19th, 2010

Dr. Andrew Rawicz,
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6

RE: ENSC 440 Project Post Mortem for Cost Effective Braille Embosser

Dear Dr. Rawicz,

With passion and commitment, the four engineers in Sense Solutions are devoted to creating a practical, affordable Braille embosser for the visually impaired. Our product will give people a chance to own a personal Braille embosser at a minimum cost for everyday use. Please find the attached Post Mortem for a cost effective Braille embosser.

This document outlines the entire project: the current state of the device; deviations from our original design; future plans; budgetary and time constraints; and explains the difficulties encountered. In addition to this, the personal experiences of each group member for the semester are described as well.

Sense Solutions consists of four innovative and skilled engineers who have various valuable backgrounds. All of us feel obliged to apply our knowledge and experience to develop products that will not only be useful and competitive, but also will benefit the society as a whole. We are Brendan Fairs (CEO), Yiran Du (COO), Heedong Park (CFO) and Rio Li (CTO). If you have any questions or concerns, please feel free to contact us at ensc440-sensesolutions@sfu.ca, or myself directly at bmf2@sfu.ca.

Sincerely,

Brendan Fairs
Sense Solutions, Chief Executive Officer

Enclosure: Post Mortem for Cost Effective Braille Embosser

Elementium

Cost Effective Braille Embosser

POST MORTEM

Management Team:	Yiran Du Brendan Fairs Rio Li Heedong Park
Contact:	ensc440-sensesolutions@sfu.ca
Submitted To:	Dr. Andrew Rawicz - ENSC 440 Mr. Mike Sjoerdsma - ENSC 305 School of Engineering Science Simon Fraser University

Issued Date:	December 19, 2010
Revision:	1.0

Abstract

This document outlines the entire project: the current state of the device; deviations from our original design; future plans; budgetary and time constraints; and explains the difficulties encountered. In addition to this, the personal experiences of each group member for the semester are described as well.

In its current state, the *Elementium* is a functioning prototype that produces embossed Braille text from a user defined text file. The file is read by the client program, translated into the appropriate Braille binary representation, and sent to the embosser. The embosser feeds paper into the proper start location, and uses the binary code received from the PC to select the appropriate pins and embosses the surface. This process is repeated until the file is completed.

We deviated from our original design in that we had to change our embossing pins and press mechanism. This was due to experimental findings not producing the results expected, and thus having to revise our design.

In the future, we have many improvements to be made to both the mechanical and the software components in order to manufacture a reliable product, as the current device is only a prototype and not yet ready for production.

For our budget we were slightly over the original estimate, but this was mostly due to the high research and design costs involved in trying to get the exact technique for embossing worked out. However, our overall production parts cost was quite close to the original estimate.

Our time constraints were fairly accurate, except for having to extend the mechanical design process, and thus the testing a bit longer due to designs in the experimental phase not producing the results we wanted.

These sections are described in greater detail in this document, as well as the personal experiences written by the individual members of Sense Solutions.

Table of Contents

List of Figures

List of Tables

Glossary

DC	Direct Current
Grade I Braille	Braille conversion letter for letter - words spelled out entirely
GUI	Graphical User Interface
ICSP	In Circuit Serial Programming
MAC	Macintosh Computer (Linux, Unix, Apple OS)
PC	Personal Computer (Windows)
UART	Universal Asynchronous Receiver and Transmitter
USB	Universal Serial Bus

1.0 Introduction

Sense Solution's innovative *Elementium* is a practical, functional and cost-effective Braille embosser for the visually impaired. All four engineers in the corporate team have devoted a significant amount of energy in design and implementation. Although the final product has some minor differences compared to the original specification, it undoubtedly provides a means of developing a marketable embosser with further improvement.

2.0 Current State of Device

Elementium is able to translate text into Grade 1 Braille and emboss the contents onto paper. Users can input any text content they want to print into a text file and print them out. By pressing the print button on the provided software interface, *Elementium* will initialize and start printing Braille onto paper. The user can stop printing at any time by pressing the cancel button, and then *Elementium* will stop and dispense the paper out and reset to the initial state. *Elementium* is compatible with both PC and MAC and requires a USB connection and the household power supply to run.

Figure 1 shows the overview of the whole system with processing order from left to right. The translation software developed converts the text to digital binaries which will form a Braille Dots Matrix. Each line of the converted digital binaries will then be carried to the microcontroller via USB connection when user prompts the print command in the software application which accompanies the device and is installed on a PC. The microcontroller will then process the digital input and it will send electrical signals to corresponding actuators that will determine the embossing of the Braille dots on a paper. The microcontroller will also manage positioning of a paper during the printing process.

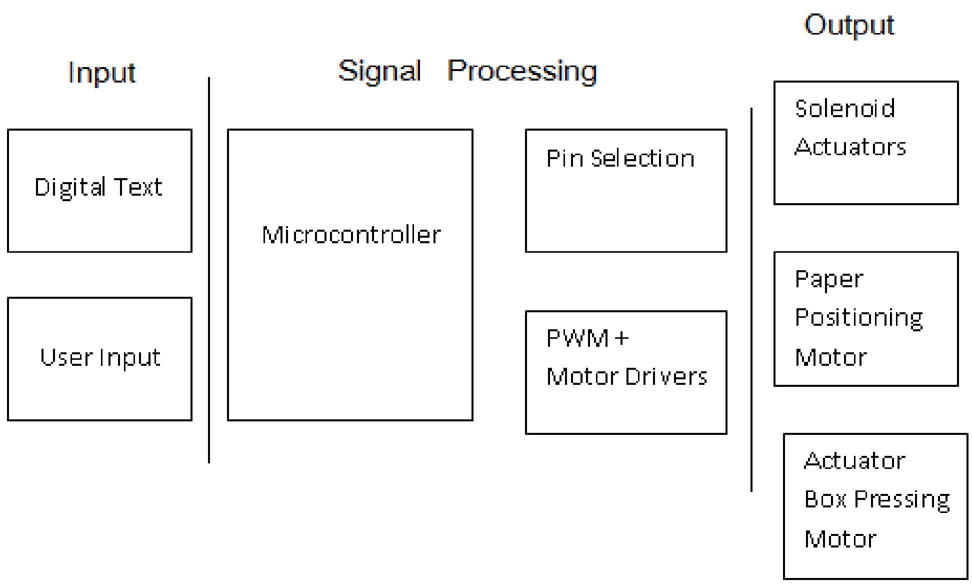


Figure 1: System Overview

There are several important parts of the system. The following content will present in detail their current status.

2.1 User Control

User can use the provided software to control *Elementium*. The software consists of three modules: communication; translation; and GUI. The user is free to save anything they would like to print into a text file. By specifying the file name in the GUI and pressing "print", the software will use the communication protocol we implemented to send the translated data to the microcontroller. The microcontroller will then generate corresponding signals to *Elementium* where the Braille text can be printed out. The user can cancel printing anytime by pressing "cancel" then *Elementium* will end embossing and roll the paper out. The user can also just stop printing by pressing "stop/resume". This way *Elementium* will hold up the printing process and by pressing the same button again it can go on finishing the remaining lines.

2.2 Microcontroller

Elementium is using the Arduino microcontroller board which interfaces with the Atmel ATMega microcontroller. It has 54 digital input/output pins (of which

14 can be used as pulse width modulated outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz internal clock, a USB connection, a power jack, an ICSP header, and a reset button.

The microcontroller intakes translated text and user commands, then sends corresponding signals to actuators to select pins and pulse width modulated signals to motors to position paper and press the actuation box, respectively.

2.3 Mechanical Parts

There are three mechanical components for *Elementium*: actuation of pins; positioning of paper; and embossing. The first part involves pin placement and movement.

2.3.1 Actuation of Pins

Elementium uses standard American Braille Dimension as a guideline, which is shown in Figure 2 below.

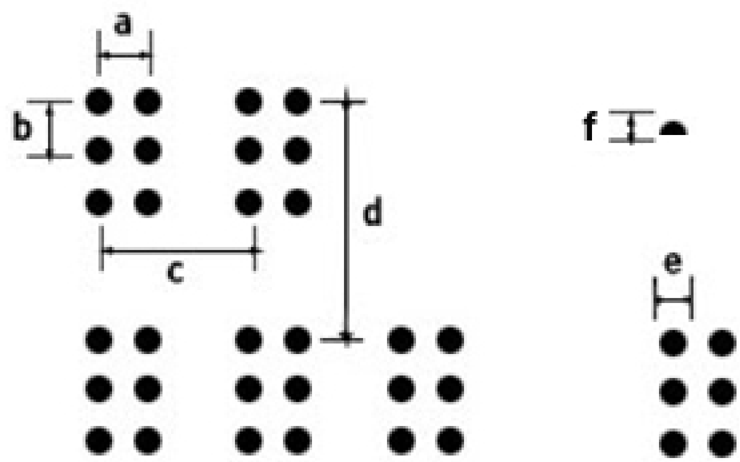


Figure 2: Standard Braille cell dimensions

The unit for the dimensions in the table below is mm. This is the standard from American Standard Sign, which is widely used in North America[1].

Horizontal dot to dot	Vertical dot to dot	Cell to cell	Line to line	Dot base diameter	Dot height
a	b	c	d	e	f
2.28	2.28	6.09	10.16	1.5	0.5

Table 1: Size of standard Braille cell dimensions

We used ball point pen heads as pins to emboss the paper. These pen heads have a hemispherical shaped tip which is ideal to make dots according to the standard. Also, there is an indentation between the metal tip and the plastic body, which makes it convenient to control their position. Last but not least, they are readily available and easy to cut. *Elementium* actuates the emboss pins using the solenoids indirectly. The emboss pins that are corresponding to each Braille dot in a line are placed in a plastic case shaped with an indentation in vertical direction. Figure 3 illustrates the position of various parts. When the tail of the emboss pin does get fixed by the actuation of the solenoid plunger in horizontal direction, the emboss pin will also be fixed in position. Then, when the emboss pin is pressed against paper, the paper will be embossed. Otherwise, when the emboss pin does not get fixed by the actuation of the solenoid plunger in horizontal direction, the emboss pin will be displaced from the default position when the emboss pin is pressed against paper, thus it will not emboss.

According to the standard, the letter sized paper can display 20 characters (40 dots) each line. *Elementium* embosses 40 dots on each line and each character line is finished after three embosses. The solenoids are configured by the microcontroller for each embossing. If there is a dot, the corresponding solenoid is activated, thus blocking the pin from moving. Else the solenoid will not move. Each plunger can return to its default position pushed by a returning spring inside the solenoid. There is a shallow notch right under each pin on the emboss surface which helps improve the quality of embossing.

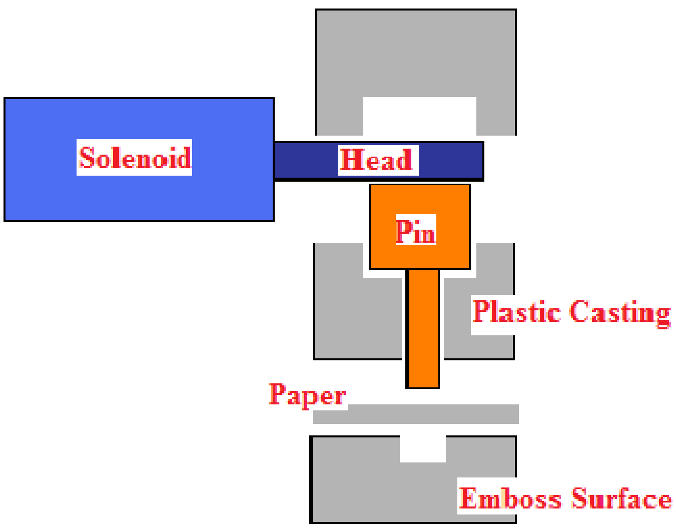


Figure 3: Graphical concept representation of the embossing unit in side view

2.3.2 Positioning of Paper

The paper positioning system is consisted of a DC motor, a series of gears to control the movement of paper and paper guidance part. We obtained the first two parts from an obsolete printer for this mechanism since they are easy to control and can provide high precision. The DC motor consumes more current than the maximum the microcontroller can provide, so we built a motor driver to supply extra current. The direction and time of motor movement are determined by experimenting and verified by multiple tests. The paper is moved to the position where the first line should be printed when initialized. After embossing the first line, the paper is moved by the distance of "b" in Figure 2 and then moves same amount to complete a character line. If there is another line to print, the *Elementium* will repeat the above steps, otherwise it will roll the paper out. Due to the length limit of the structure of pins, we had to raise the embossing surface higher than the original position of the paper. Several wheels with tiny teeth are also built to lift the paper onto the embossing surface and an aluminum metal sheet is placed to guide the paper back to the way out of the embosser.

2.3.3 Embossing

After pins are selected by the microcontroller and a piece of paper is moved to the right position, the embossing is done by pressing the actuation box against the embossing surface. We implemented the mechanism by fixing a DC motor onto the embosser right above the actuation box and pressing down vertically. Figure 4 shows the position of the motor and corresponding gears.

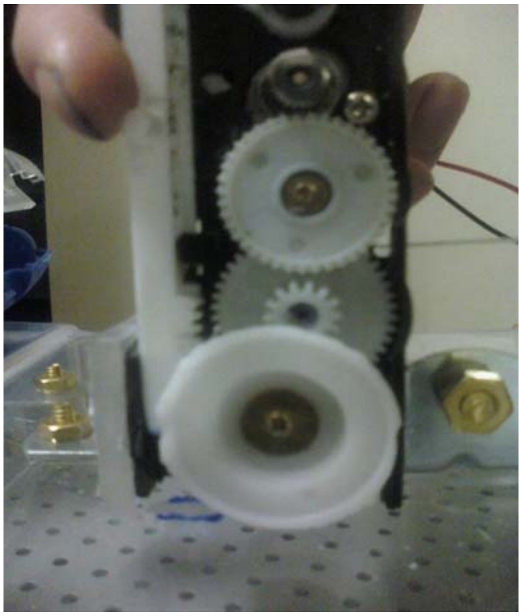


Figure 4: DC motor drives the gear network and linear motion moves the actuation enclosure vertically

The motor is driven by the same motor driver as the paper positioning motor. It turned out that the current required to provide enough torque was about 2 amps, which was far more than that the microcontroller could give. This torque is essential in embossing in that it is the key whether the pins can emboss marks on the paper. If the torque is not big enough, the dot will be very shallow and it can be easily pressed back. We obtained the gears from an obsolete CD disk drive which can convert rotational motion of the motor into linear motion of the side bar, which can be directly used to push the actuation box at a pre-calculated position. The spot of pushing is also carefully selected such that all 40 pins will fall into the corresponding notches without tilt to give maximum pressing force. The side bar can return to its default upper position by rotating the motor in the opposite direction, this way the actuation box will also return to the default upper position pushed by springs on the four guidance rods.

3.0 Deviation of the Device

This section will discuss how we deviated from our original design plans.

3.1 Overall System

We have used an obsolete printer parts to retrofit and accommodate parts that require high precision to build, which made us unable to build them. Also, a few mechanisms of modules have been modified to meet requirements that we assumed initially that they can be met with prior proposals for the mechanisms. We also used a part that was not part of our initial list, but later found to be needed to meet the requirements.

3.2 Mechanical Actuation of Pins

Initially, we proposed to use electromagnet and magnet or actuators to emboss on a paper directly. However, they all cannot produce enough force to emboss on a paper directly. Therefore we changed the idea and used the actuators in horizontal direction and their plunger to limit the vertical movement of the corresponding pins when selected. In this way, paper can be embossed with small current supplied to each actuator and meets all the mechanical requirements presented in functional specification document.

3.3 Mechanical Press

Initially, we proposed to lift the actuators enclosure in guided motion. However, it turns out that the motion using DC motors requires high torque, since the enclosure weight is quite large. Hence, we revised the idea to a push down motion using bars as guides and spring to return it to the default position and a DC motor with rack gear to push the enclosure down. When the DC motor releases the rack gear, it will push up by the spring return force.

4.0 Future Plans

In order for the current Braille printer prototype to become more acceptable and reliable device with market potential, many improvements must be considered. There are a few areas that we would concentrate on, and others that were suggested by the course instructors during the final presentation.

4.1 Reliability

The mechanisms we presented are built on such a small scale; the reliability of the device is that much depends on precision of production with consistency. Therefore, methods of manufacturing consistent mechanical parts used in the project must be investigated to ensure that all parts function reliably as expected. We will also be constantly researching new methods and materials for the Braille Embossing as technology improves and reduces in cost to become more suitable for integration into our device that is committed to be economic.

4.1.1 Embossing Pins

We could not meet the standard American Braille scale with the pins used in current design. We could not produce or obtain the exact size of the pins. To meet the standard American Braille scale, the pins should be produced with the size according to the scale. According to our design the pins have indentation (top cylinder + bottom cylinder) and it acts as constraint of the pin movement in the horizontal direction. We would prefer using the pins that have longer bottom cylinder and made of metal (heavier), so they have some weight. The main reason for the above suggestions is that they make the pins move more straight vertical path and reset to default position when the plate with indented holes where pins placed lifted up.

4.1.2 Integration of Pins and Actuators

We used cheap miniature solenoids as actuators for the selection of pins. We placed them in a way such that their plunger actuates in the horizontal direction to limit the movement of the emboss pins. The size of the solenoids are large compared to the Braille dots alignment based on the standard American Braille scale, hence we could not place each solenoids by side, but instead we placed them in two stages. We can overcome the size limitation of the solenoids by producing custom solenoids and plungers that fit to the size constraints and still has enough strength to move the plunger into the desired position.

Among many difficulties we encountered during this project, increasing the precision of mechanical cutting and integration of the pins and actuators was the most difficult task. Later we realized that the precision is the most critical factor of success to our design and it can only be achieved with help of machine tools that has accuracy in small scale. Like professors suggested the whole actuation structure may built through a plastic molding process.

4.1.3 Paper Feed and Paper Positioning Mechanism

We used parts from an obsolete printer for the paper feed and paper positioning mechanism along with electronics that controls the parts. We plan to use the same or similar structure, but choose the most cost and space efficient printer parts that are already sold in market. We have no other suggestions for improvement in this, since they are proven working and used in current inkjet based printers.

4.1.4 Press Mechanism & Guide

We currently used rack gear and DC motor combination to provide a press motion of the actuator enclosure. Bars with springs to return the enclosure to the default position used as a guide for the press motion. As for now, we think the rack gear with DC motor is the most economical way to achieve the mechanism. So far, we researched other methods, but no other method can satisfy the force requirement other than high torque DC motor with gear network. We think we can improve the design by using 4 of them to press the actuators enclosure in a uniform manner. We also think the guide bars can be replaced by cylinders with return force that is attached with the enclosure and the printer shall improve in accuracy and reliability.

4.2 User Interface

We implemented buttons that help users to have more degree of control. They can perform cancellation of print, stop and resume of print. However, some current Braille printers in market have sound assist systems that tell user about system status or respond upon pressing buttons. We plan to scale the final cost of the device having the system and if it can be done with a small price increase, we may implement the feature for better user experience.

4.3 Software

We implemented three modules for the software that will be accompanied with the device. It will be packaged with platform specific installers and when it is installed, it will be displayed as graphical user interface. We can improve the software for the user to paste the digital text directly on the user interface or drag and drop the text file or browse the text file that they wish to emboss. Also we think implementing the sound feedback system responsive to the user interaction in the user interface will increase better user experience.

5.0 Budgetary and Time Constraints

This section will discuss our overall budget and timeline for the project.

5.1 Timeline

Our Gantt chart was created at the beginning of the semester and served as a good guideline as to when things should be done to finish on time, However, there were several design problems that were encountered that caused several deviations from the proposed timeline. A change in mechanical design for the pins and actuators integrations and also we had to integrate them repeatedly to improve precision of the mechanical system. We could finish the software and electronics design and implementation early, but the mechanical implementation took longer than what we expected. The final testing of the device proved to be very challenging because we wanted to achieve consistent and accurate embossing. Having manufactured 40 pins and measured and cut the enclosure box with a hand drill, there is a lot of inconsistency and imprecise results, therefore many issues arise to solve the consistency of correct pin embossing.

We could not do an actual potential user test due to unexpected delay in producing process.

The updated Gantt chart is included in Appendix A, with the red lines representing changes in the timeline.

5.2 Budget

We were very fortunate to have several components already available at hand. We initially estimated the budget, but later we had to spend more than the expected amount. The breakdown of our budget is presented in Appendix B.

6.0 Personal Experiences

6.1 Yiran Du

The past four months were challenging but rewarding. I am very grateful to work with such innovative and diligent engineers in Sense Solutions, who made the whole design and implementation process exceptionally valuable. To deliver a final marketable product from scratch is no way an easy task, but we did it! Well done!

Our project was highly sophisticated in both design and realization, which exceeded my initial expectation. I learned a lot of technical skills such as programming and mechanical design. I also gained much experience in decomposing a big task into smaller and smaller modules such that we can finish them in one or two days, which is key to keep the whole process on schedule. The project was mechanically intensive which I didn't have much knowledge in beforehand, but I learned a lot of hands-on experience working together with Brendan and Heedong. I also accumulated extensive experience on modification and optimization of solutions based on the resources available. We built the embosser by making use of an obsolete printer and redesigned and added some parts, so it can be fully functional in such short period of time.

Of course there were hard times. The high precision of our project kept us revising and building parts repeatedly. Some parts of the original plan didn't work out, such as the pin design which is critical for embossing. We analyzed the problem carefully and brainstormed many ideas to figure out the solution. Fortunately, we found the ball point pen heads met all the requirements. This greatly improved the reliability and functionality of our product.

All the members were very corporative, supportive and hard working. We delegated our best to this project and successfully completed all the tasks. I am really proud of what we have achieved.

6.2 Brendan Fairs

This was definitely the most difficult, yet rewarding project I've worked on to date. It provided an opportunity to develop pretty much anything feasible that we could imagine. After much brainstorming even before the semester began, we decided to develop a cost effective Braille Embosser; a project that has taught me a lot.

To start out with, we knew and were warned that this was going to be a difficult project, since it was heavily mechanical and we had no real training in that area. Having the most experience with power tools, I took initiative of building most of the mechanical components with input from my other group members, and help from Heedong. It took many brainstorms, prototypes, and experiments to finally come up with a design that worked.

Even after building each of the parts and ensuring that they all worked individually, it was extremely difficult to bring them all together into one working product. Due to the high precision involved in a machine like this, it took a lot of fine tuning and refining to get things to a workable state.

This project has taught me a lot about the engineering design process, splitting tasks amongst group members, getting things done on a tight deadline and budget, software, hardware and mechanical engineering. I'm glad we decided to pursue such a difficult and unique project, and that I had such a great group to do it with.

6.3 Rio Li

For me, the purpose of this project was mostly for learning. The most valuable lesson I learned in building the Braille printer is that I, along with my team members are capable of successfully completing such a project. At the beginning of the semester I had only bits and pieces of knowledge collected in each of the courses I have taken, this capstone project has allowed me to put everything together in a real engineering project. Thanks to all my team members, we had an enjoyable and memorable time in the lab.

My main responsibility of some part of programming and making the GUI form. At first, I was kind of behind schedule as I had to learn the Arduino and Netbeans IDE software and the use of its Application and Programming functions. I spent many hours browsing through examples and started programming.

Also, I was referred to part of the mechanical work. The mechanical design and building are challenged for me since I didn't have relative experience before. Although not smooth at first, I was delighted to see progress. After countless hours of working with all my teammates, I was able to successfully gain some mechanical skills.

In addition to the technical achievements, I gained more valuable skills on how to work in a team. I realized the importance of listening to my team members and asking for help when help is needed. The weekly meetings gave us the chance to discuss what everyone has been up to and what is to be done. I am happy to say that we build up very good friendship during this project. Last, I just want to say thank you to all my teammates and the people who give help in our project.

6.4 Heedong Park

It was the most challenging semester for me but also the most rewarding of my entire student experience. I also realized how hard to apply an idea to make in a real world application. I started to admire the hardship and effort of those who do research for better of mankind. I participated in all the parts of this project and some parts were very challenging, since I had no prior experience in the areas. However, I could work with joy and excited that I will soon start my career as an engineer who will try to solve real world problems and help people. I started this project with a small passion that it may be able to help the visually impaired people, especially those who cannot afford Braille education in third world. However, through the course I realized that it requires more than just a passion to develop such device that completes my wish. If I have chance in near future to start a career as a researcher in engineering, I want to try again in this topic as well.

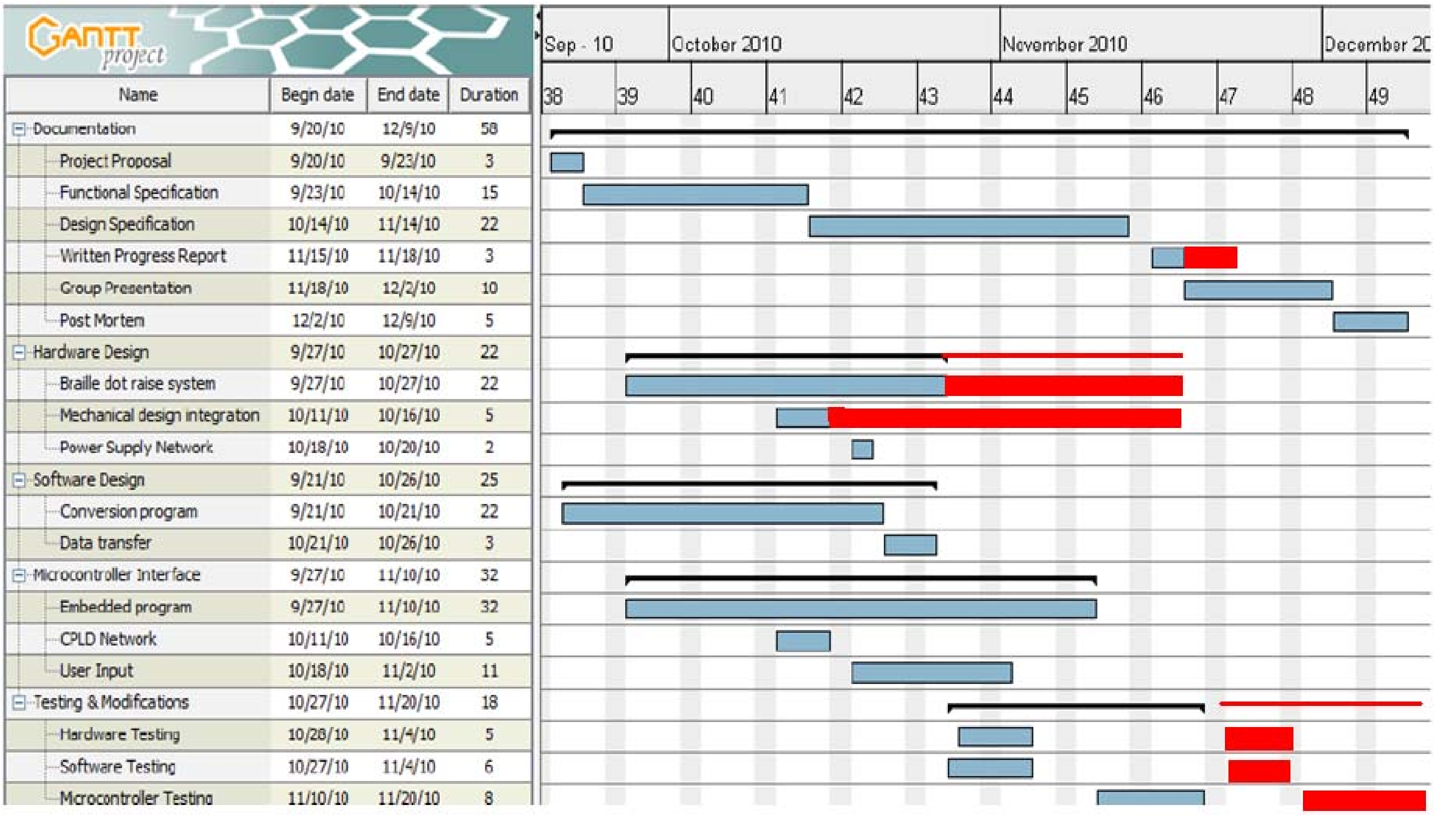
I really enjoyed working with Brendan, Yiran and Rio as group, and thank them for their effort in this project.

7.0 References

[1] Royal National Institute of the Blind Scientific Research Unit (SRU), 2009, "Braille Cell Dimensions." http://www.tiresias.org/research/reports/braille_cell.htm.

Appendix A

Timeline



Name	Begin date	End date	Duration
Documentation	9/20/10	12/9/10	58
Project Proposal	9/20/10	9/23/10	3
Functional Specification	9/23/10	10/14/10	15
Design Specification	10/14/10	11/14/10	22
Written Progress Report	11/15/10	11/18/10	3
Group Presentation	11/18/10	12/2/10	10
Post Mortem	12/2/10	12/9/10	5
Hardware Design	9/27/10	10/27/10	22
Braille dot raise system	9/27/10	10/27/10	22
Mechanical design integration	10/11/10	10/16/10	5
Power Supply Network	10/18/10	10/20/10	2
Software Design	9/21/10	10/26/10	25
Conversion program	9/21/10	10/21/10	22
Data transfer	10/21/10	10/26/10	3
Microcontroller Interface	9/27/10	11/10/10	32
Embedded program	9/27/10	11/10/10	32
CPLD Network	10/11/10	10/16/10	5
User Input	10/18/10	11/2/10	11
Testing & Modifcations	10/27/10	11/20/10	18
Hardware Testing	10/28/10	11/4/10	5
Software Testing	10/27/10	11/4/10	6
Microcontroller Testing	11/10/10	11/20/10	8

Appendix B

Cost Breakdown

Total Expected Expenditure: $400

Breakdown of Expenditure:

Item	Cost($)
R&D Costs	79.84
Actuators	109.1
Electronics	119.64
Structural Materials	160.51
General Supplies	32.2
Shipping	151.7
Total	652.99

Cost of Device Parts (bulk):

Item	Qty	Cost($)
Microcontroller	1	$64.95
Pins	40	$31.84
Switches	3	$3
Enclosure	1	$20
Motor Driver	1	$19.95
Solenoids	40	$70
Total		$209.74