Baby Guerrero Technologies

Post Mortem for the Smart Stroller Braking System

ENSC 440/305 Capstone Project

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1 INTRODUCTION

Over the course of the last four months, the Baby Guerrero Technologies team has brought to conception the first prototype of their design line up: The electronic brake stroller. The five members making up Baby Guerrero have worked countless hours to turn this concept into a reality and bring a new safety standard to parents everywhere. This report documents the progress of the project, and the various design variations and deviations that took place in building this endeavour from the ground up.

2 SYSTEM OVERVIEW AND CURRENT STATUS

What was once an amalgamation of bright ideas was soon made into a reality. Baby Guerrero's prized possession, the reversed automated braking system. The braking system has the following functionality: the stroller has been equipped with a tactile sensor to detect the driver’s grip on the handle of the stroller. This tactile sensor is not only discrete but very simple to use and work with. The tactile sensor detects the driver’s grip on the handle of the stroller and sends a signal to the microcontroller in charge of operating the braking motor. Upon receiving a touching signal, the microcontroller activates the motors to disengage the brakes. On the other hand, when the driver releases the handle, the tactile switch sends a signal to the microcontroller which in turn engages the brakes.

The braking mechanics of the system have been facilitated through the use of a DC motor, which provides the necessary amount of torque to safely stop the stroller. The stroller has been equipped with a bicycle braking system. In order to detect a full unlocking of the brakes, our system is equipped with a rotary potentiometer which provides the angular displacement feedback of the pulley as it turns towards a locking or unlocking of the brakes. By reading the position of the potentiometer via the microcontroller, we are able to obtain an accurate reading of the position of the motor which allows the system to stop the motors once the braking levers have been pressed or depressed to their optimal positions when braking or disengaging the brakes.

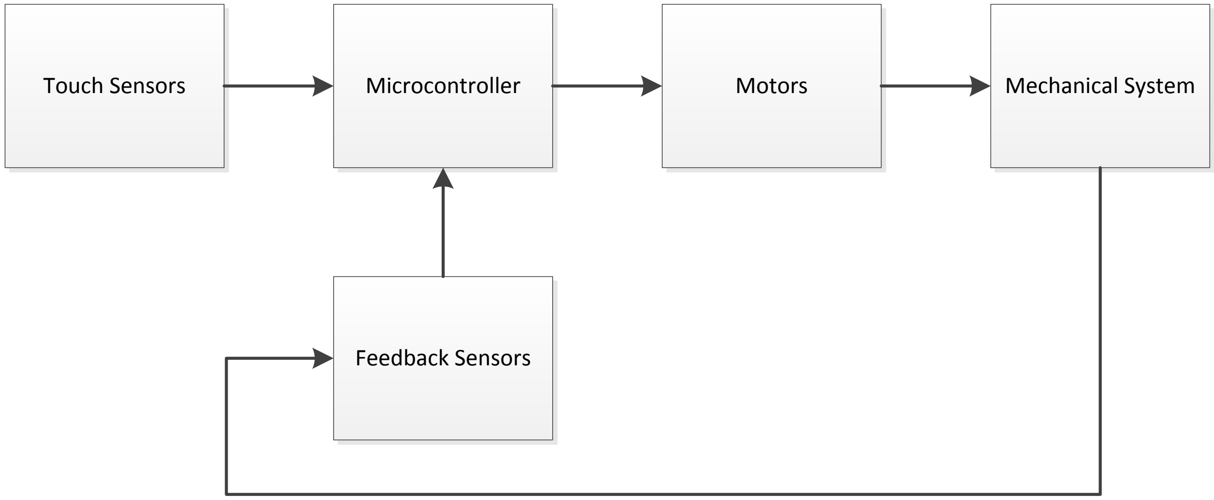

Figure 1: High Level Flow Chart

3 PROJECT CHALLENGES

This particular project was the personification of Murphy's Law. Everything that could possibly go wrong did go wrong. The project was very mechanically challenging due to the lack of mechanical depth possessed by the Baby Guerrero team. Due to the driven, ambitious individuals that make Baby Guerrero; it was a silent agreement that no task was too difficult, no problem was too hard and every obstacle came with a solution.

The first step in the production of the prototype was to mount the wooden base. Upon mounting the wooden base, we noted horizontal play along the axis of the shaft. To remedy this problem, we inserted wedges between the mounting brackets to decrease the freedom of movement with the metal mounting clamp and the shaft. Once the wooden base was mounted on and provided a rigid immovable foundation, we were able to successfully aligned the position of the brakes.

As a result of the brakes lacking chirality, both the brake calipers required custom mounting positions in order to optimize the brake pad's braking surface with the rim of the wheel. We remedied this problem by installing varied heights of wooden platform that correlated with the most optimized positions. Once the brakes were mounted we then needed to invent a way to mount the brake cables onto the pulley that is driven by the motor.

Soon we realized that in order to remain in our budget we had to purchase a worm gearbox that drastically increased the torque of the motor while maintaining the budget of the motor. Upon installation of the gearbox and the motor, an ideal pulley had to be purchased with a respective clamp hub that attached to the shaft of the motor.

The first prototype of the braking system involved leading the brake cables through an L bracket which attached itself directly to the pulley. At maximum torque that was amplified by the gearbox, we realized that we still couldn't provide enough torque to apply the braking force to meet our design specification. A decision was made to invest in a motor with a torque rating that was 5 times higher but also 5 times slower.

The new motor while it did provide adequate torque to brake properly did impose a very assertive presence on the worm gearbox. It was soon discovered that the plastic gear on the worm gearbox had worn itself down little by little due to the excessive torque from the system. It was worn down to a point where at the most optimized braking position, the gear would skip resulting in a non braked position. We first improved the system by reducing the torque needed to fully brake the system by installing brake levers. The mechanical advantage did reduce the torque load, but also consequently slowed the system down. The plastic gear still skipped at the point where the most amount of braking force was applied. Initially we contacted several companies to help us fashion the particular plastic gear. Some companies even quoted us upwards of $1000. Naturally we refused and kept looking for alternatives. We initially located a grad student at SFU that aided us in the usage of a laser cutter to cut gears out of acrylic. Concurrently a contact from BCIT returned our message and was able to cut the gear out of metal.

Once the metal gear was installed, we realized that the gear wasn't malleable enough to allow movement of the worm-drive. The motor shaft started to contort upon testing and the eventual decision was made to revert back to the plastic gear and hope that it would hold for the capstone presentation.

4 DESIGN DEVIATIONS

While the scope and purpose of the project remained the same throughout the prototyping, the implementation details of various aspects of the stroller varied as we dove deeper into the gritty details of implementation and integration. With regard to the function specifications we set out to meet at the beginning of the semester, we stayed true to the task at hand and met the large majority of our highest priority requirements. Unfortunately, due to timing constraints we were unable to complete the final enclosure for the mechanical and electronic system, as well as the mechanical override mechanism in case of power failures.

4.1 Touch Sensor Design

The touch sensing system has undergone some of the most drastic changes in implementation compared to the original design specifications. Originally, the VCNL3020 IR sensing IC was to be used for touch sensing. Plenty of research and preparation was performed in anticipation of the arrival of this part, including firmware prep. However, when the VCNL3020 chips arrived, we were quite surprised to find that the chips were not packed, making them very difficult, if not impossible for us to use in our design. Thus, due to our missing this detail in choosing and ordering parts, a new method for touch sensing had to be designed.

The next candidate for our touch sensing system was a simple capacitive sensor using the provided Arduino IDE libraries. Initially, the design worked well. We dedicated an Adafruit Trinket to handle the capacitive sensor, and communicating with the main microcontroller for rapid touch detection. However in the integration and testing stages, we found the capacitive touch sensing we set up was not suitable for this application. The capacitive sensor we designed was unable to detect human touch through gloves and clothing as we set out to do in the functional specifications. Furthermore, once the circuit was tested without a ground through the usb connection as had been done for previous tests, the capacitive sensing circuit became completely useless. Due to this mishap occurring shortly before our demo date, we decided to implement a very simple and basic tactile switch circuit to ensure we have a working circuit for the demo. After testing with this new sensing system, we were able to detect touch through gloves and clothing, meeting our original functional specifications.

4.2 Feedback Sensor System

In our original design, we planned to have a feedback system with wheel encoders, however as we entered the implementation phase, we found that given the limitations of our motor, no wheel encoder feedback was required for our design. Instead, what we required is feedback to detect a full lock or unlock of the brakes on the stroller wheels. We first tried to do this by using the built in encoder of the motor. However, we soon found out that we were unable to accurately keep track of the position of the motor due to the high frequency and low resolution of our microcontroller. Furthermore, the nature of the encoder output made it impossible to pinpoint the absolute position of the motor and brakes, as all movements recorded were relative to the initial position upon powering up.

To overcome this, we decided to use a linear potentiometer to track the position of the motor, and detect locking and unlocking of the stroller brakes. Attaching the rotary potentiometer to the worm drive required us to design a gear to mount on the rotary potentiometer, and attach to the worm drive. We were able to get access to the laser cutter at SFU where we our attaching gears came to life. The resulting setup allowed us to accurately track the position of the motor and the brakes, and ensure a full lock of the stroller brakes upon releasing the touch sensors.

5 SCHEDULE

In the completion of this project, we prepared a Gantt chart for us to follow to ensure we finish the project by the demo deadline. The Gantt chart is shown in figure xx. Despite our best efforts to meet all the deadlines we set on the original schedule, unforeseen deviations in the design and implementation of the system took their toll on our schedule, extending most of the time spent on the project specifications past their original deadlines. The revised Gantt chart showing the actual timeline of our progress is shown in figure xx.

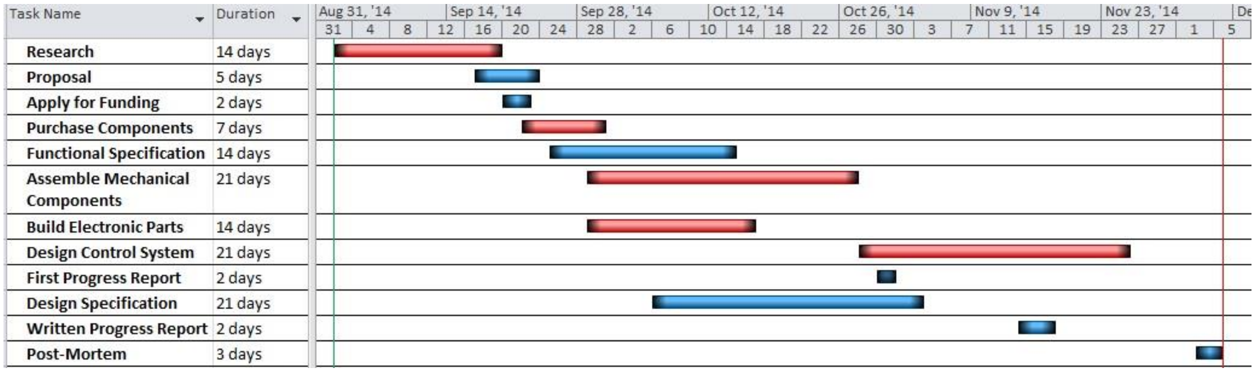

Figure 2: Original Planned Project Schedule

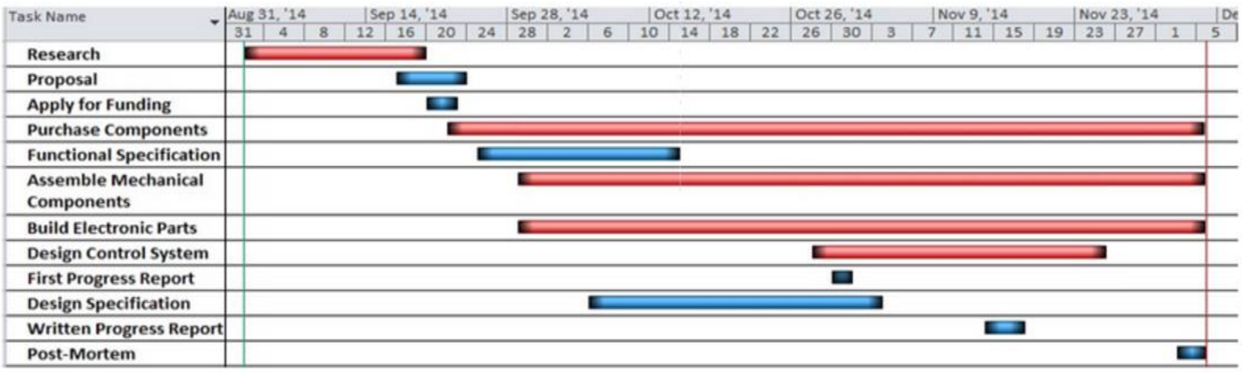

Figure 3: Actual Project Schedule

6 BUDGET

Our initial budget for this project at the time of the proposal was estimated to be $834.00. We obtained $450 via the ESSS student fund and we are hoping to recover some of the remaining budget via Wighton fund. Our budget was created to anticipate potential accidents which require replacing parts. In order to keep our stroller at an affordable price to the consumer and to reduce the cost of the proof of concept prototype, we have implemented different design choices. Table 1 lists the strategies we followed to reduce our cost to $502.

Table outlining the estimated cost of the components at the beginning of the project and the actual cost

Table 1: Table summarizing estimated and actual project cost

part	initial budget estimation	actual cost
stroller	250	60
brakes	120	22
gearbox	N/A	70
batteries	35	0
battery charger	40	25
motor	150	100
electronics	71	85
microcontroller	120	80
building material	48	60
Total	834	502

7 GROUP DYNAMICS AND WORKLOAD DISTRIBUTIONS

The biggest problem we faced as a group was the location of each of our team members. Two of our teammates were located in Surrey while the rest of us were located closer to SFU Burnaby. This proved to be a little challenging to work around. But other than this trivial issue of geography, we had an incredible amount of fun while completing tasks, overcoming obstacles and trouble shooting problems. All in all, we all agree that this was the enjoyable project that any of us had ever worked on.

7.1 Workload Distributions

Table 2: Workload Distribution Tablel

Task	Elyas	Houssam	Nick	Santiago	Majed
Documentation	xxx	xxx	xxx	xxx	xxx
Software Development	x	x	x	xxx	xx
Software Debugging	x	xx	x	xxx	xx
Sensors and Electronics	x	xxx	x	xxx	xx
Mechanical System	xxx	xxx	xxx	x	xx
System Assembly and Soldering	xxx	xx	xxx	x	x
SolidWorks	x	x	x	xxx	x
Testing	xxx	xxx	xxx	xxx	xxx
Administrative Tasks	xxx	xxx	xxx	x	x

9 INDIVIDUAL REFLECTIONS

CEO - Elyas Siddiq

From the very get go, we knew this project was going to be an ambitious undertaking. Little did I know how ambitious it really was. I took the knowledge required for mechanical design for granted and it humbled me. I was exposed to machine tools required for wood and metal fabrication. Handled drills on a daily basis, sawed wood and expanded my knowledge in metal and wooden fasteners. The exposure to different type of actuators such as AC, solenoids, stepper, servo motors and the application of DC motor in the braking design really aided my understanding of actuators as I was taking a sensors and actuators course concurrently. In addition to the application of the motors, the various sensors we used during the implementation phase of the braking design facilitated my understanding of the course. I learnt about the importance of mechanical advantage and how it takes speed as the sacrificial parameter. The importance of correct material selection was made evidently clear throughout the project's lifetime.

The laser cutter was utilized to cut several gears that were used on the rotary potentiometer. This was the first time I was personally exposed to that particular tool. A modelling program called SolidWorks was used to design the gear. In order to design a gear, I had to grasp concepts about the parameters of gears such as pitch angle, high-low hole diameters etc. Then once these concepts were understood, the gear was taken to a grad student that helped us convert the SolidWorks file to a CorelDraw File and helped us bring our digital model to a reality.

A very important piece of information that I learned from this whole project was to treat the data sheet with a grain of salt. The plastic gear in the wormdrive was rated to handle much more torque than it did after we purchased it. It was a specialty piece of equipment and we couldn’t easily replace it. It handled a fraction of the torque it was rated to handle before it started to break down. Not only was the plastic gear at fault, but the screws and fasteners that was listed in the data sheet were also incorrect. After we had stripped the machine screws bare, we needed to order new machine screws. The data sheet revealed that they were 7mm M3 screws, but after we ordered them from Fastenal, we realized that they we needed 10mm M3 screws.

Along with all the newly acquired mechanical skills from designing the stroller, I also furthered my skills in networking and business exposure. When things went wrong and parts started to break down, we emailed several people one of which included a contact from BCIT. Our contact Brian, pointed us in the direction of Ernie Janzen whom helped us fabricate the gear out of steel. Even though the gear wasn't usable in our design due to its excessively sharp teeth, the help we received was deeply appreciated. We also acquired free materials from places such as Home Depot and Rona when we explained the undertaking of our project. In addition to honing my networking skills, we also had to acquire funds, and build rapport with people that could potentially help us in the near future. Capstone really opened my eyes to the world of entrepreneurship and as scary as it is, I am enticed by the challenges.

Baby Guerrero's braking system has been one of the most enlightening projects that I had ever embarked on. I was exposed to mechanical design that no course at SFU taught and I strongly believe that it made me a better engineer by the end of the project.

CTO - Houssam El-Hariri

One of my instructors once said: "You always underestimate the task, and overestimate yourself". I did not quite understand the meaning of this phrase until I experienced ENSC 305/440. Although this course was fraught with difficulties and challenges, it was educative and fun. After completing this course with some great group members, I gained a bounty of technical, business, and interpersonal experiences.

Perhaps the most important technical experience I gained from this project is mechanical knowledge. I learned about the different types of motors and actuators (e.g. DC, AC, servo, stepper, spring-loaded solenoids, linear, etc.). Specifically, I learned what the different types of motors are used for; their strengths and limitations; how they are controlled; and their pertinent specifications. I also learned about different types of gearing mechanisms (e.g. spur, bevel, planetary, worm, rack-and-pinion). Based on some difficulties we had with the built-in plastic gear of the worm drive and the necessary fasteners, I learned about the importance of choosing the suitable design and materials, even the smallest ones, in a timely manner.

I also gained some experience with electronics circuits, sensors, and microcontrollers. Because we had to choose a suitable tactile sensor for the handle, I researched the different kinds of sensors available (e.g. tactile switches, capacitive, IR, ultrasonic, inductive, force-sensitive, etc.). I especially learned about the challenges involved in using capacitive sensors (i.e. analog and digital algorithms, grounding issues, lack of sensitivity, isolation, etc.). I even went as far as designing and prototyping my own electronic circuit that quickly senses capacitive touch.

When it comes to business experience, this course was a reality check. I experienced the challenges involved in starting a company, including fund-raising, planning, organization, documentation, intellectual property, and material sourcing. I had previously underestimated the effort involved in starting a business, but now I know otherwise. Difficulties experienced in this course will not deter me from starting my business in the future, but will make me more aware and prepared when challenges arise.

There is still an ocean of experience I am lacking, but at least I got to take a short swim. I made many mistakes, but I have no regrets because this is the best way of learning. I gained much technical and business experience, but I also gained invaluable interpersonal experiences.

COO – Nick Holden

The biggest and most important thing that I have learned throughout this project is to not expect things to work on the first attempt. Even if the plan in your head seems flawless, there are always certain factors that were not considered in the design plan. Specifically regarding this project, mechanical design is no easy task. Even the simpler sounding tasks such as mounting components proved to be a challenge at times. Factors such as component materials temporarily derailed us a few times during this project.

Another thing I learned this semester is that the mechanical components you picture yourself needing, are not always as accessible as one would think. It is not as simple as just cruising down to Home Depot and picking up components that you feel would be sufficient for the job. They will most likely not have what you are looking for and you will be forced to compromise and choose something that will that in the end will prove to be insufficient. This wastes a lot of time.

Yet another thing I learned was to not trust the data sheet provided by suppliers. Specifically, the worm drive we ordered came with two mounting screws. After installing and removing them repeatedly numerous times, the screw heads became stripped. We consulted the provided data sheet which informed us that the screws supplied were 7mm long. This was not the case… and of course since no local supplier had any of the screws in stock, we had no other choice but to order some in. After a few days the screws came in and we were eager to install them and test our project. To our surprise the screws were too short and we were left order longer ones and wait another three days for them to arrive. All these incidents above add up to some serious wasted time and that is very costly when balancing 440 with your other classes.

On a more positive note, this semester taught me how all of these numerous difficulties encountered can be overcome with solid team. I feel honored and fortunate to have taken on this ambitious project with the fellow members of BGT. Even when things were looking grim, this team worked together to solve all of our issues and persevere. This quality in a team proved to be extremely valuable to raise morale when it was desperately needed.

CSO - Santiago Roche

The capstone project experience for me has been one filled with many lessons, challenges, as well as fun times working with a great team. Through the course of this semester, I had the opportunity to learn about various aspects of prototyping and group dynamics that I would not have had the chance to do otherwise.

As a member of this team, my previous experience in software development allowed me to work on the microcontroller programming aspect of the project, something I was quite interested in prior to starting the semester. As a result, I was able to dive in to the Arduino IDE and learn about developing firmware in preparation for our IR sensing chip, which although did not end up seeing its use in the project, proved to be a valuable learning experience for myself. Despite being in charge of integrating the mechanical and electronic systems via software, this project presented me with the opportunity to learn about much more than microcontrollers and programming, and that is one of the things I value the most about this experience. I learned about different types of motors, actuators and sensors, something I had never had the chance to study before. Because of the mechanical nature of the project, for better or for worse, I was forced to revisit physics concepts I had not considered since my first year physics courses. I was able to get hands on experience assembling mechanical components and working with new tools. The hardships faced in implementing electronic circuits in the real world gave me a new appreciation for the effort and attention to detail that goes into turning the “theory” I have learned in classes into the working products that I use every day.

Besides the technical aspects of this project, I found the experience in project planning and working in a team towards a common goal incredibly rewarding and a great learning experience. I was truly privileged to work with a group of such talented individuals, and it is due to this experience that I learned the importance of having a good work relationship and team dynamic in the workplace. At times, if it were not for the motivation and encouragement provided by the team, the various challenges faced during the course of the semester might have brought productivity to a halt. I learned to overestimate time requirements in implementation and integration, as time and time again the project provided friendly reminders that things will always go as planned, so allotting extra time for tasks is always a good idea.

In closing, I had a great time working on this project, collaborating with the rest of the BGT team and found the experience to be incredibly rewarding. Writing this reflection at the end of the semester, I have to admit that after seeing the potential for professional development as well as the amount of work that goes into this course, it is definitely one of the most valuable experiences of my undergraduate career in SFU engineering.

VP of Engineering- Majed Kawam

I was excited for this course because this is the first time we got to choose our own project and basically be in control of how the course will be heading. I joined a fantastic group, Elyas, Houssam, Nick, and Santiago. Some of them were good friends of mine even before the start of the semester and others I became good friends with during the semester. I realized that I was not the only one enthused about this semester because in our first few meetings, we kept coming up with many different creative ideas. To the point where we couldn't decide on an idea until a week before the proposal.

After we finally decided on the Smart Stroller Braking System, I was very excited about the project because it was my first real mechanical project throughout my engineering degree. However, going through the details of the design made the project seem really simple and will be done by mid-November. The moment we faced our first obstacle I realized that we all lacked mechanical experience and that having an overall design idea is not enough to complete our project.

At the end of the semester, after facing several different kinds of mechanical problems, I find myself more knowledgeable in mechanical design, dealing with motors and gears, and prototyping. Also it was fun having hands on experience in woodworking, drilling and building the body of the project, and integrate it with the electronic and software systems.
My team was a big factor in helping me improve my ability to work in a group. We had an amazing chemistry and each one of us had a good role in supporting one another at least once throughout the semester.

10 CONCLUSION AND FUTURE WORK

The men that make Baby Guerrero Technologies persevered through the hardship, faced each obstacle head on and as a result invented a brand new braking system for strollers that works. We have full faith that the new system will save lives and have a positive impact on stroller related incidents. The team melded together and solved problems. More importantly we have made lifelong friendships. Project Capstone surely has had a positive influence in our undergraduate engineering career.

Unfortunately, the members of Baby Guerrero Technologies will not be pursuing future work on the reverse electronic braking system. However, given the opportunity to continue work on the project, with an improved budget and design plan and perhaps more background in mechanical systems, future work would include developing a more robust brake to suit the stroller. Also a refining of the touch sensor and system enclosure would be completed to improve on the current state of the project.