April 22, 2016

Dr. Andrew Rawicz
School of Engineering Science
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Re: ENSC 440W Post Mortem for the Direct Interference System for Coordination Limitation by Amplified and Stimulated Emission of Radiation (DISCo LASER)

Dear Dr. Rawicz:

The following document, *Post Mortem for the Direct Interference System for Coordination Limitation by Amplified and Stimulated Emission of Radiation (DISCo LASER)*, outlines the process our team went through when designing and implementing our project for ENSC 440W. The goal of the project is to develop a nonlethal alternative to weapons used in war and minimize casualty count by utilizing light to temporarily blind enemies in an area.

The purpose of the post mortem is to detail the current state of the device, outline deviations from our original plans, and summarize our future plans for the device. In addition to this, we outline some of the budgetary and scheduling issues we encountered throughout the term, and explain the interpersonal and technical experience gained by each member from working on the project.

If you have any questions or concerns, please contact Fabio Bollinger at fbolling@sfu.ca.

Sincerely,

Ashley Francke, CEO
DISCo

Enclosure: *Post Mortem for the Direct Interference System for Coordination Limitation by Amplified and Stimulated Emission of Radiation (DISCo LASER)*

POST MORTEM

For the Direct Interference System for Coordination Limitation by Amplified and Stimulated Emission of Radiation (DISCo LASER)

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Executive Summary

The DISCo LASER presents a novel approach to non-lethal tactics for use in non-combat scenarios by the military, or other offensive squadrons. Its goal is to prevent unnecessary death through the deployment of non-lethal security tactics, where no effective products are currently available. The device is portable, and can be mounted onto mobile equipment such that soldier's hands can remain free. It behaves as a shield of light by targeting any individual's face with a powerful and nauseating beam of white light. Doing so is not harmful and causes no permanent damage, and as such can be used indiscriminately between enemy combatants and innocent civilians alike.

The design of the DISCo LASER is effectively a synthesis of 4 main units: Sensors, Processors, Motors, and Lights, which communicate between one another using a main circuit board with custom pins, designed in a modular fashion for easy assembly and disassembly. The sensor unit consists of a camera which provides images to the processing unit to detect faces. The coordinates of the faces are then converted into steps for the stepper motors, which make up the motor unit. The motor unit the moves the attached LED array, which is part of the lighting unit. The fire signal for the lighting unit comes from the processing unit, once it has been moved to the appropriate position, which is tracked through a signal sent from the motors to the processor.

By the end of the device's production, the team has developed the DISCo LASER to effectively take an image from the camera, detect faces, and convert the measured location of the faces into steps which are sent to the motors to rotate, and then aim and fire the LED array. The processing unit did not have the computational power to achieve the desired 6 frames per second which the team had initially hoped for, but instead operated at a single frame per second, which was deemed sufficient for proof-of-concept purposes. Through this, the DISCo team achieved the goal of a functional product, but not to the standard that had been initially set.

The DISCo team has decided to stop pursuing this product, as the costs to develop and pursue it further would be high, and the prediction of the market state is lower than was initially hoped. Currently, it appears that the main market for the DISCo LASER would be the military, particularly within the United States, but acquiring a large enough investment to penetrate this market seems unlikely. Further marketing opportunities that could be followed involve municipal security applications, such as within public areas, but due to the large costs to create a viable prototype, this option will not presently be pursued.

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Glossary

DISCo: Direct Interference System Corporation
DISCo LASER: Direct Interference System for Coordination Limitation by Amplified and Stimulated Emission of Radiation
LED: Light Emitting Diode
Processor: Hardware circuit which executes programs
Stepper Motor: Rotary actuator that allows for precise control of position, velocity, and acceleration via steps of movement

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1. Introduction and Background

Welcome to the future of security. Until now, violent and lethal tactics have been the only choice for soldiers to control crowds of enemies and civilians. Even during non-combat related missions, soldiers have had to be prepared for unpredictable firefights and risk their own lives, as well as the lives of innocent people. Unnecessary death of soldiers, civilians, and enemies has been inevitable. In an ideal world, soldiers would be able to carry out their missions while the potential enemies were completely incapacitated and unable to start violent firefights. Having the enemies incapacitated would not only keep the soldiers and civilians safe, but would also allow much more efficient use of the soldier’s skills, while reducing their payload.

The DISCo LASER is the vehicle with which soldiers will be brought into this future. Figure 1 is a basic preliminary design for the DISCo LASER prototype, which includes all of the functional features of the device. Fundamentally this device is a face-targeting non-lethal incapacitation turret. Traditionally, soldiers would use non-lethal weapons to incapacitate a small number of potential threats, which quickly becomes cumbersome and inefficient. The DISCo LASER provides soldiers with the ability to complete missions while reliably and non-lethally incapacitating all other enemies and civilians within visible range, drastically reducing the risk of death on the battlefield. This product works by using light to incapacitate an area of people using facial recognition for targeting, effectively creating a shield of light around a squadron, functioning to protect them across all areas of a battlefield as a safe, non-lethal, and autonomous weapon.

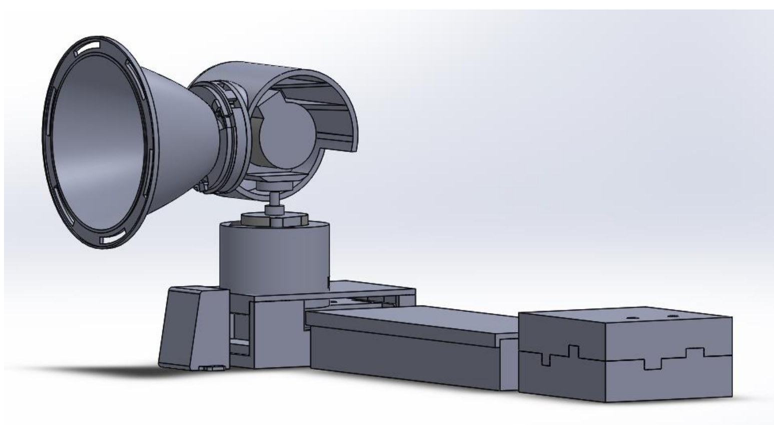

Figure 1 Basic Design of the DISCo LASER Prototype

2. System Overview

The DISCo LASER is composed of four functional units: processing, motor, lighting, and sensor. Figure 2 is a detailed box-diagram of the main circuit board, showing the connections between all components. The device is powered by two 24VDC power supplies: one used for the lighting unit and another used for the motor unit. Another 12VDC power source is used to power the op-amp portion of the lighting unit circuit, and a final 5VDC one is used to power the processing unit. The overall enclosure for these four units were 3D-printed and designed to meet requirements for operation in all temperature and weather conditions.

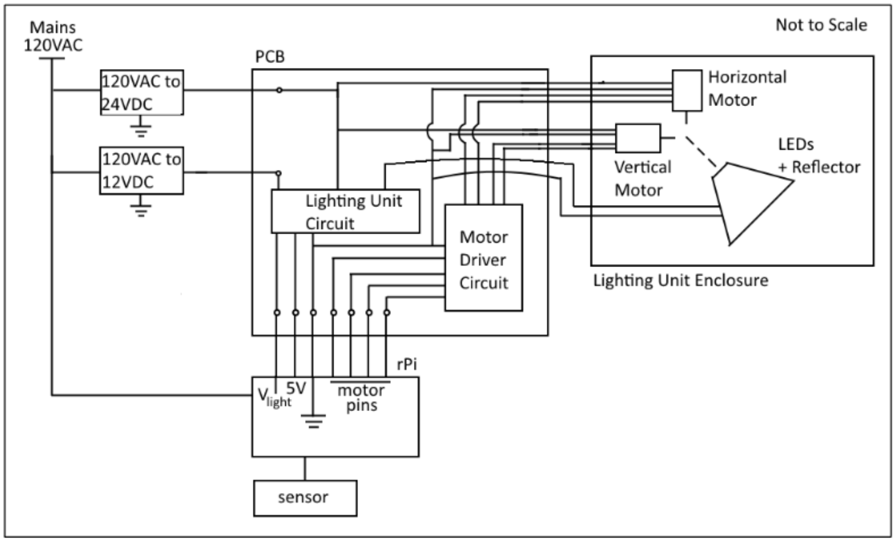

Figure 2: Block-diagram of the main circuit board of the DISCo LASER, showing the connections between all components.

The lighting unit is designed with a fuse for 750 mA to prevent the LEDs from being damaged from the high current draw. Ambient light was taken into consideration through the use of a photo-resistor to control the brightness of the LED array; it is unnecessary to have the LED array at a high level of brightness in a dark environment. The processing unit is made up of a Raspberry Pi, which features a quad-core processor to handle the image processing of the data acquired from the sensor unit. The sensor unit is a camera designed to work with the Raspberry Pi, which functions to film the environment while the Raspberry Pi processes the images. The acquired coordinates of faces within the images are then placed on a queue. When coordinates reach the top of the queue, they are taken and calculated into angular values which are then sent to the motor unit to control rotation of the lighting unit. Once the lighting unit has reached the required destination, the Raspberry Pi has a control pin designed to turn the LED array on and off.

2.1 Processing Unit

The processing unit is made up of a Raspberry Pi. The amount of available GPIO pins on the Raspberry Pi allowed the team to effectively control motor signals and the LED array. The Raspberry Pi's quad-core processor and 1GB of RAM allows the device to have greater efficiency for image processing and motor control. It features interfaces for the camera and was easily able to be programmed through a Linux-based operating system, which allowed for the importing of libraries such as OpenCV to be utilized for face detection.

2.2 Motor Unit

The motor unit is made up of two stepper motors powered by a motor driver circuit, which consists of two H-Bridge ICs, as shown in Figure 3. In order to move the lighting unit, the team created software to track the position of the stepper motors and send them the required steps via the processing unit to aim the attached LED array. This software was designed to utilize the offset of the motor from the camera to ensure correct targeting. The two stepper motors are used separately for horizontal and vertical rotation of the lighting unit, with each utilizing an individual control signal from the processing unit to make their movements independent. The stepper motors require 24V and 450 mA when moving at full speed, but pull a large amount of current while stationary, though not all of the current is required to be supplied when stationary. This variance in required current is due to the motor having a low internal resistance at DC, but having a higher impedance at higher frequency due to the inductance of the coils in the motors.

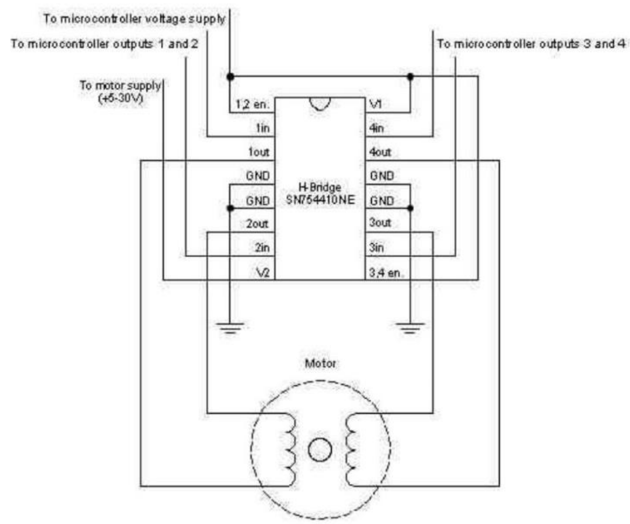

Figure 3: The motor unit circuit for the DISCo LASER [1].

2.3 Lighting Unit

The lighting unit was designed to ensure safety for individuals at the receiving end of the device. It was created to make sure the LED array would not cause blindness, but still be bright enough to deter any opposition from the target. The lighting unit consists of an LED array with an attached reflector to collimate the beam of light at the target. The circuit itself is shown in Figure 4. It consists of a control circuit to control the LED array brightness, with an attached photo-resistor to automatically adjust the brightness of the LED array for ambient lighting conditions. The LED array turns on when the control signal from the Raspberry Pi is sent from one of the GPIO pins.

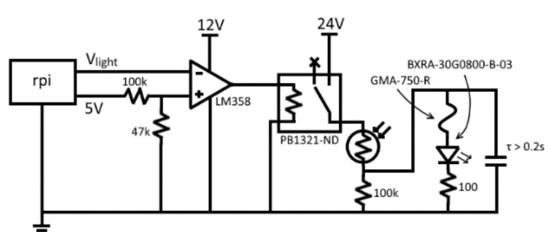

Figure 4: Lighting unit circuit for the DISCo LASER.

2.4 Sensor

The sensor unit consists of a camera designed to connect to the Raspberry Pi. The libraries and drivers to operate the camera came from sources online, and allow for a resolution of 1280x960. While these libraries did not allow the device to utilize the full 2592x1944 resolution of the camera, the 6.5-meter facial detection distance that it allowed for was deemed adequate by the team for the proof-of-concept prototype. The camera is attached directly to the device enclosure to allow for motor rotation target calculation.

3. Finances

The funding for the DISCo LASER came from ESSEF, the Engineering Student Society Endowment Fund, and was set as the ceiling of the project's final budget. Due to the purchase of additional miscellaneous electronic and enclosure components, the project was forced to go over budget. The team plans to make up for the difference through an application to the Wighton Fund. The initial budget for the DISCo LASER is given in Table 1. Within the initial design, the team had planned to utilize two infrared cameras, multi-coloured laser pointers, an Arduino microcontroller, and associated Arduino DC motors for movement.

Equipment List	Estimated Unit Cost
Arduino and Accessories	$128.99
Infrared Camera (2)	$352.65
Multi-colour Laser Pointer (2)	$30.42
Reflector	$48.65
Arduino Small DC Motor (2)	$40.00
Misc. Electronics (resistors, switches, etc)	$75.00
Outer Casing/Protection	$100
Total Taxes	$93.09
Total Shipping	$0.00
TOTAL COST	$868.80

Table 1: Initial budget for the DISCo LASER.

Due to the high price of the infrared cameras and the limited processing power of the Arduino microcontroller, the team decided to move to regular cameras for facial detection, with a Raspberry Pi 2 as a processor. In addition to this, the team decided to utilize stepper motors for the movement of the device rather than servo motors, due to a large price discrepancy. Finally, the team decided to utilize a white light LED array rather than multi-coloured laser pointers for safety reasons. The final project for the budget is outlined in Table 2.

Equipment List	Estimated Unit Cost
Raspberry Pi 2 and Accessories	$109.00
Raspberry Pi Camera and Enclosure	$42.98
LED Array	$11.16
Reflector	$38.68
Stepper Motor(s) and Motor Driver(s)	$137.84
Power Supplies	$56.43
Misc. Electronics (resistors, switches, etc)	$57.99
Enclosure and Mounting Supplies	$141.80
Total Taxes	$71.62
Total Shipping	$0.00
TOTAL COST	$668.49

Table 2: Final budget for the DISCo LASER.

4. Schedule

The original implementation schedule is given in Figure 5. Aside from the due dates of the required documentation, it provides the projected dates for the completion of the project's major milestones: the parts testing, turret implementation (motor and processor unit implementation), software development, hardware-software interfacing, test plans, and final prototype.

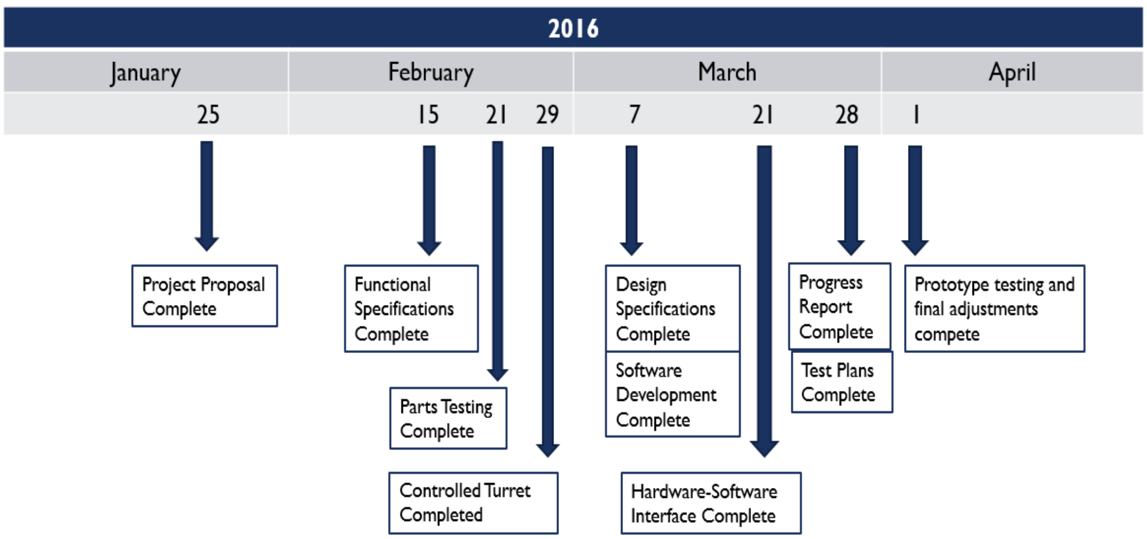

Figure 5: Initial implementation schedule of the DISCo LASER.

Due to some concept changes and decisions on materials, the team deviated from this schedule. The final implementation schedule of the project is given in Figure 6.

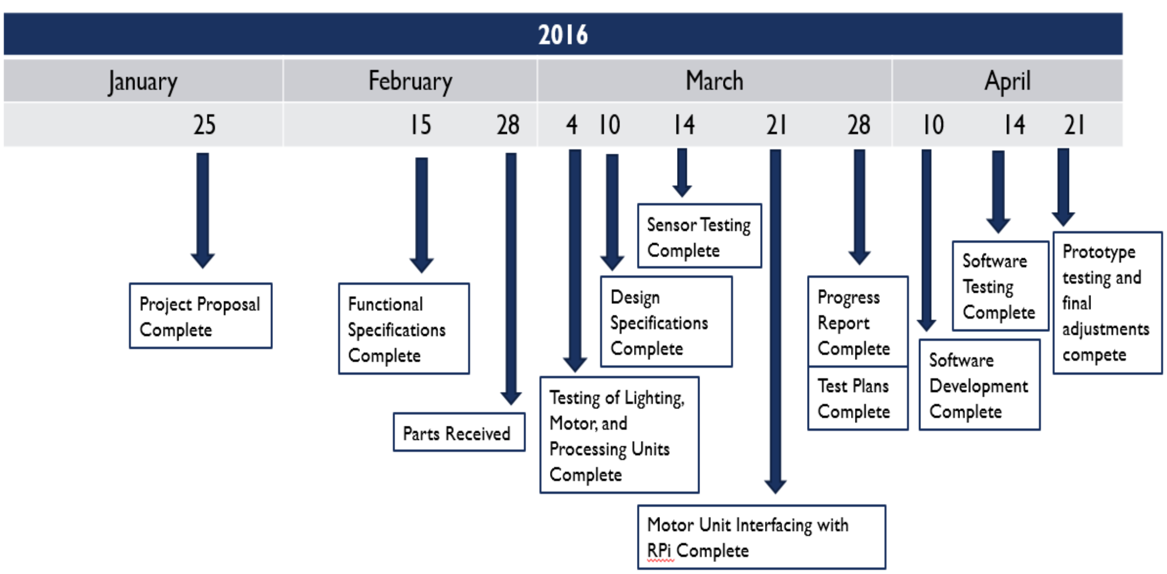

Figure 6: Final implementation schedule for the DISCo LASER.

5. Business Case

While wars might always be fought, the DISCo team aims to improve their outcomes. When military squadrons are focusing on completing missions, they must be prepared for spontaneous combat and enemy resistance. In these scenarios, the soldiers are put in danger, the likelihood of success of the mission is put at risk, and violence tends to escalate on both sides of the conflict. Currently, many non-lethal weapons exist, but they tend either tend to focus on halting only individuals or they risk permanent injury to the victims [2]. These weapons prove to be inefficient when dealing with crowds, especially when civilians and enemies are close together, and enemies are still capable of dealing lethal damage to the squadron [3]. It therefore might appear as though the most ideal solution would be to camouflage the squad and have them complete their missions without the enemies being able to see them. This would prevent conflict to some degree, and it would give the squad the ability to focus on the task at hand. Currently, the closest breakthrough of true invisibility only exists on a nanoscopic scale [4]. However, one interesting phenomena that has been "well documented" is one that renders a person blind, disoriented, and overall quite disoriented for several minutes [2]. Currently, this phenomenon is being applied by Homeland Security in the United States as a method for border control. The light which strikes the eye is so bright and overpowering that the intracranial pressure builds and the nervous system becomes confused [5]. The team at DISCo will be utilizing this technology in to allow squads in potential combat scenarios to easily blind and disorient anyone not in the squad, effectively rendering them invisible.

5.1 Market

The market for a non-lethal incapacitating device would consist of security and military applications. An example use case would be in the setting of a riot. The police would not need to worry about civilian or officer injury due to riot repellant (rubber) bullets or tear gas, and the device could be attached to a drone to easily subdue a riot before a large amount of damage is caused. Another example use case would be for bank security, where an armed robber is threatening customers and employees with weapons. The device could be deployed within the bank to safely stun people, including innocent bystanders, without lasting harm, and would allow for officers to make effective arrests. Our final example use case is within the military. The military setting would involve a drone equipped with the device to safely enter a city to subdue potentially violent crowds mixed with enemies and civilians. Through deploying the DISCo LASER rather than traditional methods, unnecessary death would be reduced by 100%.

As every government likes to invest in national and municipal security, our market will be quite large and will be based on the successful trials and demonstrations of our product [6]. The success will translate into many customers, as security is a concern across the globe, and will provide a nonlethal means for maintaining security.

5.2 Competition

The main sources of competition for the product will come from two stems: the already existing and widely used lethal weapons, and the developing nonlethal weapons, which are meant to stun opposition [2]. From the lethal side of things, there are the commonly known guns and explosives such as grenades or aerial strikes. But as previously stated, our device is meant to cut down on casualties, especially innocent people that are caught in the crossfire. The usage of lethal devices has already caused enough unnecessary death that our device will be easily welcomed in the market. On the non-lethal side, the DISCo LASER will be in competition with devices such as flash grenades, or the StunRay [4]. Flash grenades emit a bright light that fills the room and causes disorientation to anyone that did not shield their eyes. The StunRay is a device meant to stun enemies using light, much like the DISCo LASER. While their product is similar, it is designed to require manual triggering, unlike the autonomous nature of the DISCo LASER [7]. Due to this, it is predicted that the DISCo LASER will have minimal competition. The autonomous and non-lethal nature of the product will be the first of its kind and is bound to be successful on the market.

6. Problems and Challenges

The DISCo team has encountered and conquered many technical challenges in order to complete the major milestones of product development. The largest initial technical challenge was designing and implementing a circuit that could effectively interface with all of the device's components. This circuit was difficult because it involved interfacing high current and high voltage circuitry with low current and low voltage control circuits. To solve this, the team designed the circuit across multiple breadboards with multiple power supplies to isolate modules, then utilized electromechanical relays and higher powered components within these circuits to ensure effective operation. The sensitive nature of many of the components made this a tasking experience, with multiple iterations of circuits attempted until the final working design was decided upon. Within one of the later iterations, the team encountered issues with the stepper motors drawing more current than anticipated in certain circumstances. To account for this, the team initially attempted to increase the current from the single power supply, but this did not work, since the motor continued to draw all power supplied until it heated up dangerously. In order to solve this issue, the team decided to supply limited current to the motors, by using multiple power supplies.

Further technical issues were encountered within the interfacing of the camera with the Raspberry Pi. Since the camera was built for use on the Raspberry Pi, and was not USB-compatible, it did not have a standard driver and did not natively work with OpenCV. The team first attempted to create their own driver, but it quickly became complicated and ineffective. The next step attempted was to search for drivers online. The first driver attempted worked to interface the camera, but limited the resolution to 640x480. Finally, a working driver for the Raspberry Pi was discovered, which worked adequately, but limited the resolution again to 1280x960. Overall, this was decided to be the best option to implement the camera, so the team was never able to utilize the full 2594x1944 resolution of the camera.

In addition to technical challenges, the team encountered initial design issues which changed the scope of the device over time. Initially, it was desired to interface infrared cameras with actual cameras in order to both identify a heat signature and perform facial recognition, for maximum effectiveness. Due to time constraints in terms of interfacing and coding, as well as price constraints (due to the high cost of infrared cameras), it was decided that only a regular camera would be used in the proof-of-concept prototype.

7. Group Dynamics and Workload Distribution

The group was organized into two core teams: the programming team, and the mechanical design team. The focus of the programming team was to design a coding implementation that would allow for the interfacing of all components, process data for facial recognition, operate the motor unit, and control the lighting unit. In contrast, the focus of the mechanical design team was to design the main circuitry, as well as the 3D-printed enclosure. While the primary members of each team remained focused on the assigned tasks, the others became multi-disciplinary and helped with tasks on both teams. No issues were encountered between members of the teams throughout the term. Technical problems on either team were dealt with through full team meetings or separate group discussions, where additional members were moved around to help progression through difficult sections. The final workload distribution chart outlining major technical, administrative, and support tasks is given in Table 3.

High-Level Task	Jonathan	Shane	Fabio	Ashley	Mary
Motor Unit Circuit Design	xx	x			x
Motor Queue Programming	xx				
Motor Movement Programming	xx	x			
Lighting Unit Circuit Design			xx		x
Lighting Unit Assembly		x	xx	x	x
Processing Unit Setup	xx				
Face Tracking Programming	xx	x		x	
Face Locations Programming	x	xx	x		
Camera Interfacing	xx				
Modular and System Testing	x	x	x	xx	x
Enclosure Design		x	xx	x	x
Final System Assembly		x	xx	x	x
Parts Sourcing	x		x	xx	
Documentation	x	x	x	xx	x
Administrative Tasks	x	x	x	xx	x

Table 3: Workload distribution chart for the DISCo LASER project.

Where xx = primary responsibility; x = some responsibility

8. Conclusion

The DISCo LASER is a full security system for the next generation of safety. The prototype effectively interfaces the four independent sensor, processing, lighting, and motor units to target faces and shine a bright light to stun anyone caught in the line of fire. Through this project, the team was able write software and design circuitry to first identify faces, store their coordinates in a queue, then precisely control the lighting unit via stepper motors to target and fire collimated light at targets, rendering them stunned. As these were the goals of the proposed project, it is deemed a success.

This device has applications reaching much further than the military. Any situation in which a squad of officials needs to incapacitate a group of people is ideal for the DISCo LASER. These situations may include riots, bank heists, and police busts. In every situation, the incapacitation ensures that the number of victims of violence from either side of the conflict is significantly reduced. However, due to the limited processing power of the implemented control system, the Raspberry Pi, the device was forced to process images at a lower frame rate and resolution than originally intended. It is for this reason that this project is not viable to continue. In a use case such as a military scenario, higher resolution images and faster processing power would be required for effective deployment. In addition to this, it is predicted that due to the restricted market with Canada for military devices, it would be difficult for the team to obtain enough investment to realistically pursue the project further. It has been determined by the team that the main market would be focused towards the military, but they themselves have already invested in many military projects. Further, while our system could be used for security purposes, there are already a large number of security options available, which would make it difficult for the team to penetrate the market.

References

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Appendix 1 - Reflections on Learning

Mary

Capstone (ENSC 305W/440W) was a really great experience both technically and interpersonally for me. It challenged me to learn many new skills, including the usage of SolidWorks and documentation of specifications, as well as expanding some skills I did have, such as debugging with the multi-meter, getting information from datasheets, and interacting with other people in a group.

SolidWorks was really fun to learn as well as to use to model our enclosure. It was actually pretty easy to use once you understand the different planes and how to toggle between them and also how you can go back to different steps before. Fabio was a really great teacher and taught us all the basics which I used to model the motor and the lamp. In the end, the most difficult part of that would be measuring everything and making sure all the dimensions were correct.

There was a lot of documentation in this course and all of them demanded to be written in a different way in terms of style because of the difference in targeted audience and purpose for the papers. Some parts of the documentation involved learning new tools in Word such as the list of table and figures as well as the references, all of which helped when we had to put the different parts of the documentation together. I also had to learn to piece parts of a Milestone chart and a rough motor drawing together for some visuals in the documentation.

My teammates are really great! I learned many things from them both technical as well as random. They're always relaxed and laughing so it's really fun to be around them. I'm usually quiet around people and just watch and investigate on my own instead of trying to talk to others when I think of an idea but my teammates encourages me to voice my own opinions and concerns as well as not worrying too much about what others think.

In future projects, I would research more into the different electrical elements of the circuits before discussing them with my team members because I get lost too easily and my team members spend a lot of time trying to explain it to me. I would also look into how reliable the company we ordered the parts are for producing true non-lying datasheets.

Fabio

The very first day my team met to discuss the capstone project, I made an effort to ensure the environment was fun and productive between everyone. It was easy to do so because everyone else made the exact same effort. The result of such efforts was a new group of friends that would celebrate each other's successes and support each other during failures. The most important lesson anyone can take away from this is that trust is one of the most valuable traits.

I've always naturally been inclined to take leadership roles in groups, usually because of shyness or even blatant inaction of other members. Due to the scope of this project, I simply could not this time find myself in a dominant leadership role. I don't think anyone did. Very early on we decided to construct a modular device so that each person could effectively work separately, only concerned with the inputs and outputs of their parts. This forced me not be concerned with sections that were not my own. Since I focused mostly on the electronic circuit controlling the lighting unit, I had blind faith that my teammates would be able to activate it using the agreed upon input. It worked.

The modular aspect to the design was also a great technological academic achievement. In coursework we've only ever been concerned with either single, specific, arbitrary circuits, or abstract theoretical high-level systems. I, myself, have never taken a class that truly teaches designing full systems from the ground up. For example, the lighting circuit should have intuitively been as simple as a comparator circuit – when one input reads 'high' it outputs 'high' and powers the light. But when I was forced to consider the entire system: ambient lighting, changing power requirements, current limitations, and user control; the circuit became *much* more complicated. I had to apply knowledge from nearly all of my courses (even non-electronics courses) just to design my module with the system in mind.

Though I am extremely satisfied with this project, some of the most difficult parts came from the limitations of the prototyping equipment we were using. For one, a solderable prototyping board behaves much differently than a breadboard, and making changes to it was especially difficult. Diagnosing issues was also much more challenging because I did not have access to pins as on a breadboard. To remedy this in the future, I would like to use PCB manufacturing techniques, which eliminate the need for jumper wires, but take a nearly flawless design to properly work. I also gained experience with Solidworks and 3D printing at my previous co-op placement, but this project had mechanical structural components which had unknown material properties. It was a gamble to order the materials as late as we did, and I would definitely want to get that done as soon as possible. Finally, the only thing about the project I would change is the final connections between the modules – I would like to see them all have detachable connectors embedded into their enclosures instead of wires.

Jonathan

Through the capstone project course, for the first time, I was able to follow an engineering project through from the very beginning to the very end. It was an incredible experience being able to come up with an idea, turn it into verifiable requirements, and actually create it with minimal guidance from supervisors or professors. It was the first time that I felt like it was actually me making something, instead of just walking through steps that someone else made like we do in labs. The long hours spent alone with my work trying to make it work properly were so much more satisfying than simply asking the professor to help.

In terms of technical skills, I gained a lot through this project. I was forced to use CMake to compile the OpenCV libraries, and found that it is actually a much easier and better alternative to making your own Makefiles for compiling non-trivial projects. It was very awkward and difficult at the beginning, to the point where I had to perform a google search every time I wanted to write a line, but in the end I was able to use CMake freely to create complex build systems with multiple intermediate steps.

I also learned a lot about MS Word editing. I was the final editor for all of our documentation, so I was able to learn a lot of tools that are very useful for formal documents. In particular, I learned that you can automatically create lists of lists and lists of tables if you caption them properly and that you can create multiple sections each with a separate numbering scheme. Until seeing that requirement on the grading rubric, I had not needed to learn about that last function.

The other thing I learned that I will remember forever is to always, always read the data sheet carefully, but to never ever trust it. We had a data sheet for our stepper motors which listed the wires in different orders in different places, which resulted in our program giving the motors the wrong input sequence, costing us hours of work before catching the problem. On the same data sheet, there was a graph that said the maximum current pulled by the motors was 450mA, but at DC, the motors could pull up to 3A, which also caused an issue that cost us hours of work to figure out.

In terms of what I learned interpersonally, I learned that working in a group can actually be a positive experience. For the first at SFU, I had a group where every single person tried to pull their weight, and there was no negativity. Even when we blew up our second Raspberry Pi two days before the demo, we all just joked about it and worked to fix it. Nobody got mad at anyone, and we were able to fix everything in time. This group was definitely the best group project experience I have ever had.

One thing that we did poorly, myself included, was that we always started working late, which caused us to have some tight deadlines, mainly with documentation. If I were to do capstone again, I would start each portion of the project well ahead of time and try to stick to the schedules we made more closely, so that there is not that huge work load and many sleepless nights every time a due date comes around. Overall, I was very happy with this course, the product we made, and the group that I was able to make it with.

Shane

This project allowed me to visualize the steps of producing a product out of an idea or concept. The documentation assignments really taught me what we needed to consider when taking the idea off the page and into reality. This involved looking at standards and physical requirements of the components we desired to use and working within the constraints of these components. We really needed to look at data sheets in order to build circuits, especially when we were working with integrated circuits where we needed to know the pins.

One of the major contributions that I made was writing some code in C++ that was responsible for translating the co-ordinates of the faces detected in an image into steps for the stepper motors. With these steps, the motors would move the attached LED array and target the face, which was the goal of this project. It was a bit nervous taking this task on as I felt my skills may not be up to the ability but my project members pointed me in the right direction and I was able to do the calculations and program it with ease.

Another major contribution that I had made to this project involved mapping the schematics of our lighting and motor units onto a solderable breadboard. I did my best to make it easy to read by the other members by treating the breadboard as a grid and numbering the holes like a co-ordinate system. However, as our circuit got more complex, it did become more difficult to read the image that I had produced with all the wires jumping to various connections. Fortunately, my team members were able to read it and we were able to produce the circuit which looked much better in person. It was nice to see something that can be held when moments before it was just on paper.

I had other roles in helping with circuit construction as well as setting up and testing OpenCV, which was an open source library built for face detection. I found some sample code online which formed the base of our face detection code.

The technical skills that I have gained from this project included: increased programming skill, especially when working with others for code. The tool we used for programming collaboration was Git, which was a new experience for me. Also, experimenting with OpenCV was quite enjoyable.

My project group was full of fun people which made working on this project much easier. We spent long hours together and got along well with plenty of laughs. However, I did feel at a disadvantage amongst my peers. As I focused on my part, I did not try and learn other aspects as fully and felt I was at a technological disadvantage with my peers. If I was to do things differently, I would work hard on my portion of the work, but also keep track of what others is doing so that I can understand the bigger picture more fully and also be more useful for troubleshooting.

Ashley

Throughout the term, I was exposed to many new types of thinking, designing, and cooperative work. My time throughout the Capstone term was productive, and full of more learning and understanding than I had ever experienced in a single course. Unlike previous group projects that felt like a chore, the team at DISCo this term was nothing but pleasant to work with, and through our teamwork, we were able to master skills that seemed impossible when we first proposed them.

The DISCo LASER project was composed of many components that I had yet to be exposed to throughout my engineering degree. The first hurdle I had to overcome was designing and debugging my own circuits. Within the DISCo LASER project, we were forced to design our own circuits to interface motors, cameras, processors (Raspberry Pi), and even LED systems. We utilized and designed our own motor driver circuits with H-Bridges, experimented with separating voltages from power supplies with comparators, utilized photo-resistors and relays, and even blew up our own integrated circuit components (and had to debug the reasoning ourselves). Throughout this experience, I began to understand and become comfortable around circuits, and coming out of Capstone at this point, I feel confident that I will be able to design and create my own circuits in the future. In addition to this, I was also exposed details of mechanical design for the first time. As one of our teammates had had a previous co-op which involved creating testing enclosures and prototypes, he was able to teach us what he knew and guide us through the mechanical design process. I was able to help design our final enclosure through implementing our motor unit in Solidworks, and through this discovered how much I enjoyed making my own designs. This is another skill that I had wanted to learn in order to implement my own future 3D-printing projects, so I am ecstatic to have gotten the experience. Finally, having a computer engineer within our team helped teach me a lot in terms of computer programming and embedded systems. Using the Raspberry Pi system and OpenCV taught me how to interface with libraries and embedded systems to accomplish tasks more effectively than I previously thought possible. As OpenCV is a large system of many different libraries, knowing how to use it will help me in the future for further programming projects that I may come across.

Interpersonally, throughout the term I was continually impressed at the skills and quality of work put out by my group members. We worked together as a functional unit, and troubleshot tasks and issues as a team. We used Trello, and free online resource, as a project management website, and through that were always up-to-date with each other and on-task when things were due. Through my position as CEO, I gained a lot of experience in project management and delegation, as assigning teams and projects to tasks and assignments was a job I undertook throughout the term. I also learned the value of punctuality, a skill that I was not particularly good at previously. When I was working with a team that depended on each other, I realized how much being late can set back a group on a project. Overall, I feel that in future projects, I could improve upon my punctuality in terms of group meetings, in order to not be a burden on other group members. In addition to this, I feel that I could improve upon my timeliness in starting tasks. If I had not procrastinated in starting my portion of the coding, I could have learned more and worked more on other tasks, which would have not only helped others, but helped myself as well. Throughout this term, I feel that I grew as a person, and entered my first phase as a young professional. I am glad to have been given this experience and to have been exposed to such great teamwork and varied skills throughout the design experience.

Appendix 2 - Meeting Agendas and Minutes

December 29, 2015

Meeting Agenda: Project Brainstorm

Minutes:

- Initial Ideas:
    - Auto-injecting patch with needs (helps find veins, fluorescence)
    - Fall detection with cameras
    - Jolly jumper walker for rehabilitation
    - Sign language translator
    - Smart knee brace
    - Motorcycle ambulance stretcher
    - Nurse console unit for alarms
    - Hospital bed (bed to chair)
    - Blind glasses
    - Scan organs before surgery
    - Helmet mounted scanner for people
    - Stunner phaser laser (auto-aim gun)
    - Solar battery for winter power
    - No friendly fire guns
- Final cut:
    - Lasers
    - Nursing station
    - Auto needle
    - Ambulance motorcycle
    - Walker
    - Fall Detection
- Decision: Lasers

January 8, 2016

Meeting Agenda: Initial design meeting

Meeting Minutes:

- Idea: Non-lethal incapacitation turret
- Sensor: Infrared camera to find body heat and regular camera to find face and eyes
- Shape: Disco ball, turret shaped (like a gun?)
- Lighting: Use LEDs instead of lasers (we can't point lasers in eyes)

January 17, 2016

Meeting Agenda: ESSEF Proposal

Meeting Minutes:

- Proposal description: Fabio
  - Problem: Lethal force in the military causes unnecessary casualties of civilians (especially in crowded areas)
  - Solution: Provide a non-lethal alternative through the use of stun guns that utilize a specific frequency of light to induce nausea and disorientation (no lasting damage)
  - Automated turret that uses facial recognition to find targets
- Social/Educational Benefits: Ashley
  - Learn about microcontrollers/actuators with Arduinos
  - Programming and image processing skills
- Cost Breakdown: Mary and Shane
  - Actuators ($20) x 3
  - Arduino starter kit ($150)
  - IR Camera ($250) x 2
  - LED Pointer ($40) x 3
  - Misc. ($150)
  - Do we need actual cameras, too?
  - Total: $980
- Milestones:
  - Jan 19: Functional specifications
  - Feb 5: Parts order
  - Feb 15: Start code
  - Feb 29: Start prototype
  - Mar 7: Finish code
  - Mar 14: Interface IR
  - Mar 21: Test plan
  - Mar 28: Final design

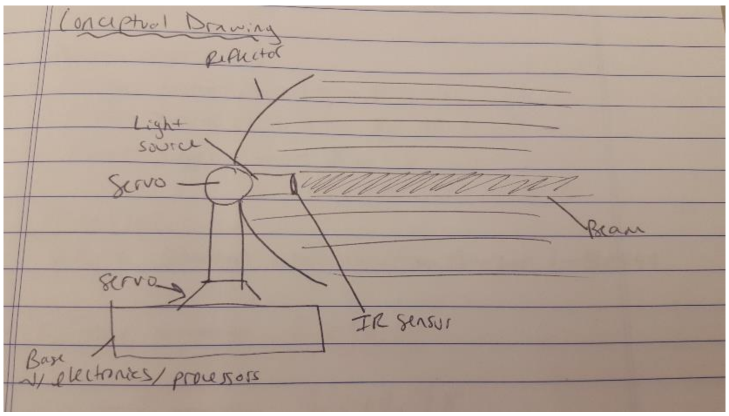
January 22, 2016

Meeting Agenda: Proposal

Meeting Minutes:

- Company name: DISCo
- Logo/company details: Fabio
- Breakdown:
  - Intro/BG: Fabio
  - Scope/Risks/Benefits: Ashley
  - Market/Competition/Research Rationale: Shane

- Company Details: Fabio
- Project Planning: Mary
- Cost Considerations: Mary
- Conclusion/References: Jon
- Editing: Jon

- Conceptual Drawing:
  - 

January 26, 2016

Meeting Agenda: Parts Research

Meeting Minutes:

- Arduino versus Raspberry Pi
  - Easier to use Bluetooth on RPi?
  - More power on RPi?
  - More code available for Arduino
- IR Camera
  - Seek Compact: $250
  - Crappy 16x4 IR Camera: $80
  - Lepton 80x60 module: $170 (has an RPi development kit)
- Motors:
  - 2 servo motors to actuate with each other

January 30, 2016

Meeting Agenda: Parts Order

Meeting Minutes:

- Ordering from Digikey
- Sensor Unit:
  - IR Camera: $283.38
  - IR Camera Breakout: $60.81
  - IR Camera Socket: $2.93

- RPi Camera Module (Amazon): $26.91
- RPi Camera Enclosure (Amazon): $15.99

- Lighting Unit:
  - LED Array: $11.16
  - Reflector: $38.68
- Motor Unit:
  - Stepper Motor (x2): $119.64
  - Motor Driver (x2): $10.80
  - Power Supply: $21.93
- Processor:
  - RPi2 Start Kit (Amazon): $109.99
- TOTAL: $696.90
- W/O IR TOTAL: $349.78

February 11, 2016

Meeting Agenda: Arduino vs Raspberry Pi

Meeting Minutes:

- Arduino Specs:
  - Voltage: 5V (operating)
  - IP Voltage: 7-12V (recommended)
  - Digital I/O Pins: 15
    - Analog IP Pins: 16
  - Flash Memory: 256 kb (8kb used by bootloader)
    - SRAM: 8kb
    - EEPROM: 4kb
- RPi2 Specs:
  - Broadcom Quad Core Processor
  - Ram: 1GB
  - 40 pin extended GPIO
  - 4x USB2 ports
  - CSI Camera Port for connecting RPi camera
- Conclusion: RPi is way better for our purposes

February 19, 2016

Meeting Agenda: Software Planning

Meeting Minutes:

- Don’t think that the Arduino can handle what we want to do with image processing
  - Should use RPi
- Temperature sensor for high temperature areas?

- For IR: we are looking at gradients, not just intensity
- For camera module: need to make sure it's an actual camera with a lens, not just a sensor
- LED array: only white light
    - Can filter individual wavelengths, but not a spectrum
    - So we can either swap between wavelengths or use a combination (white light)
- The total cost with the IR camera is starting to feel too high
    - Going to just go with a regular camera
    - Also worried about coding difficulty (trying to do too much?)

February 26, 2016

Meeting Agenda: Code Overview

Meeting Minutes:

- Code Overview: Sensor/Processor/Motor Unit
    1) Start
    2) Initialize sensors
    3) Initialize and calibrate motors
    4) Receive frame from camera
    5) Locate next face
    6) Send coordinates to motor unit
    7) Receive and queue all coordinates
    8) Read next coordinate
    9) Aim Lighting unit
    10) Send 'fire' signal to lighting unit
    11) Wait for pulse to complete
- Code Overview: Lighting unit
    1) Start
    2) Calculate ambient lighting intensity
    3) Wait for 'fire' signal (back to 2)
    4) Flash LEDs
    5) Wait for pulse to complete
    6) Back to 3

March 1, 2016

Meeting Minutes: Parts Received and Additional Parts Required

Meeting Minutes:

- Parts ordered and received:
    - RPi 2 + Accessories: $109.99
    - RPi2 Camera + Enclosure: $42.98
    - LED Array: $11.16

  - Reflector: $38.68
  - Stepper Motors: $119.64
  - Motor Drivers: $10.80
  - Motor Power Supply: $21.93
  - Taxes: $45.52
  - TOTAL: $400.70
  - Money Received from ESSEF: $513.00
  - Money Left: $113.00
- Additional parts required:
  - Fuse for lighting unit: $0.66
  - Fuse holder: $1.64
  - Relay for light circuit: $1.69
  - Power supply connector: $1.21
  - Female-male jumper cables for cleaner GPIO usage: $4.47
  - Solderable breadboard (don't think it's worth the cost to print our own PCB): $7.23
  - May need more, so not ordering quite yet

March 3, 2016

Meeting Agenda: Design Review

Meeting Minutes:

- Slide 1 – Logo
- Slide 2 – Intro/BG: Fabio
- Slide 3 – Projected implementation schedule: Mary
- Slide 4 – Actual implementation schedule: Mary
- Slide 5 – Projected Costs: Mary
- Slide 6 – Actual Costs: Mary
- Slide 7 – Sources of Funding: Ashley
- Slide 8 – Design Elements (System Overview): Jon
- Slide 9 – Design Elements (sensor, processor, motor flow chart): Jon
- Slide 10 – Design Elements (lighting flowchart): Shane
- Slide 11 – Design Elements (Risks): Shane
- Slide 12 – Design Elements (Considerations): Ashley
- Slide 13 – Progress: Fabio
- Slide 14 – Remediation: Ashley
- Slide 15 – Summary: Ashley

March 4, 2016

Meeting Agenda: Design Specifications

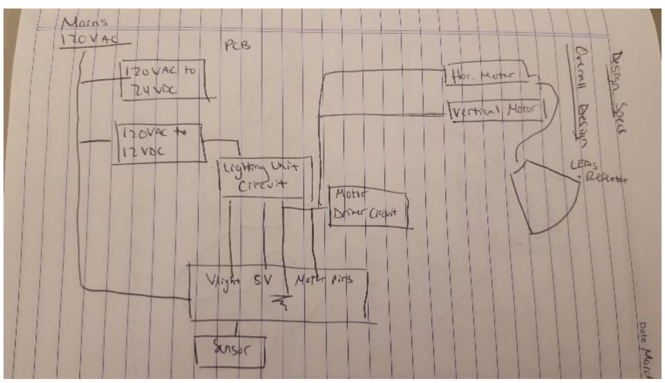
Meeting Minutes:

- Executive Summary: Fabio
- Intro: Fabio
- System Specs/Overall: Fabio
- Sensor Unit: Ashley
- Lighting Unit: Mary
- Motor Unit: Jon
- Processing Unit: Shane
- System Test Plan: Ashley
- Safety: Fabio
- Conclusion: Shane
- Editing: Jon

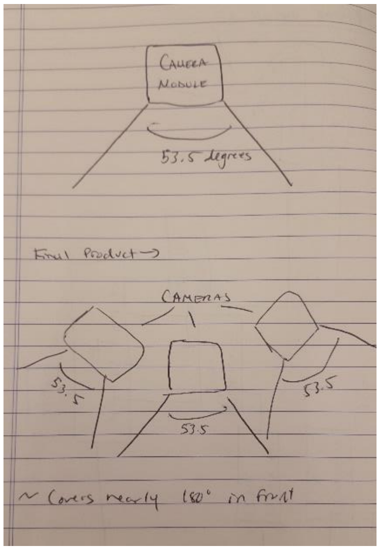
March 5, 2016

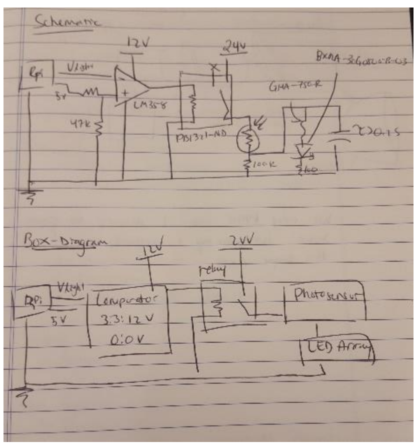
Meeting Agenda: Overall Design

Meeting Minutes:

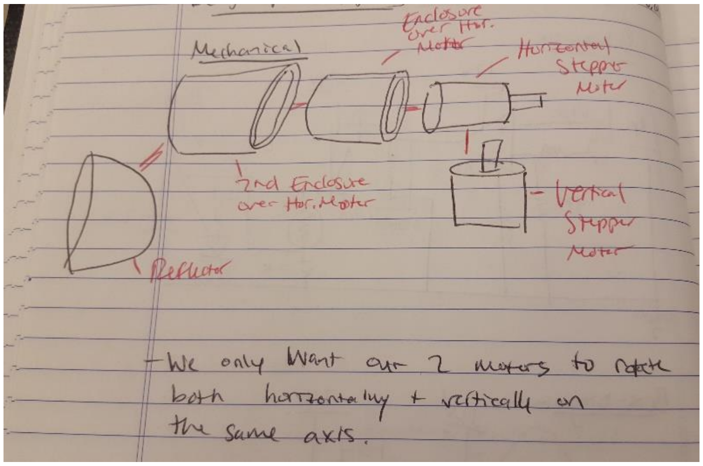
- Overall:
    - 

- Sensor:
    -

-
  - 

- Lighting:
  - 

- Lighting – Mechanical

- 

March 10, 2016

Meeting Agenda: Test Plan

Meeting Minutes:

- 1st stage: Unit validation testing
- Sensor unit testing:
  - Enable camera
  - Test image/video
  - Test image range
- Processor unit testing:
  - Processor activation
  - Sensor interfacing (+ motor/lighting)
- Lighting:
  - Activation
  - Output/Range
  - Robustness
  - Ambient light detection
- Motor:
  - Activation
- Full system:
  - Firing
  - Accuracy, range, multiple targets, selectivity, speed, environmental conditions
  - Intensity
  - Mechanical (base)

March 11, 2016

Meeting Agenda: Remaining Tasks

Meeting Minutes:

- Hook camera up to RPi: Jon
- Facial Recognition: Ashley
- Assemble full lighting circuit (solderable breadboard): Fabio & Mary
- Enclosure for lighting circuit: Fabio & Mary
- System base construction: Fabio
- Calculations for converting between pixel coordinates and angular coordinates: Shane
- Motor unit queue: Jon

March 14, 2016

Meeting Agenda: Second Digikey Order

Meeting Minutes:

- Solderable breadboard (x2)
- Fuse
- Fuse holder
- Relay for light circuit
- Power supply connector
- Female-male jumper cables for cleaner RPi GPIO usage (x2)
- Possible new power supply, so we don't get too close to maximum power capacity

March 16, 2016

Meeting Agenda: Raspberry Pi Setup

Meeting Minutes:

- Raspberry Pi setup -> loading openCV libraries for facial detection onto RPi so that we don't need to use PC
- Libraries for video facial detection
- Build time to put libraries onto Raspberry Pi = 8 HOURS!

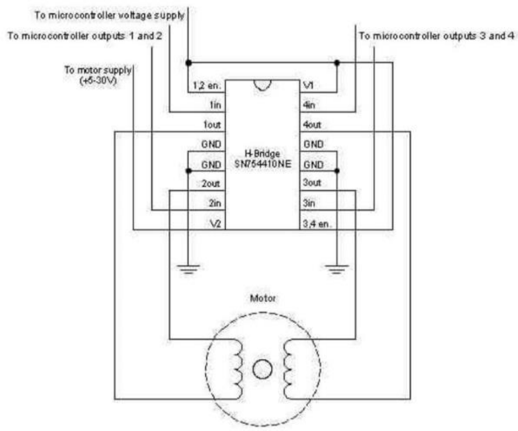
March 19, 2016

Meeting Agenda: Motor Unit Design

Meeting Minutes:

- Motor unit circuit design
- Need to interface high voltage components with low voltage ones
- Need to make sure we don't blow any sensitive control components

- Need to split voltage from power supply (RPi only needs 5V)
- Should we use separate breadboards?



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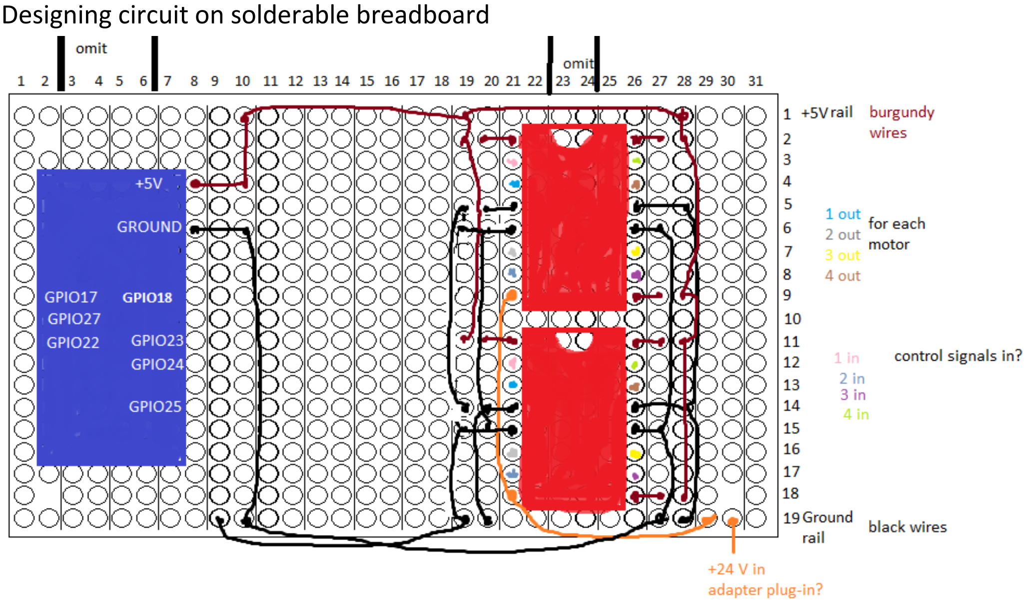
March 21, 2016

Meeting Agenda: Motor Unit Circuit

Meeting Minutes:

- Designing circuit on solderable breadboard



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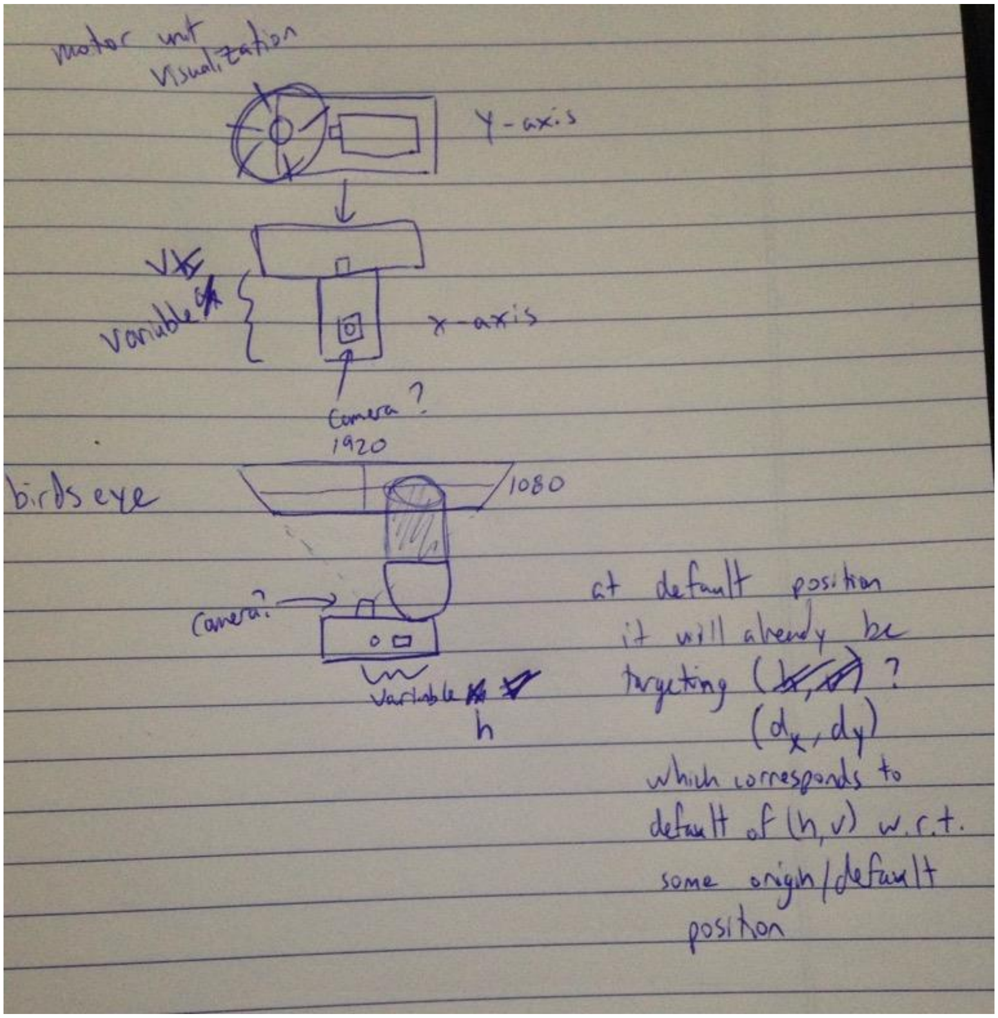
March 24, 2016

Meeting Agenda: Converting Pixels to Angular Coordinates

Meeting Minutes:

- 

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March 25, 2016

Meeting Agenda: Progress Report

Meeting Minutes:

- Introduction: Fabio
- Schedule
  - Deviated from original schedule because of concept changes and decisions in materials
  - So far: parts tested, initial implementations, test plan complete, software not started, behind schedule a bit
- Financial
  - Funding: ESSEF (so far within budget)
- Conclusion

- A little behind schedule
- Need to draw charts for scheduling up to present

March 28, 2016

Meeting Agenda: Progress Report Chart

Meeting Minutes:

- January
  - 25: Project proposal
- February
  - 15: Functional specs
  - 28: parts received
- March
  - 4: testing of lighting, motor, processing units
  - 10: design specs
  - 14: sensor testing
  - 21: motor unit interfacing with RPi
  - 28: progress reports and test plan
- April
  - 10: software complete
  - 14: software testing complete
  - 21: prototype testing and final testing complete

March 31, 2016

Meeting Agenda: Shopping for additional components at RP Electronics

Meeting Minutes:

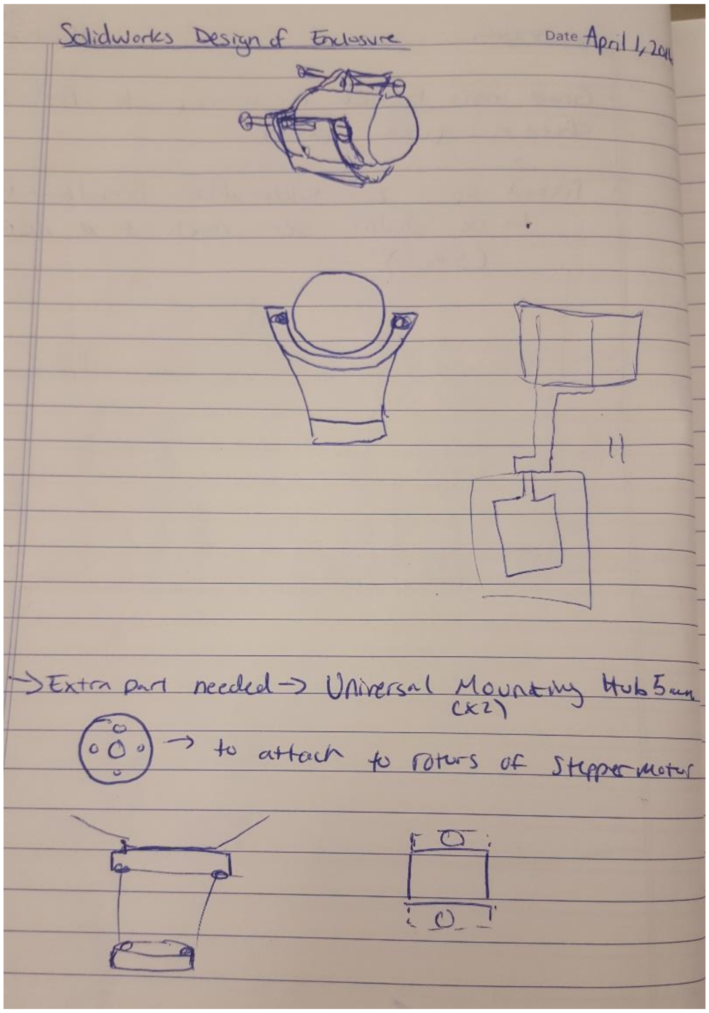
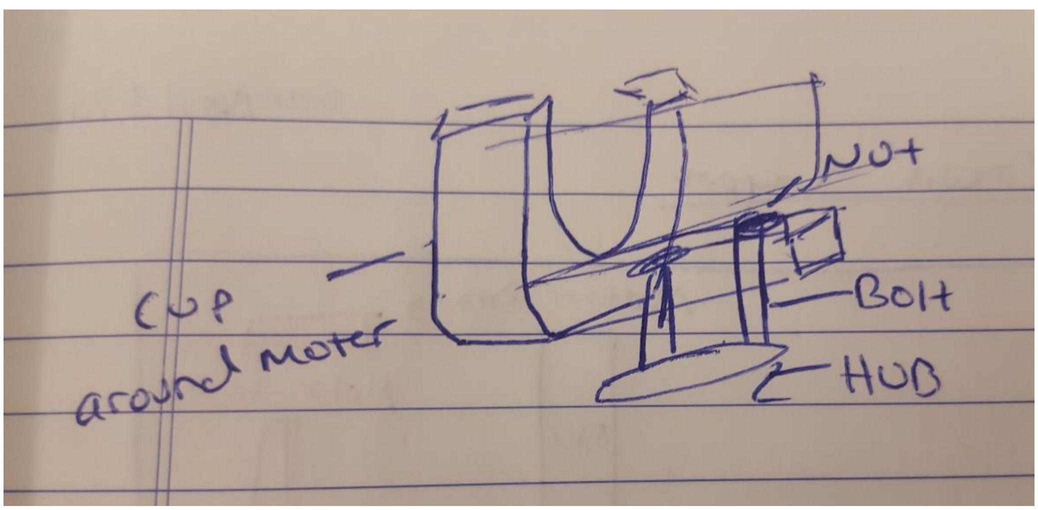
- Group visit to RP Electronics to find some cheap and quick parts
- Picked up 2 solderable breadboards
  - We didn't get much of a discount…5%?

April 1, 2016

Meeting Agenda: Solidworks Design of Enclosure

Meeting Minutes:

- Solidworks design of motors complete
- Solidworks design of motor connections complete (with hubs)

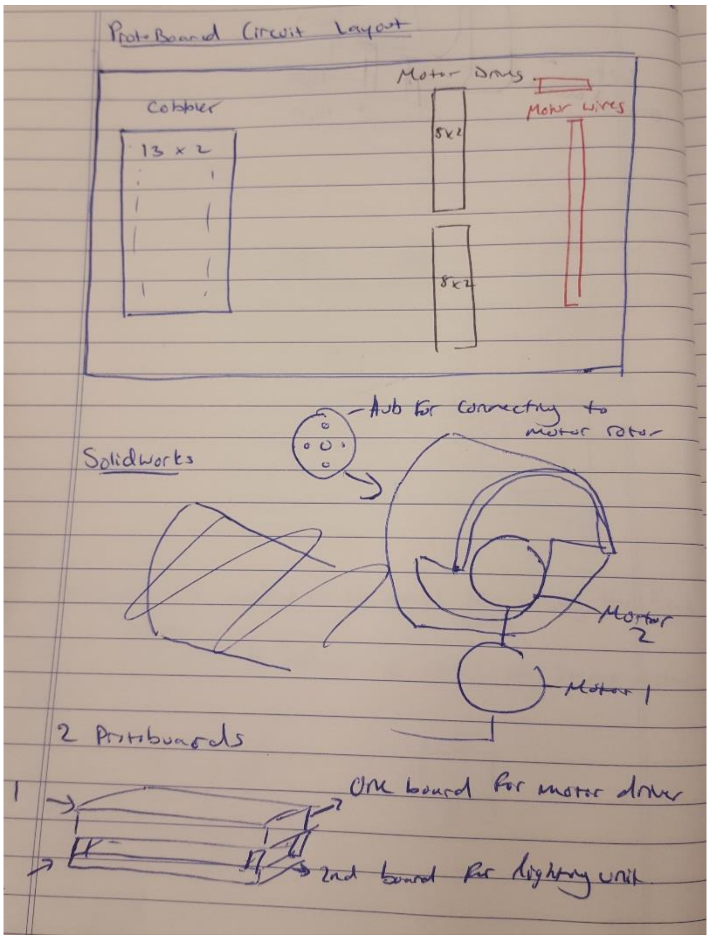
- 
Solidworks Design of Enclosure
Date April 1, 2014
→Extra part needed → Universal Mounting Hub 5mm
(x2)
→ to attach to rotors of stepper motor
-
- 
Nut
Bolt
HUB
cup
around moter

April 3, 2016

Meeting Agenda: Protoboard Circuit Layout and Solidworks

Meeting Minutes:

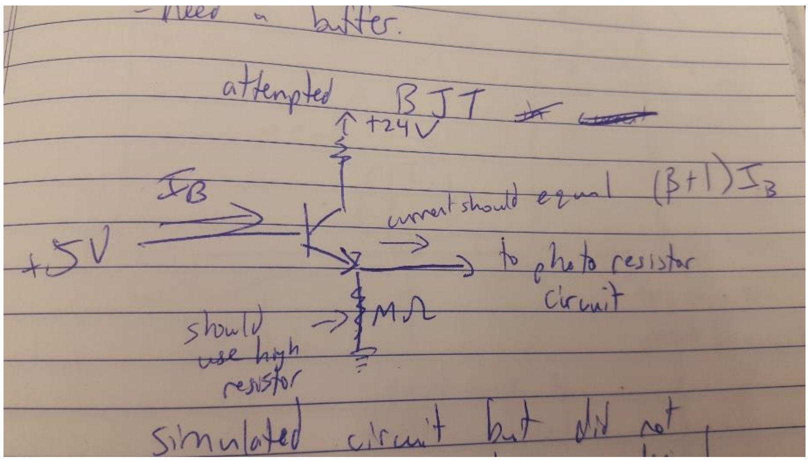
- Protoboard circuit design in progress
- Solidworks design of board enclosure and lighting unit is complete



April 8, 2016

Meeting Agenda: Lighting unit circuit re-design

Meeting Minutes:

- Looked into code briefly (opencv document)
- Redesigning of circuit to allow ambient light to impact how bright our led array should be
- Need a buffer
- Simulated circuit but did not get the current gain desired despite using power transistors with high beta (5000)
- Fabio figured out a voltage regulator buffer system
- 

April 11, 2016

Meeting Agenda: Mapping motor driver circuit onto solderable breadboard

Meeting Minutes:

- Mapped motor driver circuit onto solderable breadboard
- Using MS paint schematic
- Top row = +5V peripherals
- Bottom row = grounded parts
- Could easily be shifted, just need to note difference ie: move IC to 25 to 28 so all pin numbers increase by 3
- Reviewing with group before soldering

April 13, 2016

Meeting Agenda: Mapping lighting circuit to board

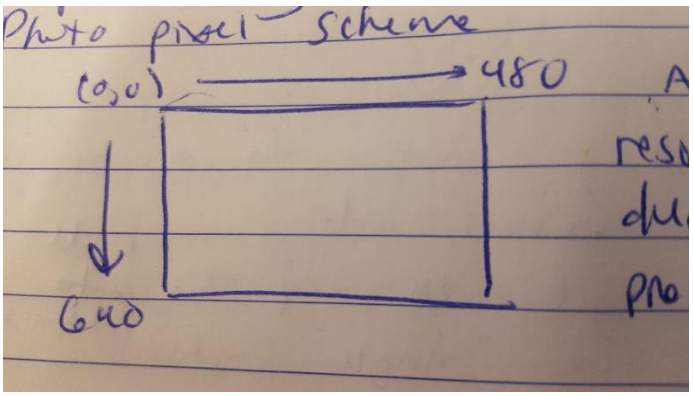
Meeting Minutes:

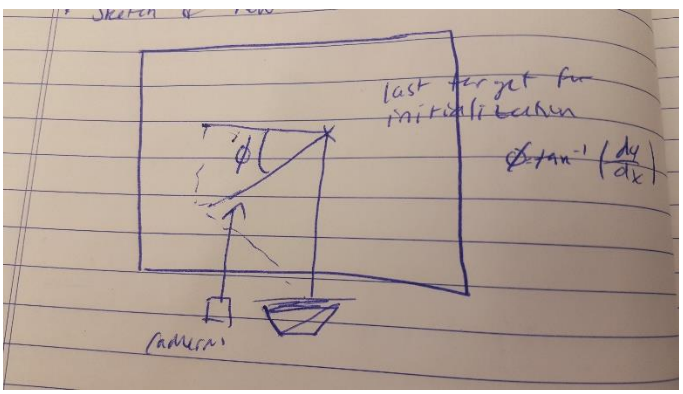
- Removed cobbler from schematic drawing
    - Don’t think we need it
- Moved wires around on motor circuit to allow lighting unit to occupy some solderable breadboard
- Began using git to acquire code to begin programming the angle functions
- Completed mapping of lighting and motor unit circuits on the breadboard
    - Awaiting approval by rest of group before sending

April 13, 2016

Meeting Agenda: Code work

Meeting Minutes:

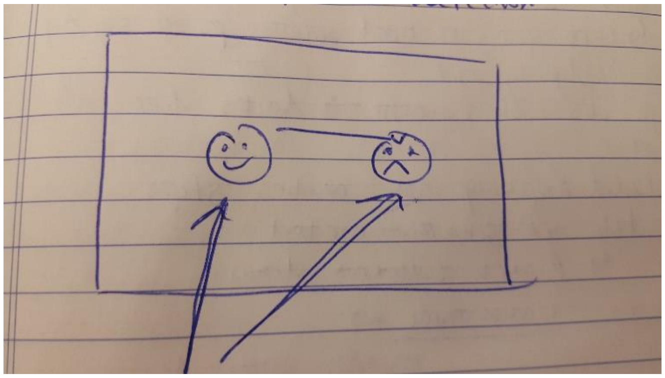
- Image processing research
- Photo pixel scheme: assuming resolution of 640x480 due to RPi processing capabilities
- 

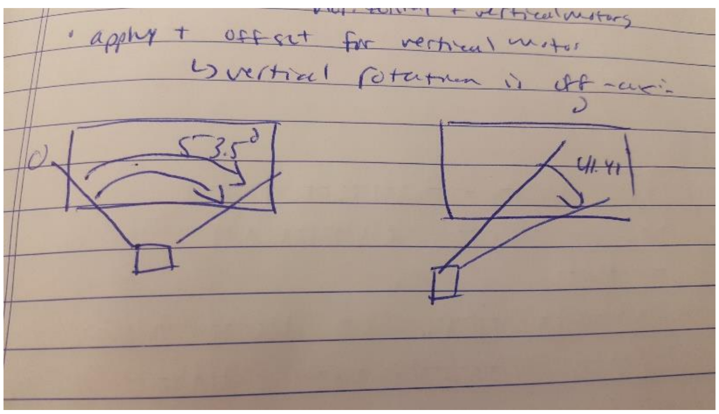
- Modified angle calculation: ability to keep track of previous position
- Sketch of how to code function:
- 

April 16, 2016

Meeting Agenda: Mapping lighting circuit to board

Meeting Minutes:

- Using raspberry pi documentation to get numbers for calculations
    - For facial detection
- 2 faces -> known
- 
- Measured pixel distance between them
- Do for both horizontal and vertical motors
- Apply and offset for vertical motor
    - Vertical position is off axis



April 18, 2016

Meeting Agenda: Troubleshooting circuit short

Meeting Minutes:

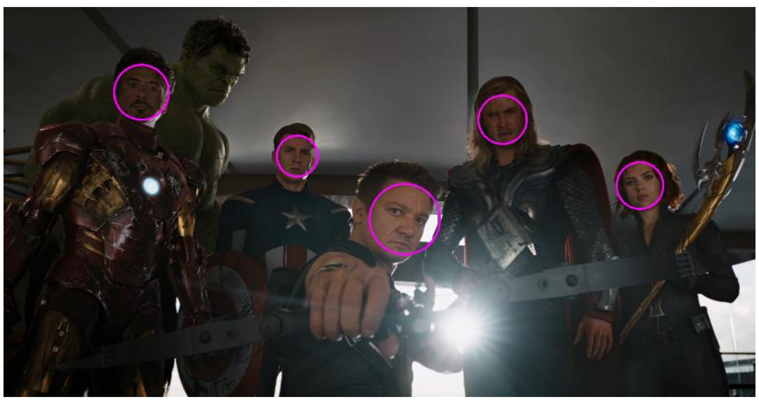
- Picked up more parts from RP electronics
- Figured out that stepper motors draw a lot of current when they're stationary
    - Going to need another power supply for lighting unit
- High draw of current -> looks like a short
- Reduced frequency of motor steps to help with smoother control
    - Lowers current draw
- Managed to fix circuit!!!

- Only thing left is to finish code

April 19, 2016

Meeting Agenda: OpenCV with Visual Studio and More Face Detection Testing

Meeting Minutes:

- OpenCV:
  - Been having issues using visual studio with opencv
    - Not a problem when using code with RPi, because it already has libraries on it
    - Just problem for debugging code at home
  - Figured it out, though!
    - Need to include directories and libraries
    - Tested face detection
  - Shane tested face detection on a picture of the avengers
    - 
    - Which he said worked except for the hulk
    - The hulk doesn't like a real person anyways
- Testing
  - Measured face radius + distance with RPi camera
  - Created formula with excel that estimates distance by face size (in pixels)
  - We increased resolution to improve face detect range (3.5m -> 6.5m)

April 20, 2016

Meeting Agenda: Post Mortem and Testing

Meeting Minutes:

- Post Mortem:
  - Working on post-mortem
    - Finished intro/bg
  - Shane is doing the body
    - I am editing his stuff
  - I am doing issues/problems

- Shane did market stuff
- Wrote up and made new tables for schedule and financing
- Added in meeting minutes, put in some pictures from out lab notebooks
- Just need everybody's reflections

- Testing:
  - Fully assembled enclosure and did final soldering
  - 11PM:
    - BLEW OUT RASPBERRY PI
    - WILL HAVE TO GO BUY NEW ONE TOMORROW
  - It wouldn't be capstone without a last minute tragedy, it's a life experience

April 21, 2016

Meeting Agenda: Final Testing and Demo Prep

Meeting Minutes:

- We got a new raspberry pi
- For some reason, our power supplies don't work -> but the lab ones' do
  - Borrowed power supply from Gary
  - Turns out we needed a more linear power supply (expensive to buy)
  - Borrowed one looks great!
- 4:45pm: worked on me, then pointed at ground: more debugging required