Tony Abdo

Portfolio

A compilation of some of my personal and group projects

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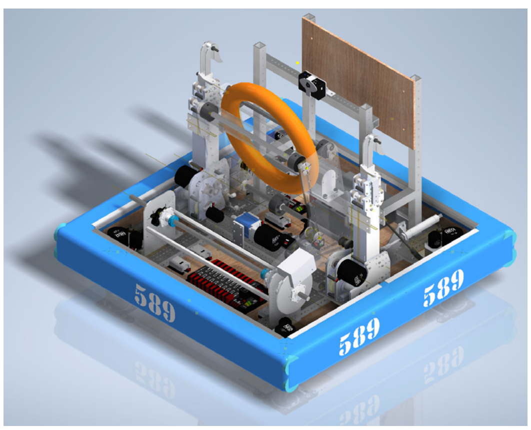
2024 Robotics Mentoring

Background

Every year, the robotics organization FIRST announces a competition for high school students to participate in wherethey build a robot from scratch to accomplish a task based on the rules of the game for that year. On average, eight weeks are allotted to design, manufacturing, and testing before first the first competition. If performance of the team is adequate, the program can run for four months which ends at the international level in Houston, Texas. Additionally, some teams have projects for the students during the off-season to further educate students on new topics.

My goal as a mentor is to teach practical engineering and problem solving skills in an effort to reinforce the material learned in a traditional classroom setting. I see such tremendous value in the program to reach this goal that not only do I mentor throughout the year at the high school I once attended, but also co-founded the non-profit Friends of Falkon Robotics Inc. 501(c)(3) to achieve a sustainable and highly impactful program.

The robot discussed in these coming sections, named *Super Nova*, is depicted below and took us to international level of gameplay in Houston. Goals of the robot were to shoot an orange foam ring named a *Note* into either a tall rectangular slot named a *Speaker* or transferred into a wall cutout named the *Amp*. Additionally, the robot would lift itself up on a chain that is only supported at two ends. In the following sections, I highlight my contributions that enabled a group of teenagers to create such a complicated system The approach I took during this season was as a result of reflecting on my previous years of mentoring and implementing improvements that I perceived most worthwhile.



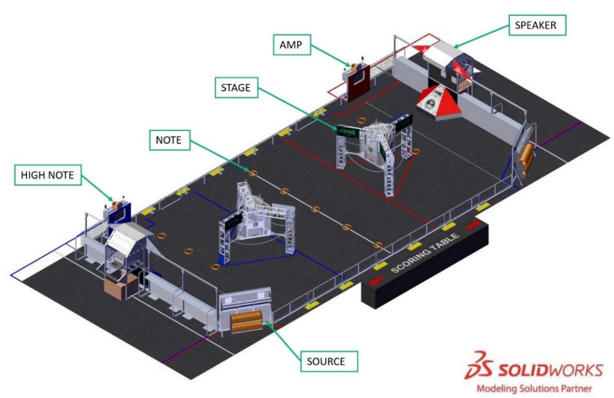


Figure 1: 2024 robot named Super Nova (left) which competed on the field in a semi-controlled environment (right)

Design Contributions

When students are told the details of the game, it's the first time mentors hear of it too. As a result, within an hour or two, I quickly read through the 150 page document that outlines all the rules of the game to guide students through unpacking what the constraints of the problems are from the first day. With these derived constraints, a few mentors and I lead the students through defining design objectives for robot as a whole. These objectives included: short enough to fit under obstructions, can climb in the middle of a dangling chain, and score into the *Speaker* at the closest point. In case we could achieve the first layer of objectives, secondary and tertiary goals were laid out as well.

After high-level constraints were set, I worked primarily with the intake and shooting subsystem to create a tangible design that would achieve desired metrics. This involved guiding students through a second pass of understanding the constraints with emphasis on how it affects intaking and shooting. After this, prototypes were generated with emphasis on having students question themselves, "What problem am I trying to understand?" Through prototyping, the final pieces came together to start putting ideas into CAD. This next step also required guidance as the experience of students with CAD was limited. The final mechanism was an arm with one revolute joint with spinning rollers that acted as both the intake, which could pick up from the ground or at designated stations, and the shooter, which could score *Notes* into the *Speaker* and *Amp*. A unique element of the mechanism was using a bicycle brake caliper with a custom rotor to hold the arm position as that would be more energy efficient and put less stress on the arm motor as the arm wasn't counterbalanced.

Even though the shooting and intaking mechanism was my primary focus, I provided quick design checks throughout the entire process for other subsystems. For instance, I guided the students through the creation of an excel spreadsheet that automated the calculations for the members of the telescoping arms that would climb onto the chain. Additionally, I helped all the students to transfer their ideas into CAD.

Manufacturing Contributions

Apart from the overseeing of students on the lathe, mill, bandsaw, 3D printing, and other various power tools, my main contribution in manufacturing was introducing CNC Routing capabilities to the program. I compiled a list of all the minimal parts for the machine we wanted, along with safety equipment, to ensure immediate utilization. After that, I conceived the entire workflow to seamlessly create and update CAM data and operate the machine which I then taught students. This capability was crucial to the creation of *Super Nova* as some machining operations were impossible without it.

Logistics Contributions

In order to accommodate the use of a CNC Router and have some form of PDM process in place, I put together a completely new workflow at the system level. At the heart of it, the service Free File Sync performs the synchronization process between a cloud target (Google Drive) and local machines. The software allows for selective syncing of files.

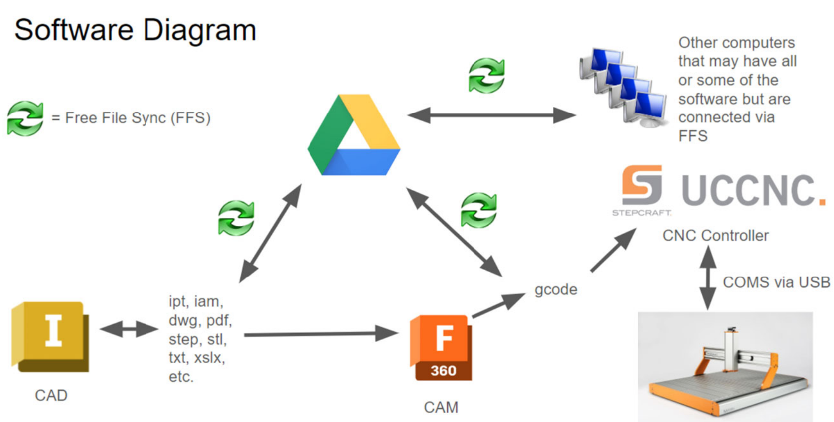


Figure 2: Software architecture for managing design and manufacturing files

The system infrastructure would be worthless though without having the CAD environment itself organized. Thus, I put together a standard for directory conventions, naming conventions, and tools utilization specific to Autodesk Inventor that allows for a large group of students to work simultaneously.

The tracking portion that comes in a good PDM solution was also missing, so before the competition season, I created a spreadsheet which automatically took the parts students would fill in on one sheet and create pivot tables in new sheets for manufacturing, purchasing, and assembly all in one Google spreadsheet document.

Leaf Suit (Wearable Air Conditioner, Co-Founder)

Project Description

What initially started as a project to further develop my engineering skills after graduating college by searching for methods to keep people cool during the summer with a wearable air conditioner, turned into an entire start-up that I co-founded named Leaf Suit which was backed by Y Combinator.

The product we developed was a vest that effectively implemented artificial sweating. The solution we landed on wasn't clear at the beginning though. First, we started with a closed-loop system that would use Thermoelectric Coolers (TEC) to replace a traditional refrigerant cycle. Then, we took inspiration from amusement park fans that have integrated misters and tried packaging that system into a vest. However, while trying to do so, we noticed secondary effects that resulted in the final approach that deposits water on the absorbent side of a bi-layer textile. This side is exposed to stream of fast moving air while the other side, which is non-permeable, allows the vest to touch the user for conductive heat transfer without getting wet. A prototype of the approach helped us receive funding from Y Combinator. Unfortunately, the prototype was far from a mass-marketable product, so we continued to iterate the best we could during the supply chain-impacted environment of 2020.

The following sections cover the work I put into creating the final version of the vest.

Electronics

My primary focus of the entire project was in electronics and firmware. At the beginning, I used off-the-shelf components to create prototypes. However, through customer interviews, it became apparent that a very slim form factor was necessary which required custom boards. Thus, I used Altium to design a 1 inch x 2 inch circuit board that ran 2 pumps and 6 fans, headers for programming ATMEGA328PB via ICSP, and powered via a micro USB protected by an e-fuse. The board was centered around the ATMEGA328PB as I used and Arduino Nano for prototyping, so using the same chip architecture helped keep code development manageable. Not only did I design these boards bu also manufactured them with a small reflow oven.

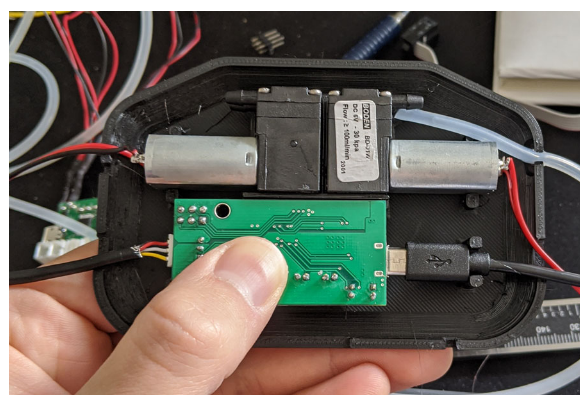


Figure 3: Finished PCBA that controls entire vest (left) and integrated with two pumps into half of the enclosure (right)

Code

As I was developing both the board and code at the same time, I was able to optimize utilization of pins while allowing for easy routing on the board. Since this vest would be sold at a slightly high premium for early adopters, reliability was crucial. As a result, code that relied upon waits was strictly out of the question as such an approach could cause unexpected behavior as more functionality was introduced. Instead, I used an interrupt driven strategy to create a loop rate of 10 Hz. The registers that needed modification to accomplish this were TCCR1A, TCCR1B, TCNT1, OCR1A, and TIMSK1. Additionally TCCR2B for Timer 2 was modified to adjust the prescaler and reduce the frequency of the PWM signal driving the fans to reduce commutation noise.

The code logic at a high level works by creating a state machine for one smart button and a state machine for the pump states. The smart button communicates its state (off, medium, low, high) via a square wave with varying pulse width for each state. These pulses generate external interrupts which enters an interrupt handler to determine the state. While the vest is on, the pump state is determined at a rate of 10 Hz dictated by the internal interrupt, mentioned above, by a function named pumpMachine(). The function checks the current state of the button and transitions the pumps from any of the states dictated by an enumeration type variable with states of PUMP_OFF, EMPTY_COLLECTOR, EMPTY_WT, NOTIFY_EMPTY, WAITING_FOR_REFILL, NO_OP. As mentioned, the vest works much in the same way as a person sweating. This water is provided by a water tank, and, if too much water is delivered, the excess is accumulated at the collector. Thus the states listed convey all the possible states of water supply.

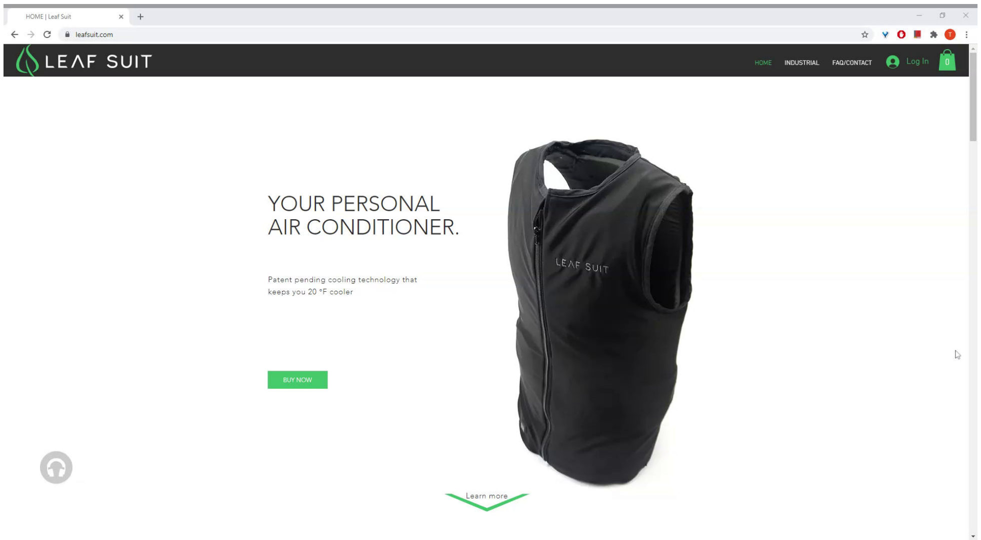
Too keep costs and manufacturing complexity low, no water level sensors were installed. However, I was able to integrate crude sensor feedback of water levels, which avoided open-loop approach of using time, by using the pumps as the sensors. Since these electric pumps are effectively electric motors, they exhibit higher current draw under load. The current could be measured by looking at the voltage drop across a resistor. In this case, the resistor was of a very small value (1 Ohm) and placed on the low-side of the motor. Additionally, the ADC was set to have internal reference of 1.1V. Thus, with a resolution of 10 bits, there was more than enough resolution to detect a change of roughly 0.5 Amps between load and no load. Unfortunately, the signal was sinusoidal in nature which the minimum very close to the no load condition. I solved this by calculating the DC signal of the sinusoid and compare that to a threshold.

Mechanical

Prior to finishing the electronics, I supported with mechanical aspects as much as possible; but after finishing those duties, I moved on to the mechanical side fully. First order was to fix leaks that had been plaguing us from the beginning. Now that I could provide my concentrated effort, I developed a hypothesis for the various leaks and developed one representative coupon to explore the variable space of time, pressure, and heat applied to the thermoplastic adhesive that bonds various layers together. After a few days of testing, I proved my hypothesis and adjusted the design and manufacturing process accordingly. Additionally, I redesigned the vest to allow size adjustment to improve comfort and these design changes not only improved aesthetics, but also improved manufacturing. By the end, one person could make a vest from start to finish in 6-8 hours. This time includes assembling the circuit board, wiring electronics, cutting fabrics, and assembling the entire vest.

Marketing

As with any start-up at the inception, wearing multiple hats is common, and that was true for us too. Another hat I wore was that of sales and marketing. This entailed attending conferences, conducting customer interviews, and finding customers. Even though it took away time from engineering, the process was worth it as it helped shape the product to be more market-ready. To facilitate a better image, I also designed a new landing page for the product with a few screenshots provided below.



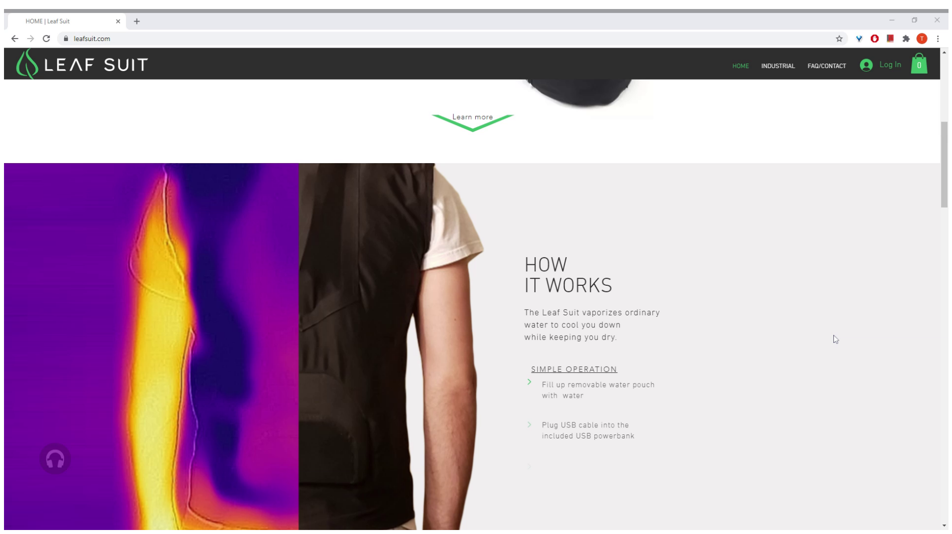


Figure 4: Snippets of website to showcase the vest

Patents and Grants

Another set of roles I had were putting together grants and patents. Fortunately, these tasks were shared with professionals. As a result, rather than writing these documents directly, my co-founder and I worked with the professional to lay out expectations and edit their work as necessary.

3D Printing

Equal Space Divider Case

This is a custom case for a used equal space divider featuring sliding latch. I got this beautiful tool for drafting as a gift, but, being secondhand, there was no box for protection. As a result, I got to designing a case with the goal of being sleek yet protective. The case features:

- Asymmetric locating features to prevent tool from rattling around when placed in either side of case
- Ribs that double as stiffeners and interface to clamp down onto divider
- Sliding lock with detents to give tactile feedback

Figure 5: Case for equal space divider showing install process from left to right

Han Solo Blaster From Star Wars

Being one of my first 3D printing projects, I learned a lot about the manufacturing process and painting as I completed the gift for my dad using the model made by PortedtoReality. This one project taught me about slicing, finishing surfaces to prep for paint, painting, and troubleshooting failed prints. The primary issue I had with achieving successful prints was managing the hygroscopic nature of some plastics, which I now solve by using a modified food dehydrator.

Figure 6: Parts for Han Solo Blaster after prepping surfaces for painting (left) and finished product (right)

Diet Tracker

Project Description

Health and fitness have always been important to me, but as my familiarity with the field has grown over time, not indulging in sweets and chips doesn't necessarily mean one's diet is healthy. Rather, proper levels and proportions of macro and micro nutrients are important for optimal health and vitality. Keeping track of all these variables by hand would be cumbersome and I didn't want to sign up for another service that didn't have all the features I wanted and would either get hacked or sell my data. Thus, I coded my own tracker in python within a jupyter notebook environment.

The code imports a csv file with the pandas library. The imported data has recommended targets and limits as well as ingredients. Then in the following cells, I create different meals and snacks using those ingredients to then combine together in diet for one day. Due to how I set up the data structure, combining ingredients by simply using the (+) operator aggregates all nutritional data into one array that I can use to visualize the diet plan with plots. The following is a result of one such diet

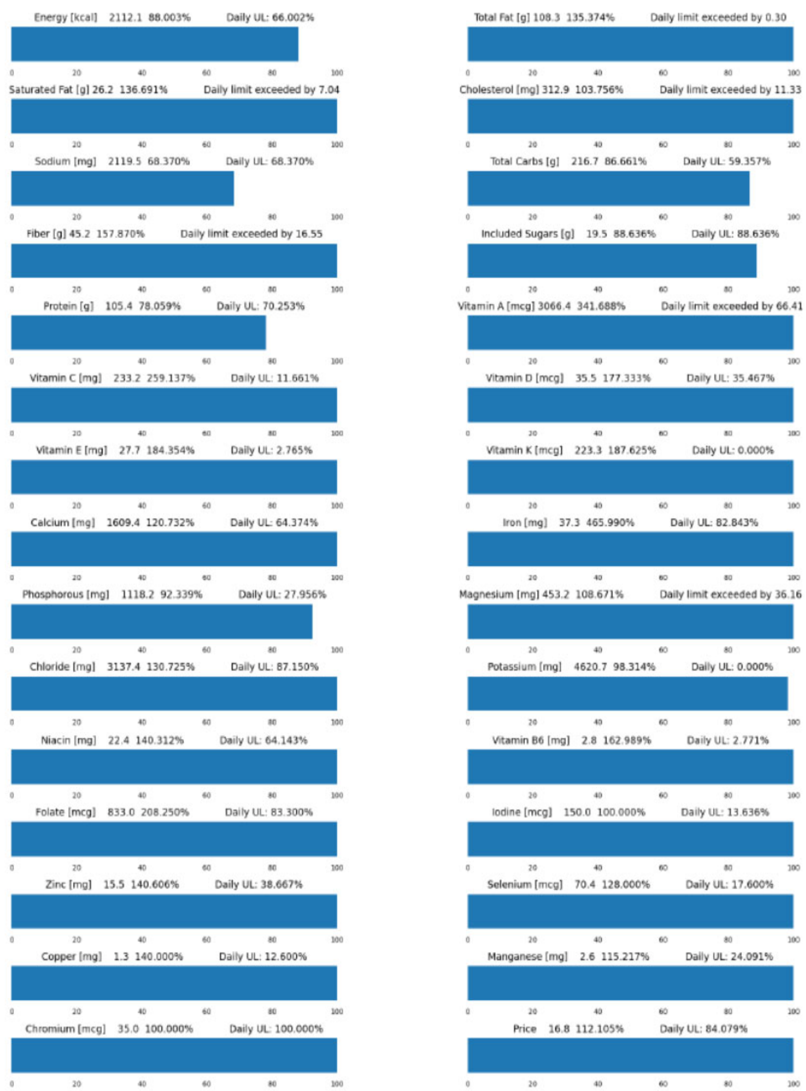


Figure 7: Output of nutritional content of a hypothetical diet for one day

Autonomous RC Car

Project Description

In this project I was tasked to construct a system from scratch that would follow a strip of white tape autonomously using a line-scan camera as quickly as possible. As a result, this project encompassed multiple areas of my studies including mechanical design, electrical design, and embedded programming. The finished product is shown below in *Figure 8*

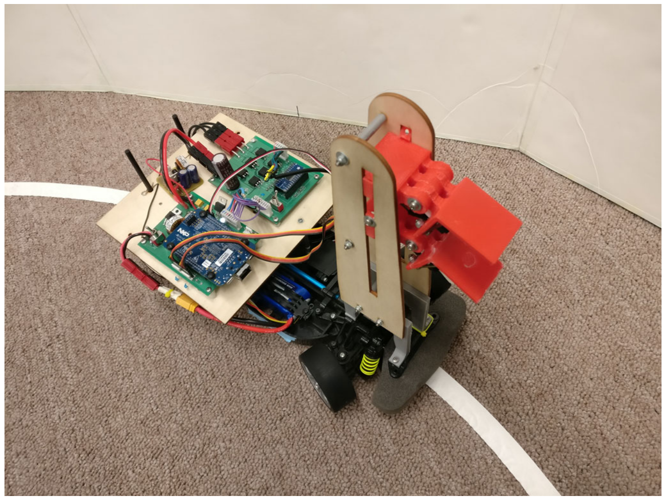


Figure 8: Finished car for EE 192

Electrical Design

The electrical components needed to make the car functional are the motors, line camera, steering, and onboard microcontroller logic. All these components in turn need to be operated from a single power source even though they might operate at different voltage levels. All these components were distributed onto two separate boards to reduce noise between high voltage and low voltage components in addition to making future modifications easier. Since the motor controller was the only high voltage component, it was isolated on a dedicated board and can be seen on in *Figure 9*. This board features very large traces with as few "squares" as possible to reduce copper loss from the large currents running through the motor at stall torque. Additionally, the power MOSFETS utilize the copper in the PCBs for extra surface area to improve cooling.

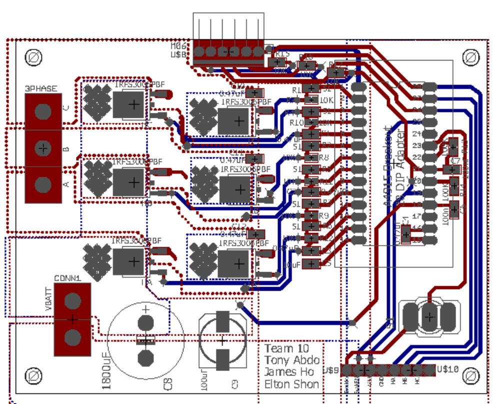


Figure 9: Motor controller board for car

The second board houses the voltage regulation components, micro controller, and camera connectors. The 3-cell LiPo (11.7V nominal) is stepped down to 5V using a switching regulator (LM2678S) to power the K64F and then stepped down again to 3.3V using a linear regulator (LM3940) to power the camera and the micro controller on the motor controller board. A layout of the board can be found in *Figure 10*. The complexity of this board was not great; however, there was an important factor to consider which was the placement of the switching regulator. The components, such as capacitors inductor, need to be close to one another and the input source to minimize noise from the very high switching rate of the regulator.

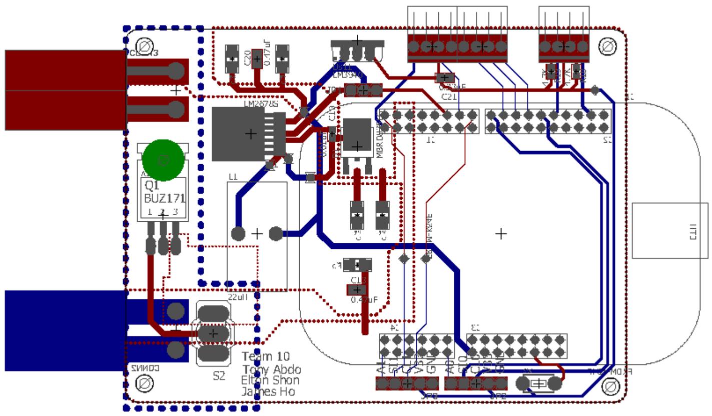


Figure 10: Board housing all other components

Mechanical Design

In order to make the control of the system as simple as possible, the mechanical components need to be designed to reduce any instabilities. For instance, having a center of gravity situated extremely high can cause large rolling behavior when cornering. Thus, creating a platform for electrical components very low and close to center of gravity was one of the design objectives. Additionally, the camera mount was constructed out of plywood since it is cheap, quick to manufacture, and rigid to minimize undesired rolling effects. Another concern was a rigid camera holder since any movement of the camera (especially pitching) can greatly impact the image quality. However, the design would need to be flexible in the sense of allowing a vertical degree of freedom. As a result, the resulting design had a large joint that had multiple faces in contact for redundancy. The size of the joint allowed for a large compressive frictional force. To allow for a vertical degree of freedom, slots were used for the side panels (which prevented lateral motion) and the side panels were used to provide a large clamping to prevent movement.

Integration

All these components were integrated together as depicted by *Figure 11* The primary goal in the integration of each electrical component was to abide by a star configuration since this kind of configuration would mitigate noise from high frequency switching components.

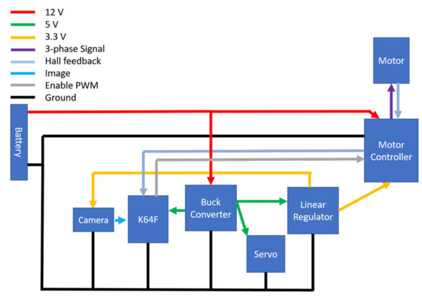


Figure 11: System overview of all components on the car

Autonomous Control

To control the car autonomously, feedback control was implemented for both velocity and steering. Velocity control was implemented with PI controller at the low level. Additionally, a higher level protocol of changing the reference velocity was employed to improve stability when turning. Velocity estimation was done by counting the number of rotations of the motor via hall effect sensors in a fixed time period. The steering control was implemented using a PID controller using data obtained from the 128 pixel line camera. The image was analyzed with threshold and width detection to estimate the line center. Both velocity and steering control were synchronized to run at 200 Hz using time interrupts.

Results

The final product was ran on a track with many glare spots and a slippery floor with an average speed of ~6 ft/s. The stability of the car on this track can be seen in *Figure 12*. As can be seen, the response was nearly instantaneous for two successive step references.

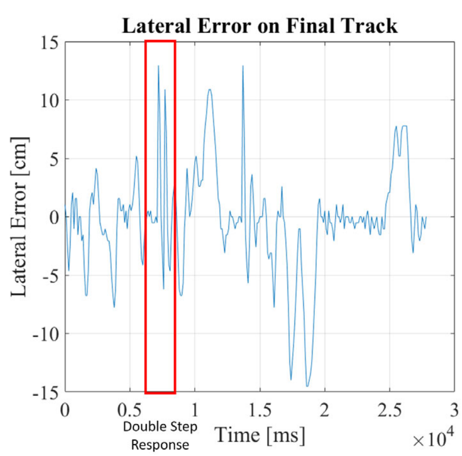


Figure 12: Lateral error on final track

Adaptive Cruise Control

Project Description

The main goal of this project was to design an experiment that assess the performance of Adaptive Cruise Control (ACC) under varying weight and following distances. Two carts were made one to be the lead vehicle and the other the follow vehicle. A picture of the two is shown in *Figure 13* where the lead vehicle is the one on the left and the follow vehicle on the right. The lead vehicle was driven with a PI controller to achieve a constant velocity, and the follow car with a PID controller to achieve constant spacing with respect to back of the lead vehicle. The experiment was carried out at 0%, 10%, and 20% added weight at each following distance of 20 cm, 30 cm, and 40 cm

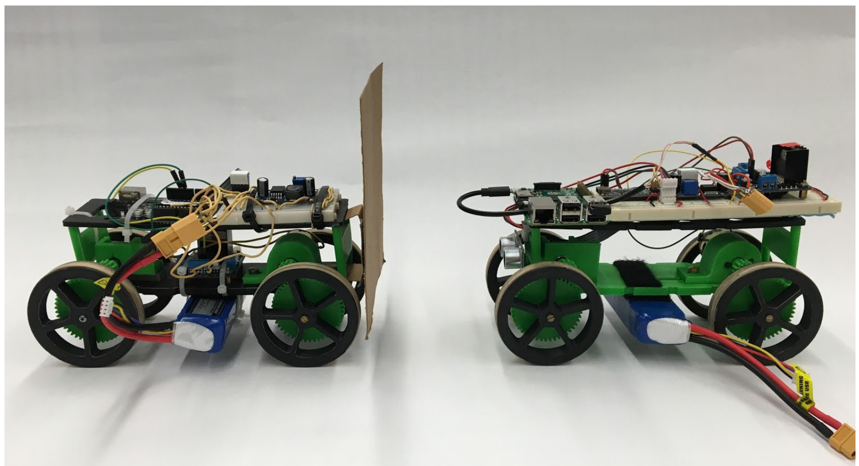


Figure 13: Lead and follow vehicles

Results

The result of the experiment on the amount of overshoot can be seen in *Figure 14*. As expected, increasing the weight of the car and reducing the following distance will increase overshoot for the same controller. Thus, different controllers need to be used for different conditions in order to ensure safety.

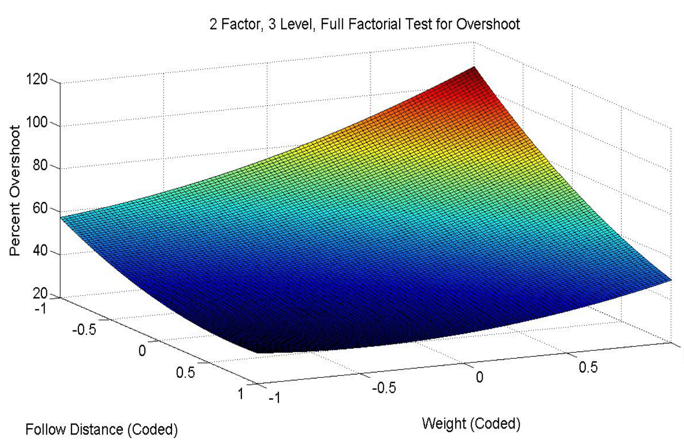


Figure 14: Relationship between weight and follow distance on amount of overshoot for ACC

Inverted Pendulum

Project Description

Over the course of a few labs, a variety of control techniques were applied to the problem of making a pendulum balance in an inverted direction which is an unstable equilibrium point. A cart travels along a metal bar using a gear to rail interface, and attached to this cart is a metal beam which is free to spin. In this controls problem, one needs to move the cart to counteract the falling of the beam by moving the cart to "catch" it.

Control Strategy

In order to bring the pendulum up from the stable equilibrium point of hanging down, a bang-bang controller was used which utilizes the idea of conservation of energy to convert the kinetic energy of the pendulum and cart to potential energy of the beam. Once the bang-bang controller gets close enough to the top, an LQR controller takes over and fully stabilizes the system. Additionally, to make the controller as smooth as possible, an observer was used to estimate the velocity of the cart and beam since numerical differentiation can lead to high noise. The controller was implemented using Simulink with the following diagram:

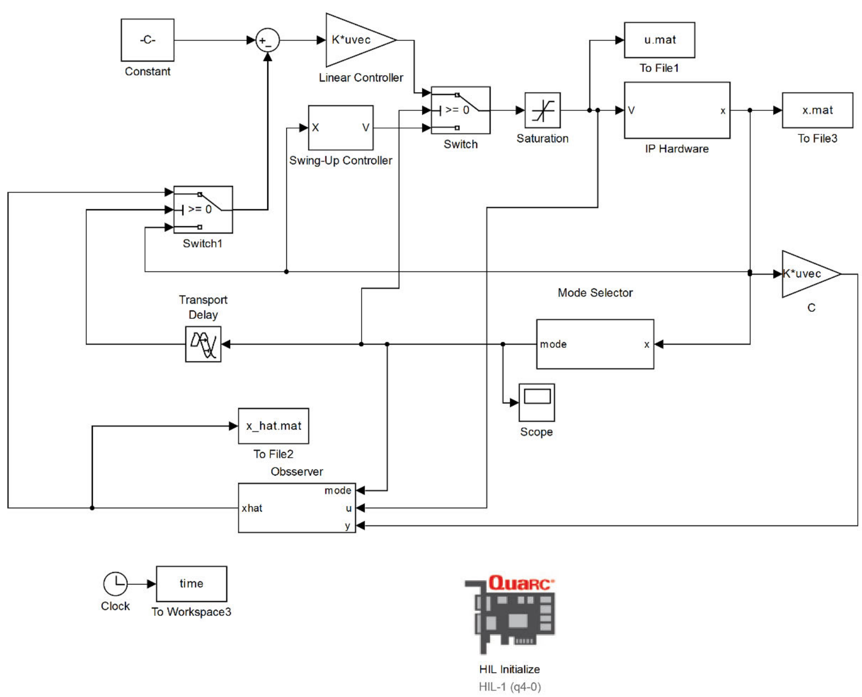


Figure 15: Controller used for Inverted Pendulum problem

Results

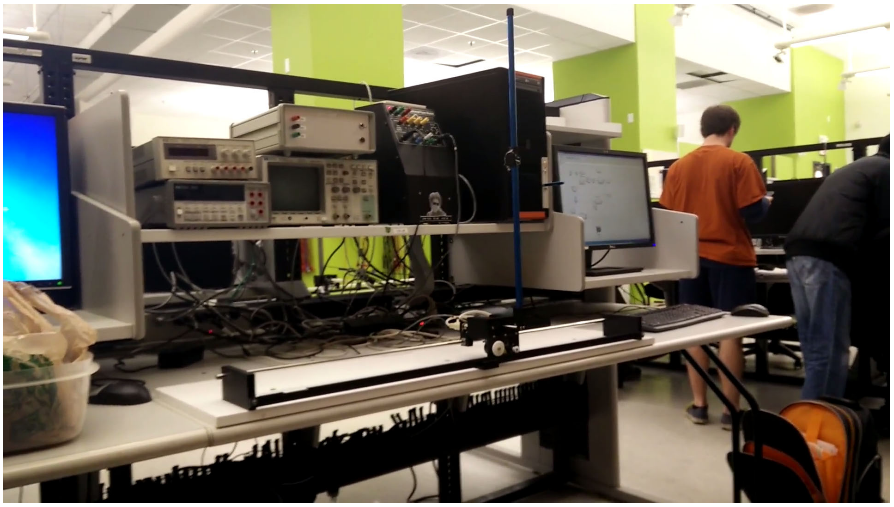


Figure 16: The controller balancing a pendulum with an extra mass at the center of the beam

A video of the controller flipping the pendulum from a stable state and the balancing it while staying as close to start position of the cart with response to perturbations: https://www.youtube.com/watch?v=fFs3c1zJ_dE

A video the controller doing the same thing as previous video except now respond to a sinusoidal reference with respect to the starting position of cart: https://www.youtube.com/watch?v=1288B9Yuy6g

Magnetic Levitation

Project Description

The purpose of the project was to levitate a steel ball which required the linearization of the nonlinear dynamics of the system about an operating point and develop a control strategy to make it work. This project was done in a lab setting, so all of the equipment was given to us. Rather than focusing on the entire system from start to finish, our main task was to design the controller that would get the system to work.

Control Strategy

The controller was implemented using an op amp in negative feedback as depicted in *Figure 17*. The values for R1, R2 and C were chosen such that this became a lead compensator and increased the phase margin of the system. It also made the system stable by pulling the poles into the open left half plane when the loop was closed. Once the ideal controller was designed and the values for the components were found, real-life components were chosen to closely match them. The controller was checked again to see how much the adjusted values affected the performance of the controller by comparing the open loop bode of each topology, and the graph is shown below in *Figure 18*.

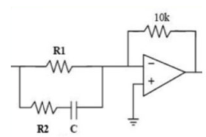


Figure 17: Analog controller used to levitate the ball.

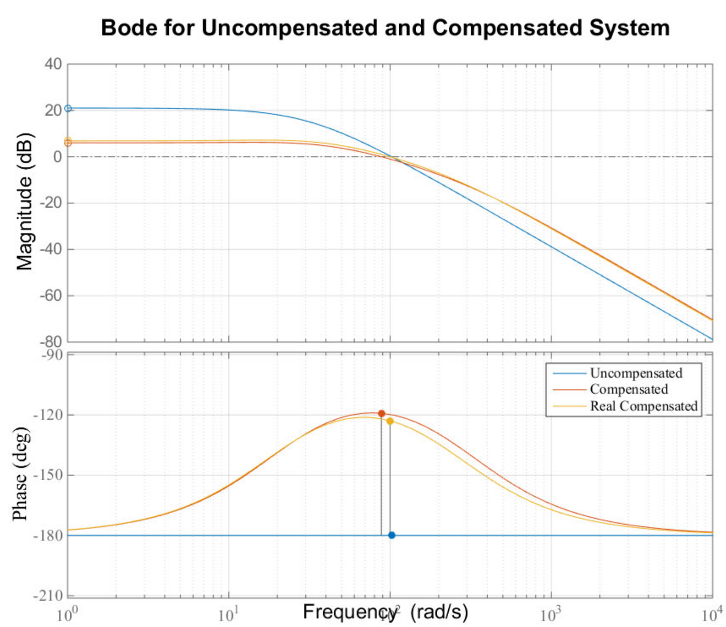


Figure 18: Bode plot of open loop system when uncompensated, ideally compensated, compensated with realistically sized components

Results

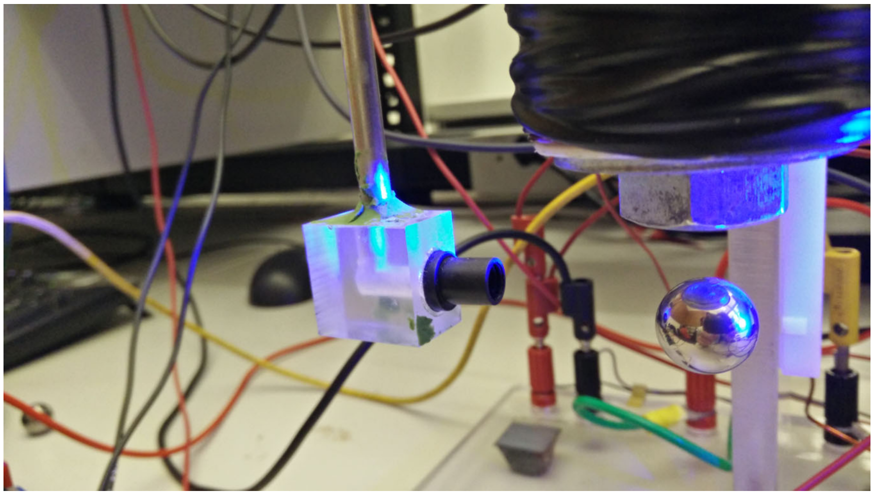


Figure 19: Steel ball being levitated

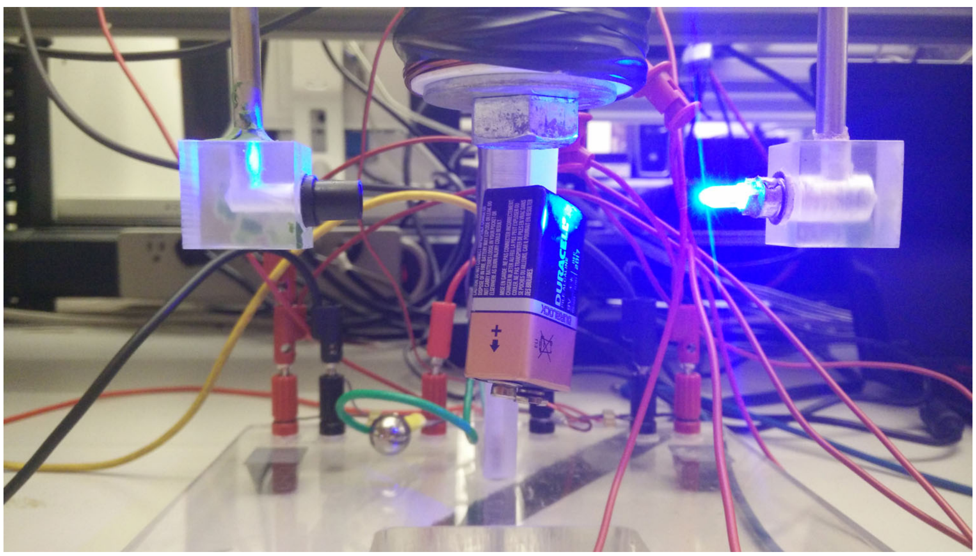


Figure 20: Battery being used with the same control system showing how system is robust to variances in plant

Video of this in action with demonstration of disturbance rejection: https://www.youtube.com/watch?v=bMzEAnzfDjM

Z-stage (Texas Instruments Intern Project)

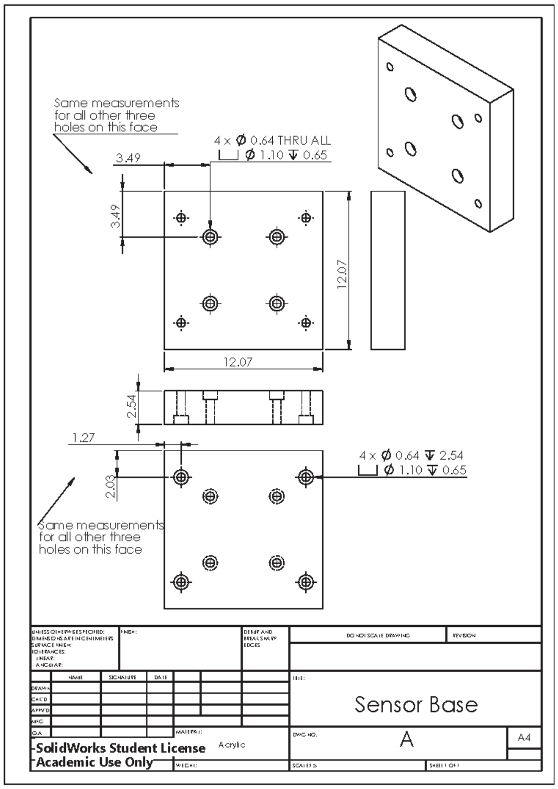
Purpose

At Texas Instruments, the IC's are characterized under different operating conditions and topologies. For the inductive and capacitive sensors, many tests have been carried out that measure the output code as an object approaches the sensor in many different conditions. However, there have been no tests done that characterizes the part while an object slides parallel to it at different distances away since the infrastructure was never there. As a result, my task was to develop a mechanical system that would allow for this type of testing to take place in a repeatable manner.

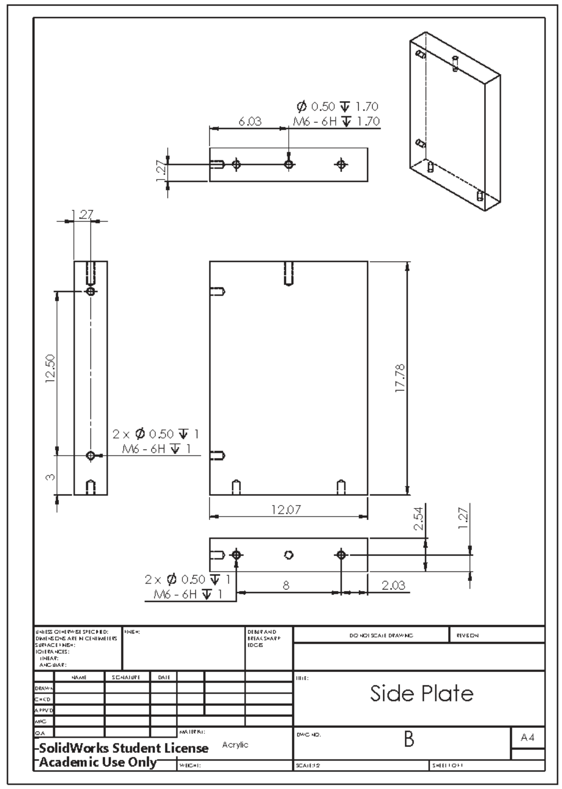
Tasks Completed

When I started designing the product I made sure that it would be structurally sound, isolate the sensor from any metal interference, make sure it can interface with the actuators that TI already owned, and keep the cost low. First goal was achieved by doing some statics on paper for parts that could potentially cause issue. Second goal was achieved by making part out of acrylic. Third goal was achieved by obtaining models of actuators and using them as reference. The last goal required me to build everything myself using limited amount of tools. Additionally, I wrote code in Teststand and LabVIEW to automate the procedure, collect data from the part, and check for values out of bound. All of this was completed in roughly three to four weeks.

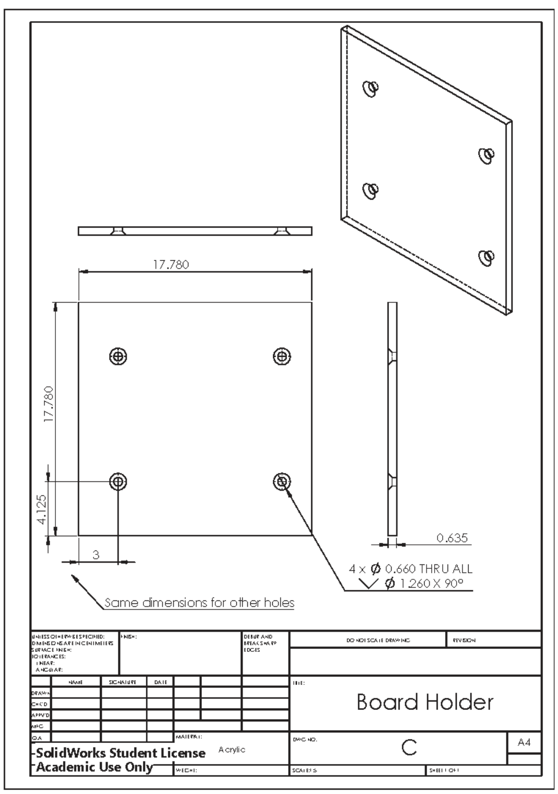
Drawings



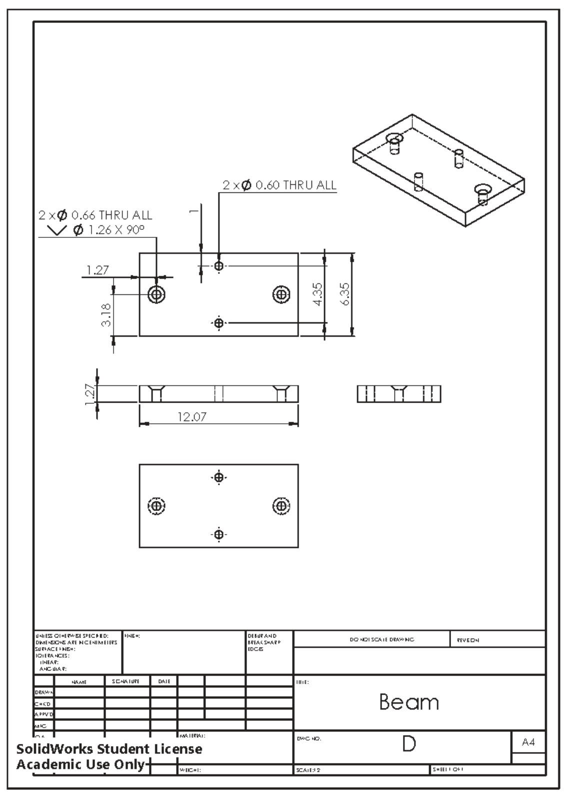
Same measurements for all other three holes on this face
4 x Ø 0.64 THRU ALL
⌴ Ø 1.10 ↧ 0.65
3.49
3.49
12.07
12.07
2.54
1.27
2.03
4 x Ø 0.64 ↧ 2.54
⌴ Ø 1.10 ↧ 0.65
Same measurements for all other three holes on this face
SolidWorks Student License
Academic Use Only
Acrylic
Sensor Base
A
A4



Ø 0.50 ↧ 1.70
M6 - 6H ↧ 1.70
6.03
1.27
1.27
12.50
3
2 x Ø 0.50 ↧ 1
M6 - 6H ↧ 1
17.78
12.07
2.54
1.27
2 x Ø 0.50 ↧ 1
M6 - 6H ↧ 1
8
2.03
SolidWorks Student License
Academic Use Only
Acrylic
Side Plate
B
A4



17.780
17.780
4.125
3
0.635
4 x Ø 0.660 THRU ALL
⌵ Ø 1.260 X 90°
Same dimensions for other holes
SolidWorks Student License
Academic Use Only
Acrylic
Board Holder
C
A4



2 x Ø 0.60 THRU ALL
2 x Ø 0.66 THRU ALL
⌵ Ø 1.26 X 90°
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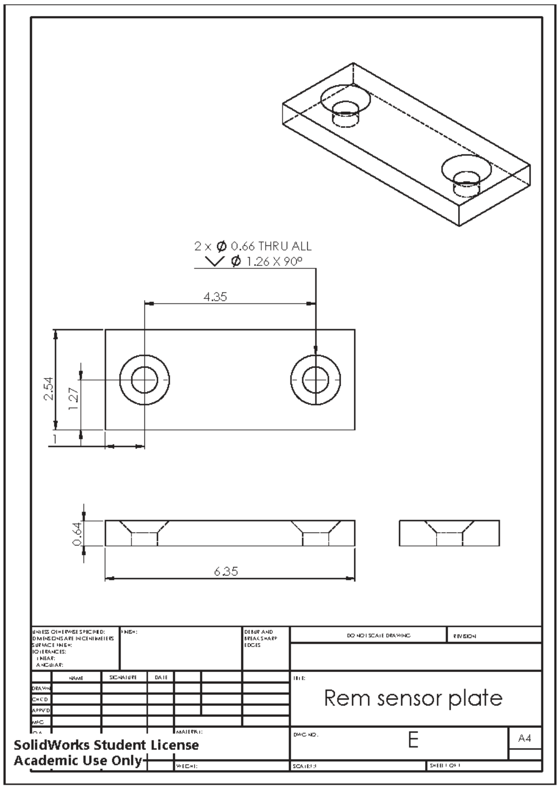
1.27
3.18
4.35
6.35
1.27
12.07
SolidWorks Student License
Academic Use Only
Beam
D
A4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⌵ ⌀ 1.26 X 90°
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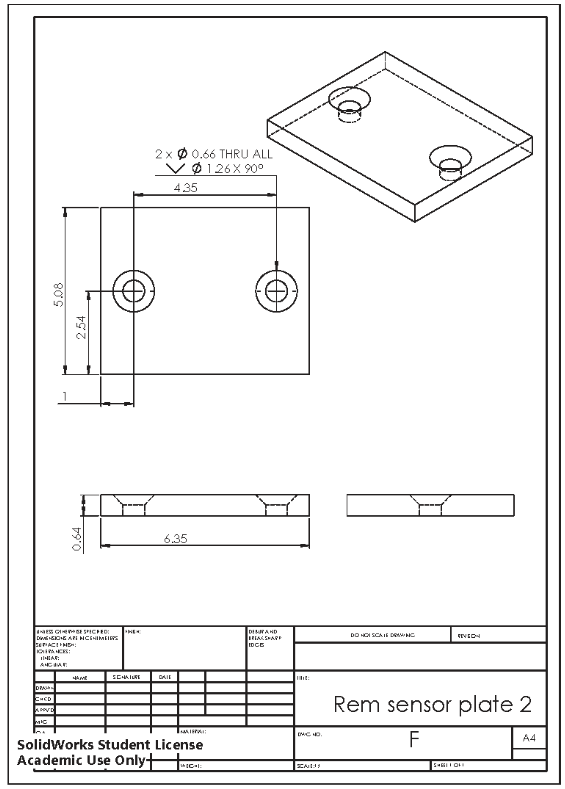
2.54
1.27
1
0.64
6.35
Rem sensor plate
E
A4
SolidWorks Student License
Academic Use Only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⌵ ⌀ 1.26 X 90°
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0.64
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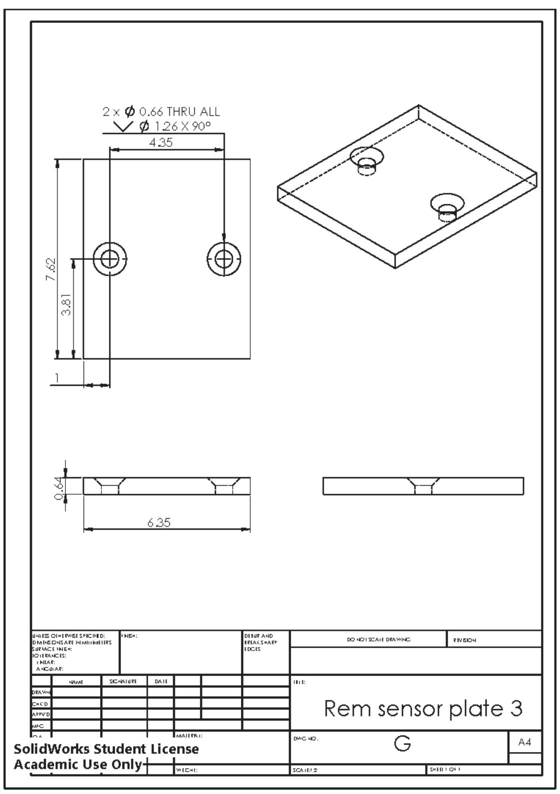
SolidWorks Student License
Academic Use Only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⌵ ⌀ 1.26 X 90°
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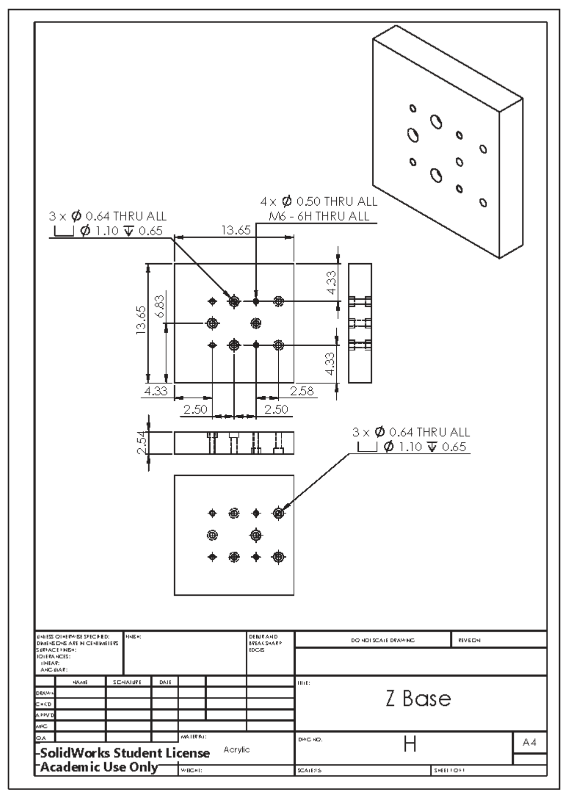
7.62
3.81
1
0.64
6.35
Rem sensor plate 3
G
A4
SolidWorks Student License
Academic Use Only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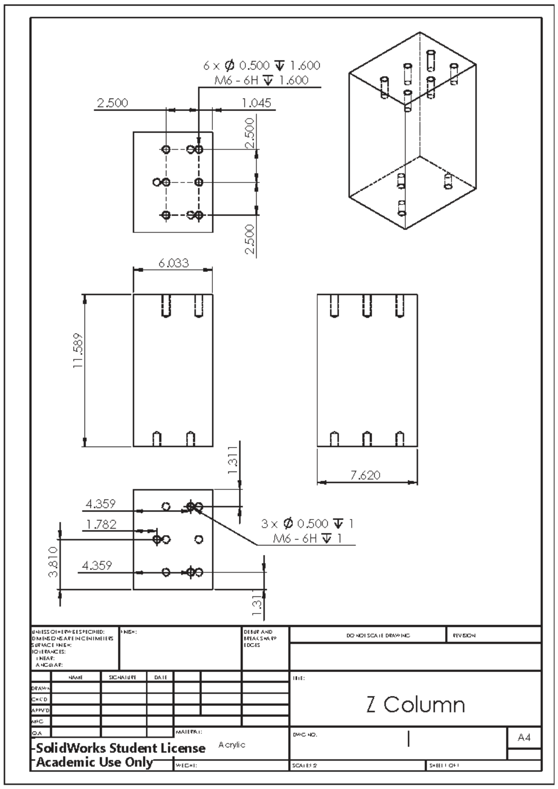
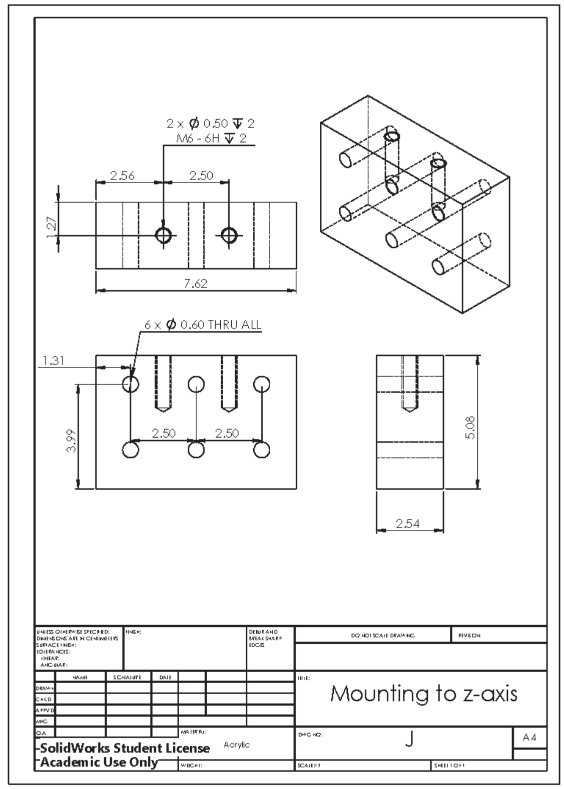
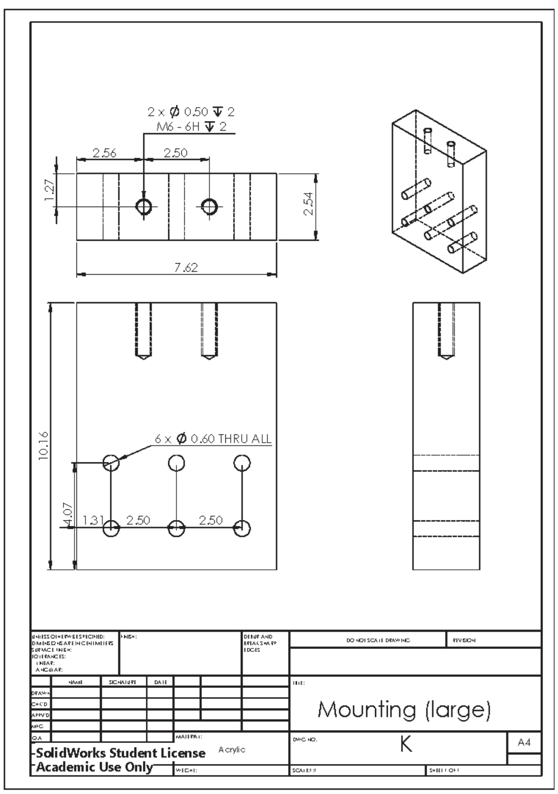
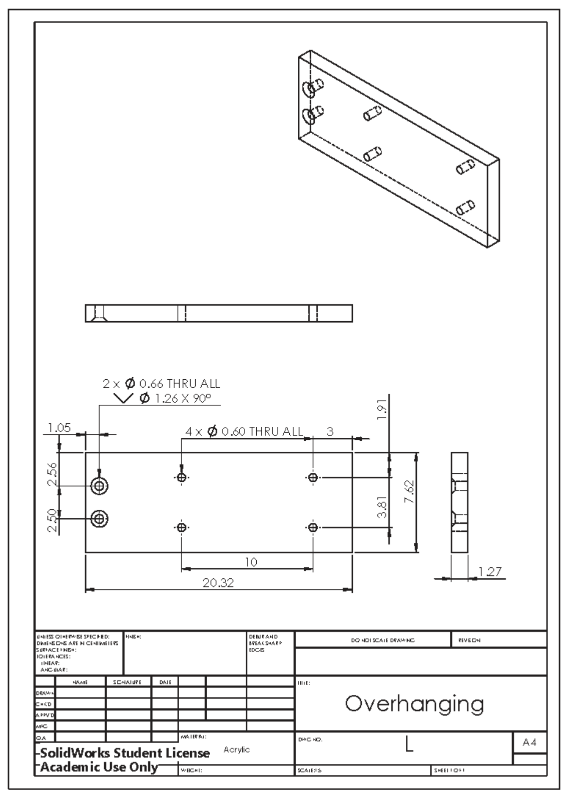
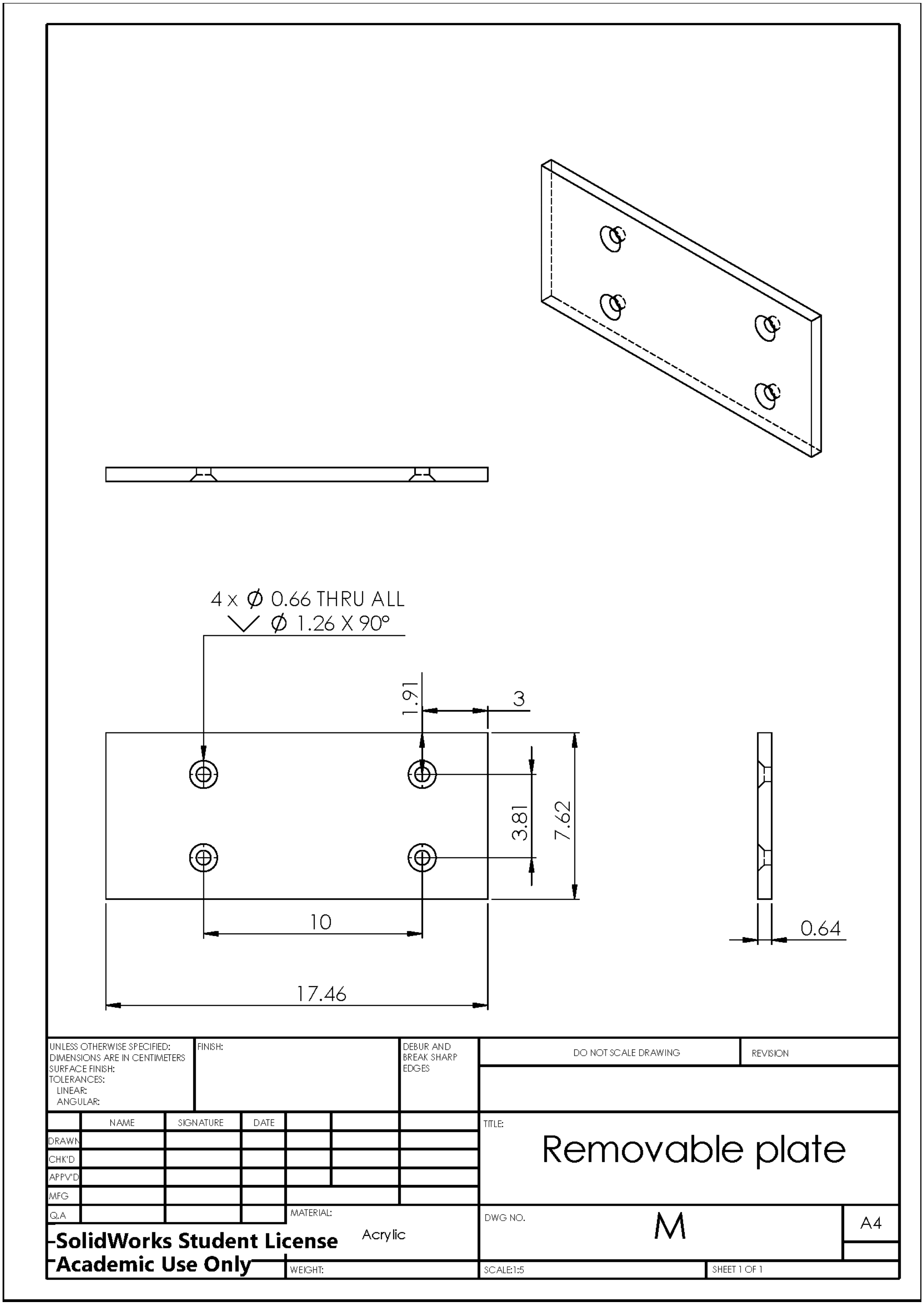
⌴ ⌀ 1.10 ↧ 0.65
4 x ⌀ 0.50 THRU ALL
M6 - 6H THRU ALL
13.65
4.33
6.83
4.33
4.33
2.58
2.50
2.50
2.54
3 x ⌀ 0.64 THRU ALL
⌴ ⌀ 1.10 ↧ 0.65
Z Base
Acrylic
H
A4
SolidWorks Student License
Academic Use Only


6 x ∅ 0.500 ↧ 1.600
M6 - 6H ↧ 1.600
2.500
1.045
2.500
2.500
6.033
11.589
7.620
1.311
4.359
1.782
3 x ∅ 0.500 ↧ 1
M6 - 6H ↧ 1
3.810
4.359
1.31
DO NOT SCALE DRAWING
Z Column
SolidWorks Student License
Academic Use Only
Acrylic
I
A4


2 x ∅ 0.50 ↧ 2
M6 - 6H ↧ 2
2.56
2.50
1.27
7.62
6 x ∅ 0.60 THRU ALL
1.31
2.50
2.50
3.99
5.08
2.54
DO NOT SCALE DRAWING
Mounting to z-axis
SolidWorks Student License
Academic Use Only
Acrylic
J
A4


2 x ∅ 0.50 ↧ 2
M6 - 6H ↧ 2
2.56
2.50
1.27
2.54
7.62
10.16
6 x ∅ 0.60 THRU ALL
4.07
1.31
2.50
2.50
DO NOT SCALE DRAWING
Mounting (large)
SolidWorks Student License
Academic Use Only
Acrylic
K
A4


2 x ∅ 0.66 THRU ALL
∨ ∅ 1.26 X 90°
1.05
4 x ∅ 0.60 THRU ALL
3
1.91
2.56
2.50
3.81
7.62
10
20.32
1.27
DO NOT SCALE DRAWING
Overhanging
SolidWorks Student License
Academic Use Only
Acrylic
L
A4


4 x Ø 0.66 THRU ALL
Ø 1.26 X 90°
1.91
3
3.81
7.62
10
17.46
0.64
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN CENTIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Removable plate
MATERIAL:
Acrylic
DWG NO.
M
A4
SolidWorks Student License
Academic Use Only
WEIGHT:
SCALE:1:5
SHEET 1 OF 1

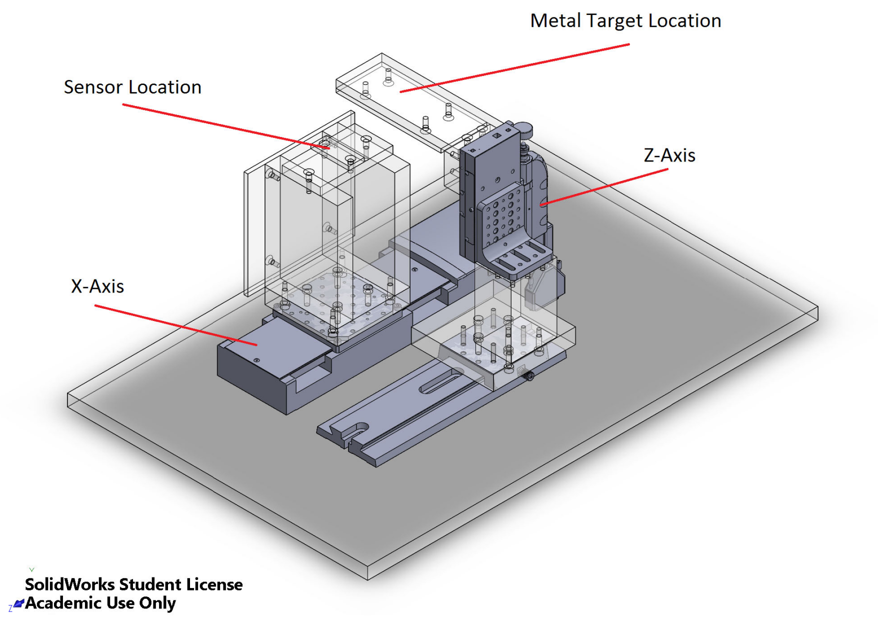


Figure 21: Isometric view of the complete assembly. Items that are clear are designed by me and made out of acrylic, while items in gray were bought already

Final Product

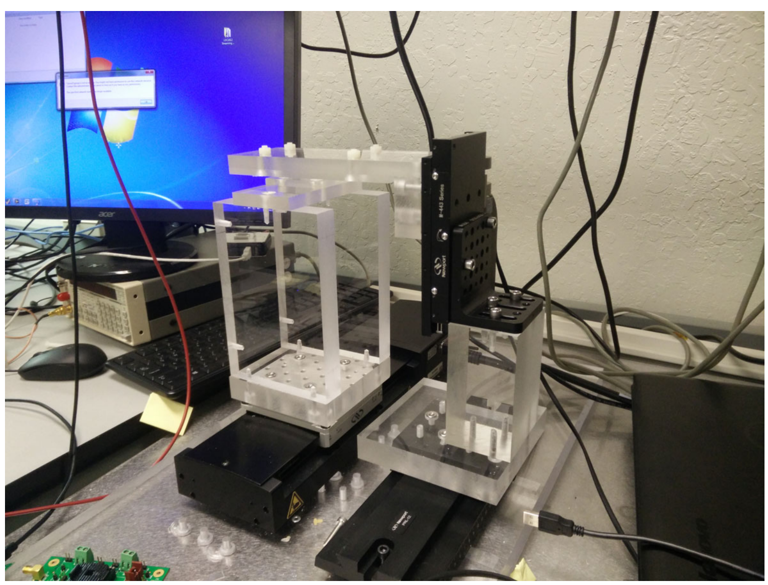


Figure 22: The final assembled product

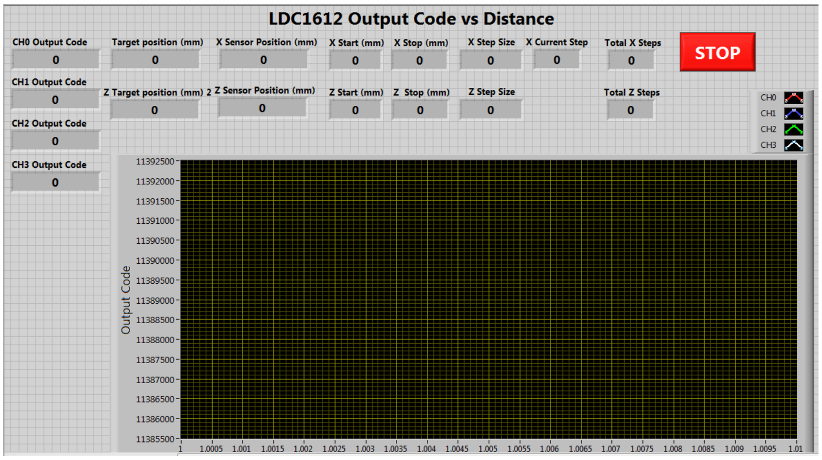


Figure 23: GUI for code written. It displays the code for each interval in the X-Axis and clears the plot when at a new position in the Z-Axis

Back to the Drawing Board (TI DIY Competition)

Description of Competition

This competition was hosted by Texas Instruments and the task was almost completely open-ended. The only requirement was that teams would have to develop either on the Beagle Bone Black or MSP 430.

Goal of the Team

In addition to music, I like other forms of art such as drawing and painting. As a result, I tried thinking of an idea that would help artists improve their trade or at least make it more enjoyable. Artists have recently need to transition in to digital forms such as tablets and drawing pads since many people consume entertainment with their phone. Unfortunately, many artists agree that it does not elicit the same feeling. Thus, I suggested making a mechanism that can allow artists to draw or paint on any surface with any tool, and produce that image digitally as well. The idea that I presented, which got made, was to have two encoders connected to a ring that read off the position of the tool. Since the ring is wide enough, any tool can be placed in it allowing for someone to use this to paint and draw.

My Contribution

When attempting to purchase string potentiometers, we noticed that they were very expensive. As a result, I created a cheap linear potentiometer using an L bracket, badge holder, two spools of thread and a rotary encoder. The mechanism can be seen in *Figure 24*. Additionally, I created the board everything sat on and wrote some code to allow the user to change the color of the pen in the virtual drawing pad.

The Product

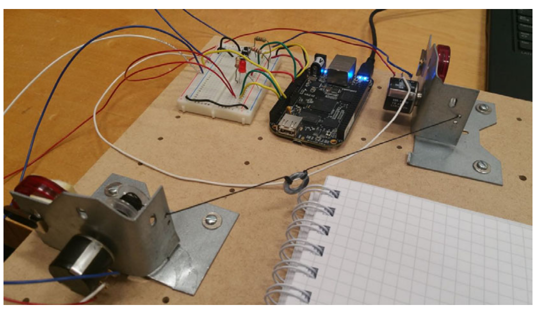


Figure 24: All components of the project

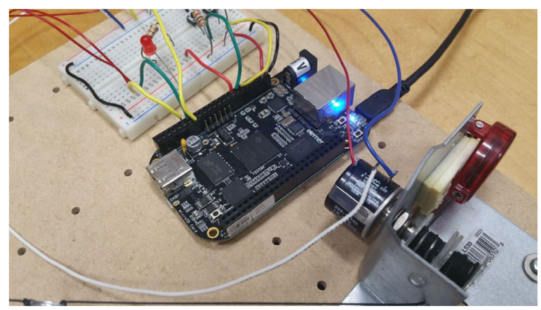


Figure 25: A closeup of the board and the in-house linear potentiometers

A video of this in action can be seen at: https://www.youtube.com/watch?v=Adoah9AO_zU

A more detailed description of project can be found at: https://www.hackster.io/cainstruments/back-to-the-drawing-board

Mini Robot

Purpose of Project

For my introductory circuits class, we built a small robot to learn about various topics such as filters, motor drivers, and op amps. Additionally, we use an MSP 430 to add some logic to the robot.

Circuit Diagram

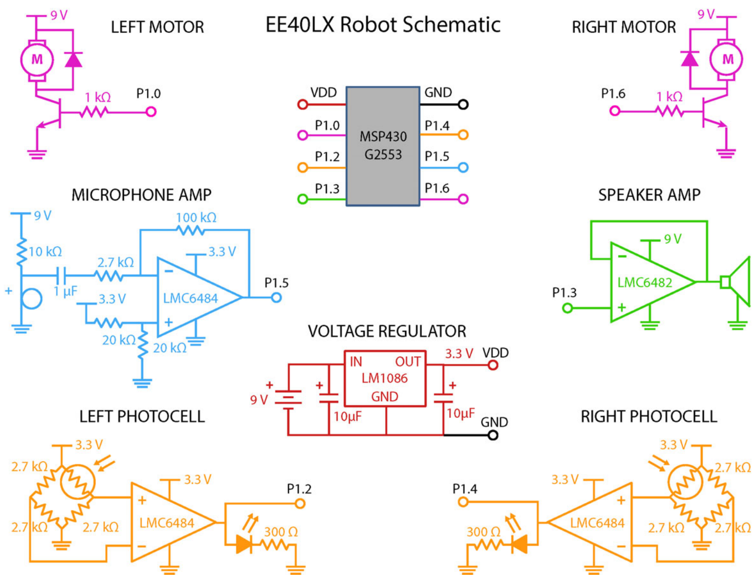


Figure 26: Schematic of all the parts put into the robot

Final Product

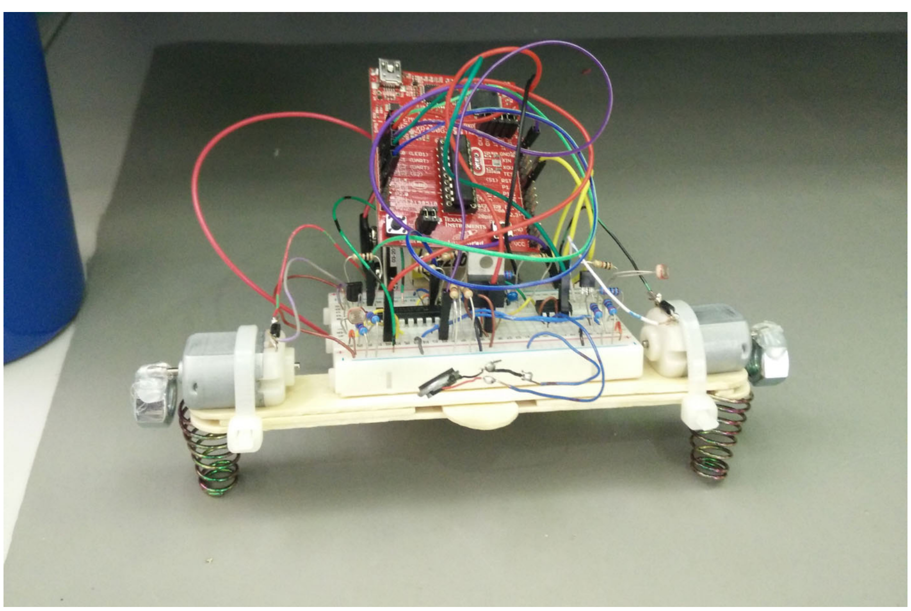


Figure 27: The final robot produced

Dancing Lights (Add-on to Mini Robot)

Purpose of Project

The purpose of this project was to add an extra analog system to the robot mentioned in the previous section. The limitations were minimal, so the project was very open ended. Since I was unsure of what to do, I turned to one of my passions, music, for inspiration. After giving the project some thought, I decided to make a circuit that would take any sound through a microphone and filter it with a bandpass filter in the analog domain. The amplitude of this signal would then correspond to the number of LEDs that are lit.

Circuitry, detailed in *Figure 28*, has the following chain of events:

- Signal from piezoelectric microphone is conditioned to fall between 0-3V with a DC offset of +1.65V
- Conditioned signal enters a Sallen-Key High Pass Filter to remove DC offset, along with other low freq signals, and magnify signal to +/-9V
- Signal goes through Sallen-Key Low Pass filter to chop off high frequency content
- Signal goes to a final op amp with variable gain using a potentiometer which is activated using a button switch
- Final signal goes to voltage divider which evenly divides the amplitude of signal into 4 sections
- Each point of division is forked into an op amp with unity gain, to prevent leakage current, that drives two LEDs with a BJT

Schematic Design

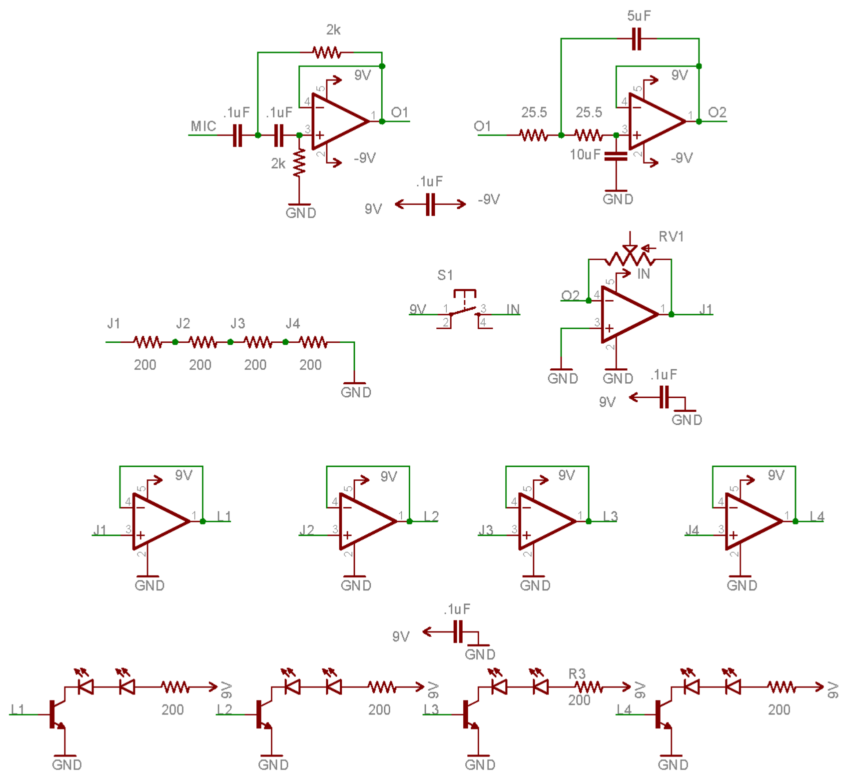


Figure 28: Schematic representation of the circuit I designed

Final Product

Figure 29: All the lights are turned on when the amplitude of the noise saturates the voltage seen across the series of resistors

A video of this circuit respond to the song "Light Pollution" by Lifeformed: https://www.youtube.com/watch?v=awmV00ETr7M

Rubens' Tube

Project Description

The Rubens' tube is a classic physics experiment used to demonstrate how sound travels as a wave, similar to light. The device works in the following way: a hollow cylinder is sealed off on both ends where one end houses a speaker and the other end feeds propane gas. Then, a series of equally spaced holes are drilled in one straight line on the outside allowing the gas to escape. This escaping gas is lit producing a series of columns of fire. Once a pure frequency is passed through the tube, points of compression and decompression cause more and less gas to escape from the drilled holes, respectively creating a sinusoidal pattern. This is depicted in *Figure 30*.

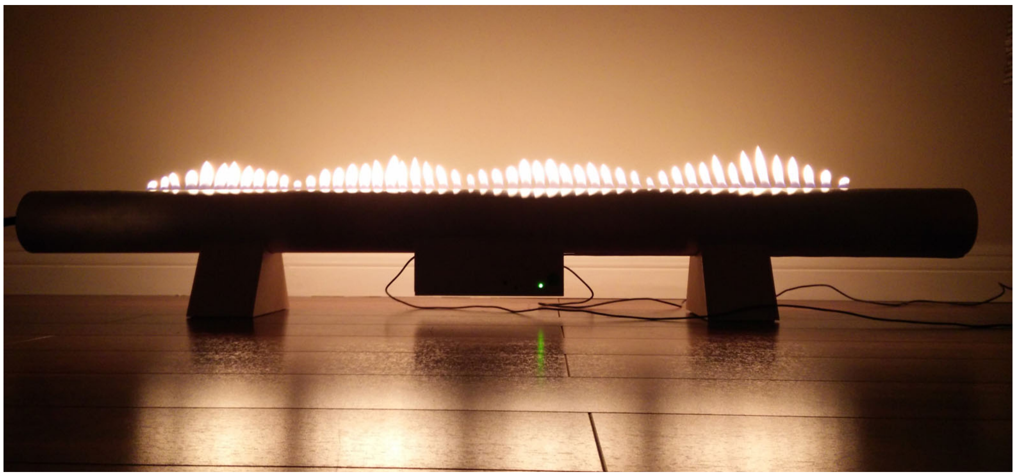


Figure 30: Rubens' tube responding to a pure sinusoid

Demonstration of the tube in action by playing the song "This Fire" by Lisa Miskovsky can be seen at: https://www.youtube.com/watch?v=6oIC_EgapOQ

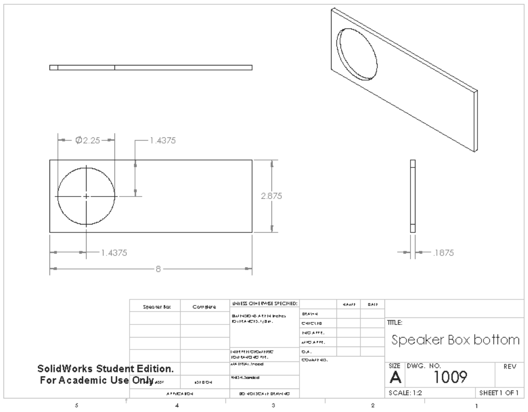
Reason for the Project

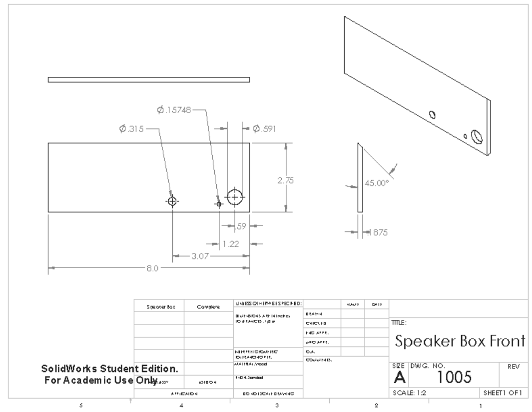
Back home, the winter season makes it too cold to sit outside during the night and relax with family. As a result, I thought I should build a heater. However, an ordinary heater is too boring; instead, I wanted something that would also be entertaining. Then, I realized that the Rubens' tube would be the perfect product for the job. Additionally, I thought my brother would benefit from learning a little about how sound works.

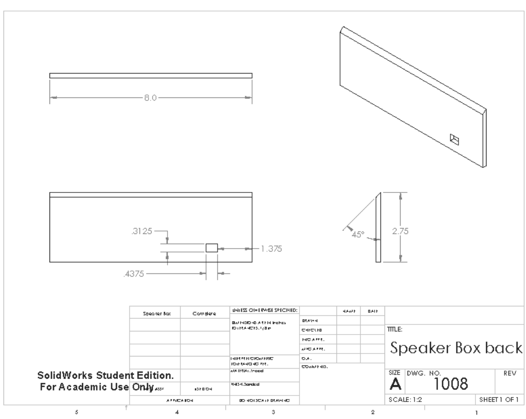
Challenges

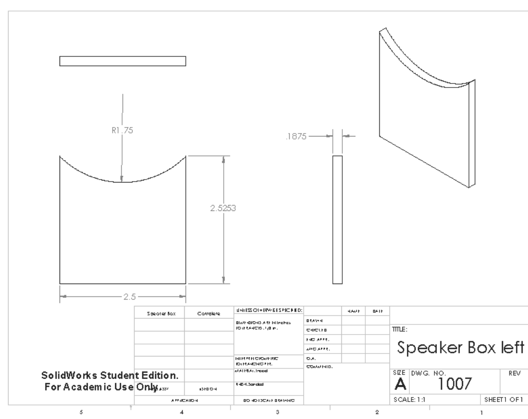
Most of the challenges came about from the manufacturing process. I did not have the right tools or materials for the job. As a result, I spent a lot of time figuring out where to buy the equipment I needed, and adjust my design accordingly if I couldn't find what I needed.

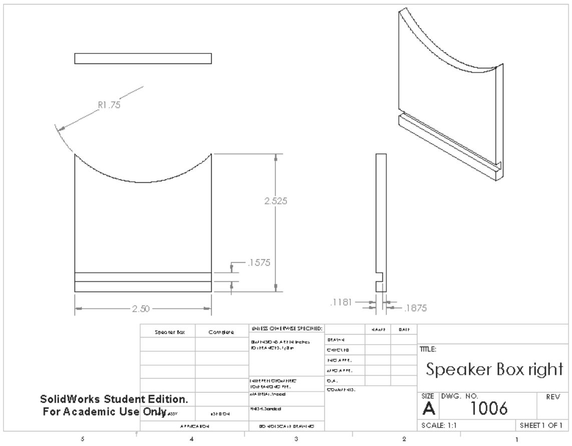
Drawings

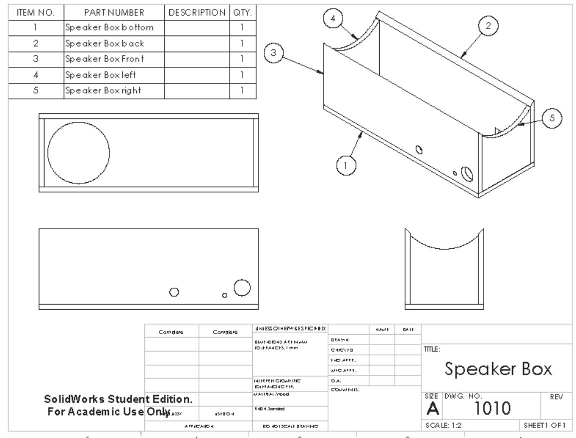

Ø2.25
1.4375
2.875
1.4375
8
.1875
SolidWorks Student Edition.
For Academic Use Only.
TITLE:
Speaker Box bottom
SIZE DWG. NO. REV
A 1009
SCALE: 1:2
SHEET 1 OF 1

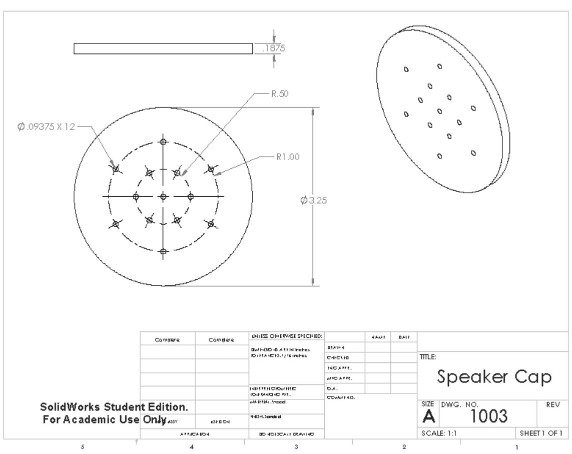

Ø.15748
Ø.315
Ø.591
2.75
45.00°
.59
1.22
3.07
8.0
.1875
SolidWorks Student Edition.
For Academic Use Only.
TITLE:
Speaker Box Front
SIZE DWG. NO. REV
A 1005
SCALE: 1:2
SHEET 1 OF 1

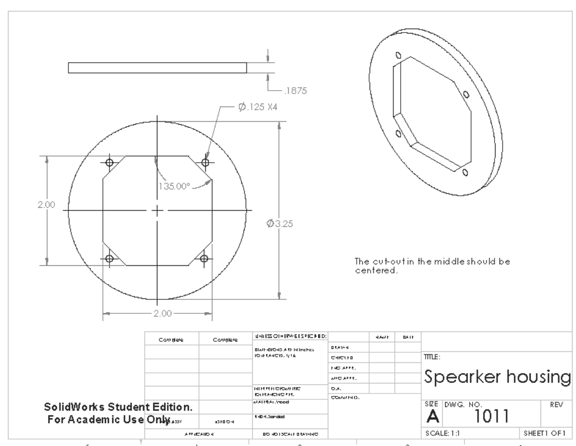

8.0
.3125
1.375
.4375
45°
2.75
SolidWorks Student Edition.
For Academic Use Only.
TITLE:
Speaker Box back
SIZE DWG. NO. REV
A 1008
SCALE: 1:2
SHEET 1 OF 1

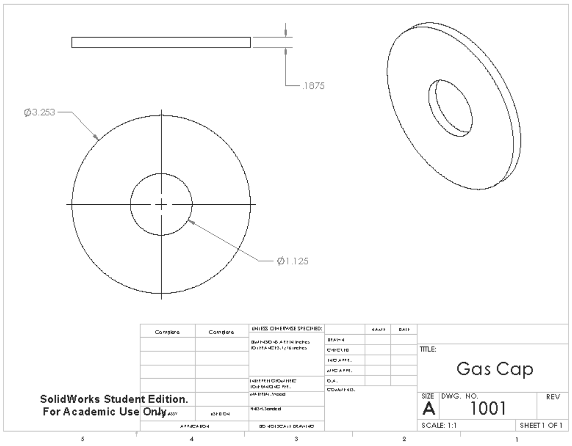

R1.75
.1875
2.5253
2.5
SolidWorks Student Edition.
For Academic Use Only.
TITLE:
Speaker Box left
SIZE DWG. NO. REV
A 1007
SCALE: 1:1
SHEET 1 OF 1

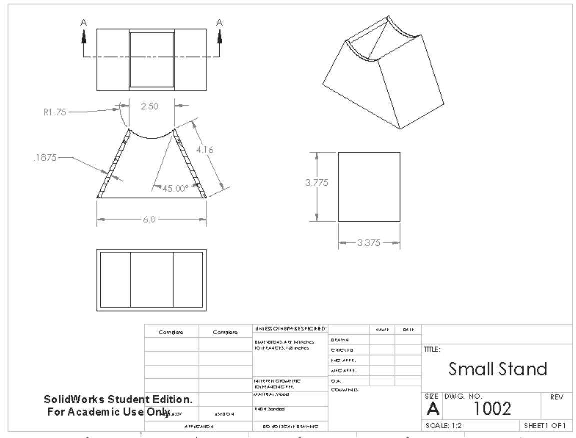

R1.75
2.525
.1575
2.50
.1181
.1875
Speaker Box right
SolidWorks Student Edition.
For Academic Use Only.
1006
SCALE: 1:1
SHEET 1 OF 1

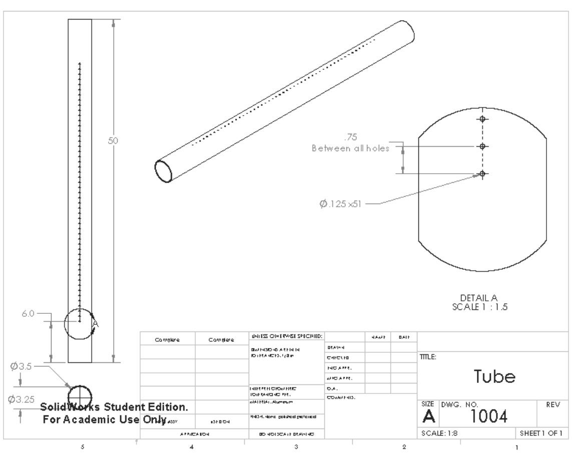

ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
1 | Speaker Box bottom | | 1
2 | Speaker Box back | | 1
3 | Speaker Box Front | | 1
4 | Speaker Box left | | 1
5 | Speaker Box right | | 1
Speaker Box
SolidWorks Student Edition.
For Academic Use Only.
1010
SCALE: 1:2
SHEET 1 OF 1

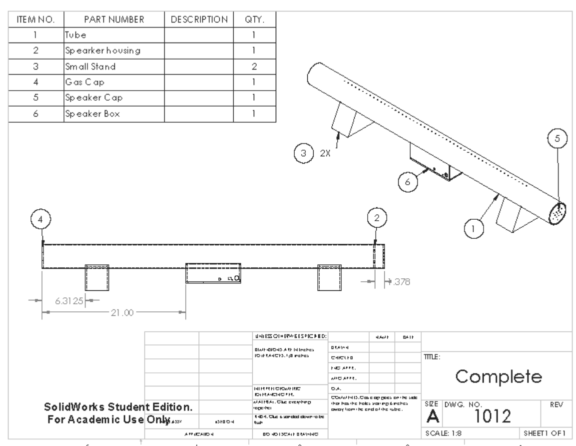

.1875
R.50
Ø.09375 X 12
R1.00
Ø3.25
Speaker Cap
SolidWorks Student Edition.
For Academic Use Only.
1003
SCALE: 1:1
SHEET 1 OF 1


.1875
Ø.125 X4
135.00°
2.00
Ø3.25
2.00
The cut-out in the middle should be centered.
Spearker housing
SolidWorks Student Edition.
For Academic Use Only.
1011
SCALE: 1:1
SHEET 1 OF 1


.1875
Ø3.253
Ø1.125
TITLE:
Gas Cap
SIZE DWG. NO. REV
A 1001
SCALE: 1:1
SHEET 1 OF 1
SolidWorks Student Edition.
For Academic Use Only.


A
A
R1.75
2.50
.1875
4.16
45.00°
6.0
3.775
3.375
TITLE:
Small Stand
SIZE DWG. NO. REV
A 1002
SCALE: 1:2
SHEET 1 OF 1
SolidWorks Student Edition.
For Academic Use Only.


50
.75
Between all holes
Ø.125 x51
DETAIL A
SCALE 1 : 1.5
6.0
Ø3.5
Ø3.25
TITLE:
Tube
SIZE DWG. NO. REV
A 1004
SCALE: 1:8
SHEET 1 OF 1
SolidWorks Student Edition.
For Academic Use Only.


ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
1 | Tube | | 1
2 | Spearker housing | | 1
3 | Small Stand | | 2
4 | Gas Cap | | 1
5 | Speaker Cap | | 1
6 | Speaker Box | | 1
2X
.378
6.3125
21.00
TITLE:
Complete
SIZE DWG. NO. REV
A 1012
SCALE: 1:8
SHEET 1 OF 1
SolidWorks Student Edition.
For Academic Use Only.

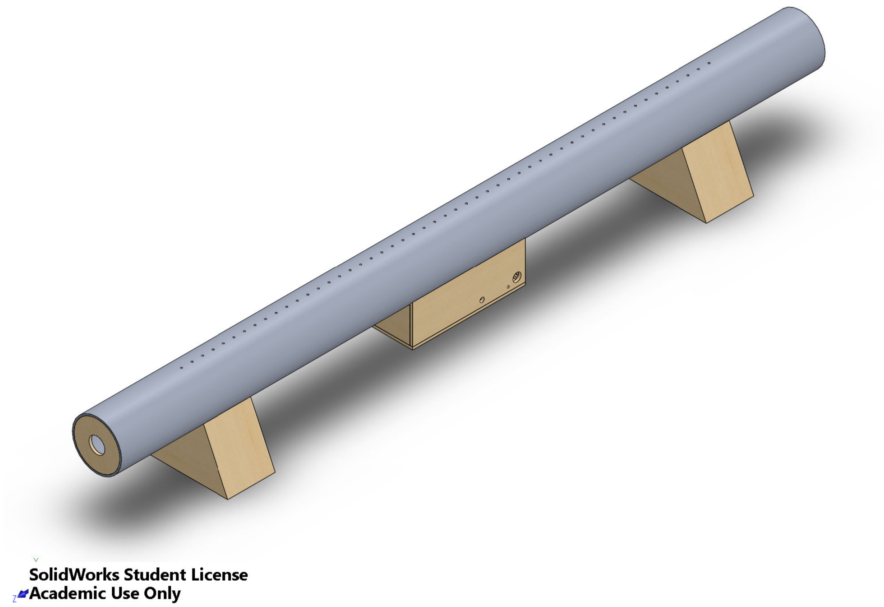


Figure 31: Isometric view of assembled product in Solidworks

Modular Robotic Arm

Project Description

For the Mechatronics Design course project, we designed and build a modular robotic system. The intended use was for applications that require repeated movements but also need flexibility due to a changing environment. Such a scenario could arise in small-scale manufacturing companies. Our group went over several possibilities, which lead to a final design where each linkage is responsible for a rotation and these linkages can be stacked on each other in the same orientation or rotated by 90 degrees.

Mechanical Design

As seen in *Figure 32*, the design was to construct a box shaped linkage that houses a high torque motor (2700 oz-in) and all of the electronics are housed internally. This allows for each unit to be replaced independent of the arrangement of the entire arm. Thus, a quick service can be made in case of mechanical failure.

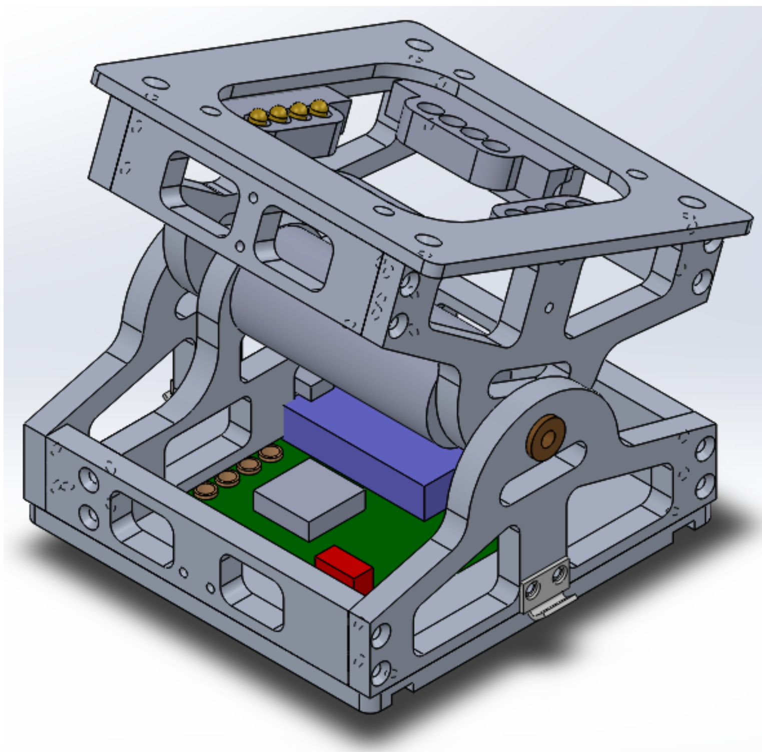


Figure 32: One linkage for modular robotic arm

Electrical Design

In order to keep the setup as modular as possible, each module had its own microcontroller (Arduino nano) which communicated to a central computing station (Raspberry Pi2) over I2C. In regards to the power delivery, all units were connected to a 36 V rail in order to minimize the current for the same power requirement which allows for thinner wires to be used. As a result, linear and switching regulators were used to step down the voltage to a safe level. The maximum expected power was computed for when 6 linkages are all stalled. A high-level schematic is shown below in *Figure 33*.

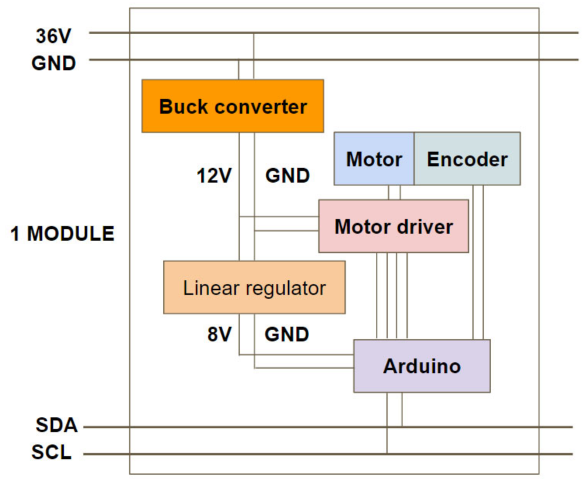


Figure 33: Electrical schematic of a single module

Final Product

The final electronics and complete project are shown in *Figure 34* and *28* respectively. Controlling the arm was done via a terminal on the Pi2, and motor controls were done with a PD controller. Additionally, the arm had other functionalities such as memorizing paths or executing paths defined a CSV file.

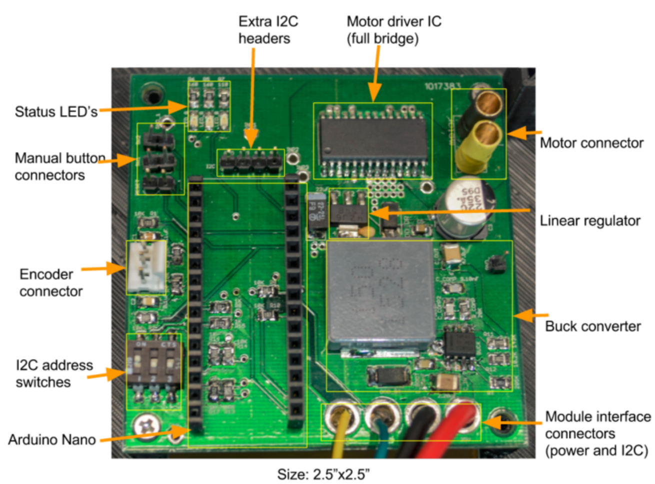


Figure 34: Final PCB housed in each unit

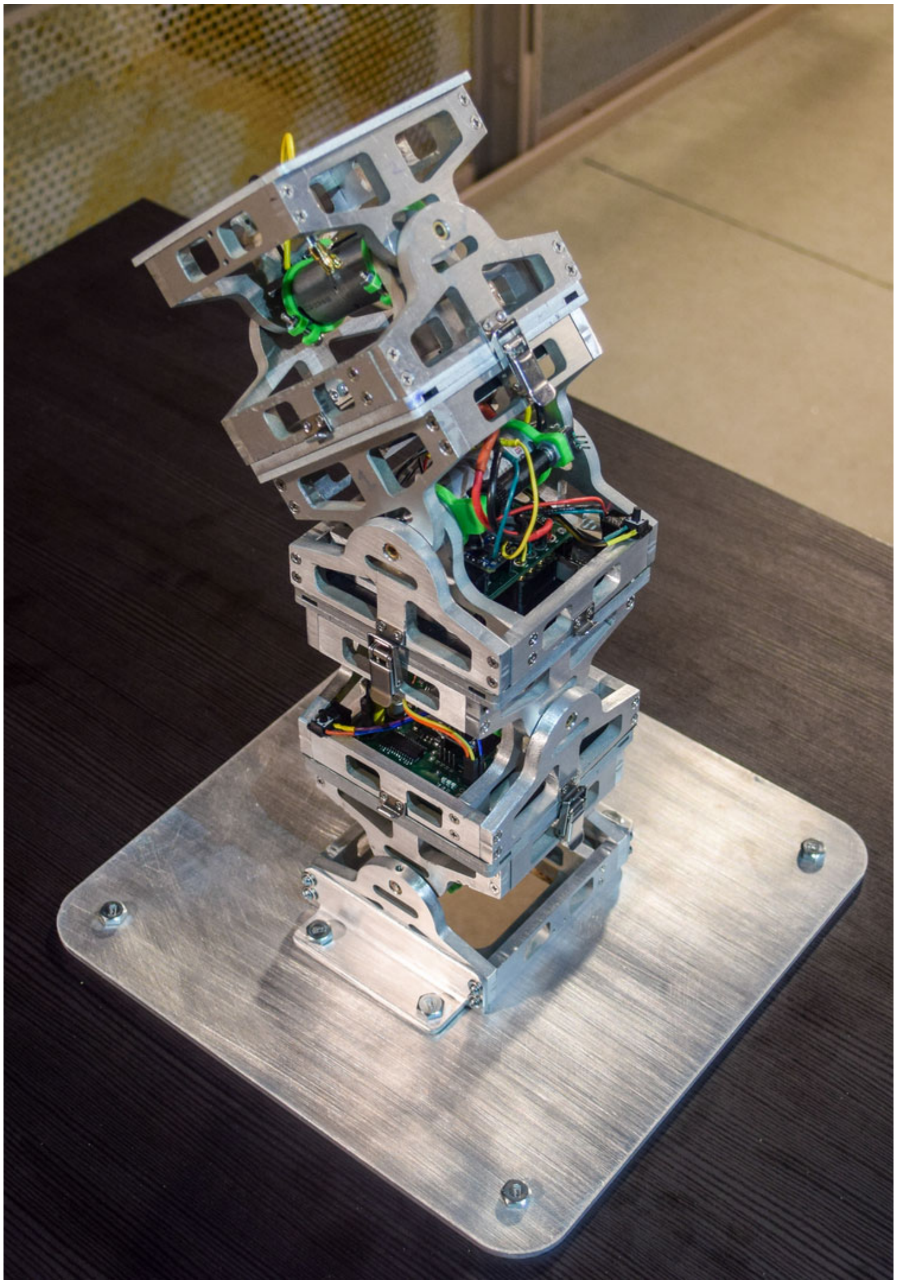


Figure 35: Completed modular arm

Lane Keeping with Obstacle Avoidance

Project Description

The goal of this project was to utilize the bicycle model of vehicles to perform a lane changing maneuver for an RC car in a closed loop. Additionally, an array of ultrasonic sensors were mounted to the body of the car to perform obstacle avoidance by changing lanes. When there were obstacles in all directions, the car would stop

Approach Taken

To accomplish this task, an analog line-scan camera was used for lane identification and, using a PD controller, the error between the desired lane location to the actual was brought as close to zero as possible. Concurrently, the readings from the ultrasonic sensors were being read via interrupts to determine if an obstacle is present. Once an obstacle is seen, the reference lane is changed in order to avoid the obstacle. To assess the performance of the lateral controller, a longitudinal PI controller was made to keep the car driving at a constant velocity. The entire system was executed on the system pictured in *Figure 36*.

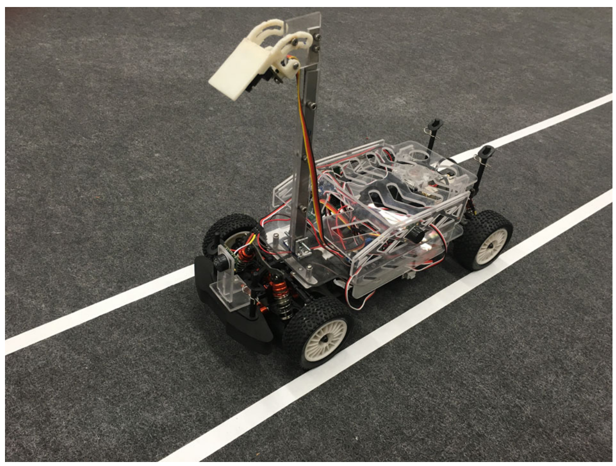


Figure 36: Car used for lane keepign and obstacle avoidance

Code for this project can be found at https://github.com/ych09041/me131lane.git, and a video demonstrating functionality at https://www.youtube.com/watch?v=5HKu7AaSsoM.

Gesture Controlled Quadcopter

Project Description

In this project, Quad X configuration drone was built on top of the APM 2.8 flight controller running the latest 3.2.1 firmware. Once built, python code was written to control the roll, pitch, and yaw angles as well as the throttle by getting feedback from the accelerometer, gyroscope and barometer onboard using a Leap Motion controller for gesture recognition. Communication was done over telemetry by using the droneKit wrapper. As a project for an embedded systems class, these goals were achieved with a methodical process by using concurrency via threads, having dynamic timing, and using broadcasters and listeners.

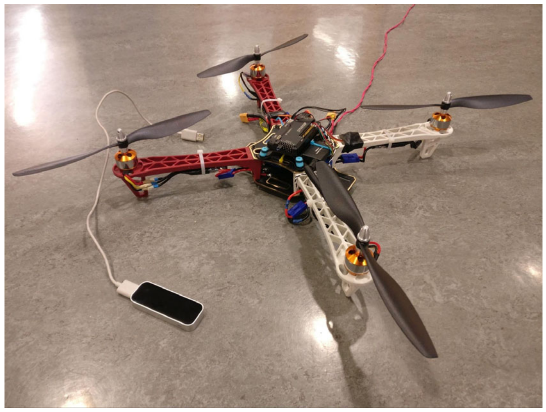


Figure 37: Drone with leap motion

The Copter

Building the quadcopter involved researching and understanding how these devices work in order to procure the right materials for construction. The two components that were salvaged from another quadcopter used in the past were the ESCs and motors due to monetary constraints. Unfortunately, the ESCs proved to be difficult to use since old SimonK firmware was flashed on them. Additionally, one of the ESCs was completely broken. As a result, a similar ESC was bought and all of the working ESCs were flashed with the latest BLHeli firmware that worked for the board. This was accomplished by using a USBAsp and soldering to the pads as shown in *Figure 38*. With the ESCs flashed, the hardware was up and running and tested using an RC controller.

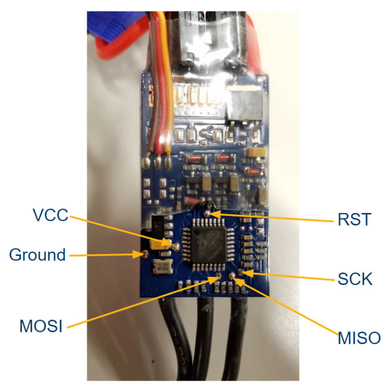


Figure 38: Pinout for flashing Spider 30A OPTO ESC

Control Logic

Controlling the quadcopter was done by using the telemetry to override the channel input of an RC controller, and sending computed values from a laptop. In order to control the roll and pitch angles of the quadcopter, feedback was used by the pre-integrated gyro data offered by the APM via droneKit using a proportional controller. Since the quadcopter was in stabilize mode, the RC channel values correspond to a roll and pitch angle. Thus, the feedback was very stable. Controlling yaw was slightly less stable since the same methodology was used, but this time the channel value corresponds to a yaw *rate* rather an absolute yaw angle. Thus, to improve stability, the maximum yaw rate was limited. Lastly, controlling throttle was done correlating the channel input to a desired acceleration. This acceleration is with respect to the global inertial frame. However, the acceleration values obtained from the quadcopter are with respect to its own noninertial body frame. Thus, a rotation matrix, seen in *Figure 39*, was applied to the vector of body-fixed-frame acceleration values and proportional feedback was done on these values. The reference values were obtained by the Leap Motion where the relative height of the left hand corresponds to the throttle and the orientation of the right hand corresponds to the desired roll, pitch, and yaw angles. Testing each component was done in steps by having the Leap only control one axis at a time for safety purposes. A statechart depicting the high-level processes done by software is shown in *Figure 40*.

$$\begin{bmatrix} \cos\theta\cos\psi & \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi \\ \cos\theta\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi \\ -\sin\theta & \sin\phi\cos\theta & \cos\phi\cos\theta \end{bmatrix}$$

Figure 39: 3D coordinate transformation with 3-2-1 basis

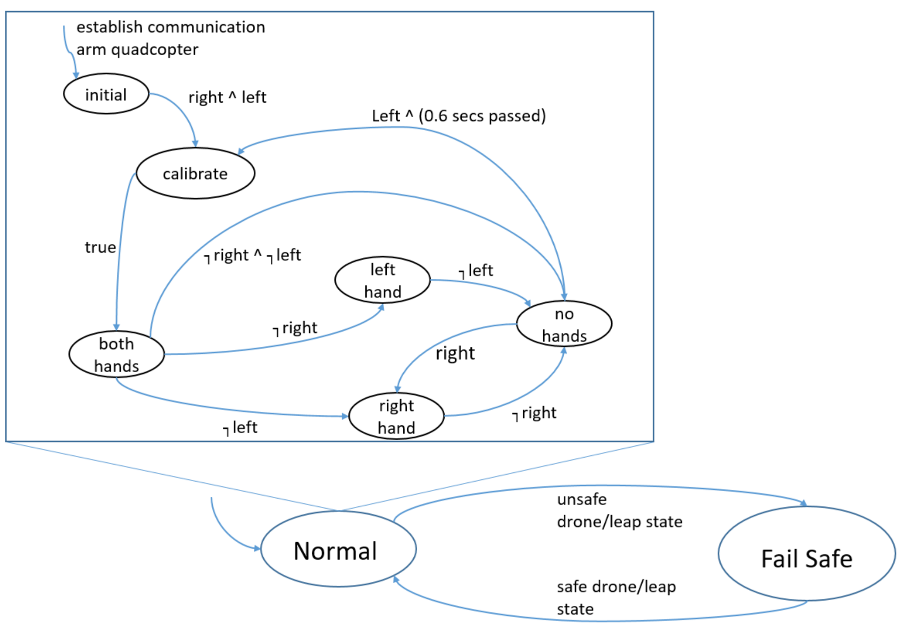


Figure 40: State chart of software architecture for gesture controlled drone

Code: https://github.com/arjunmehta94/EECS149project

Video: https://www.youtube.com/watch?v=9tlubUa04NE&feature=youtu.be

Baxter Robot Kitchen Assistant

Project Description

Utilizing the Baxter robotics platform, a kitchen assistant was created that would be given an instruction list such as cutting carrots or washing dishes and it would execute the tasks as efficiently as possible. The items to be picked up were not placed in the same position, rather AR tags were used to identify all items. Additionally, when items were moved, constraints were set in place to make sure no collisions occurred. An example environment is shown in *Figure 41*.

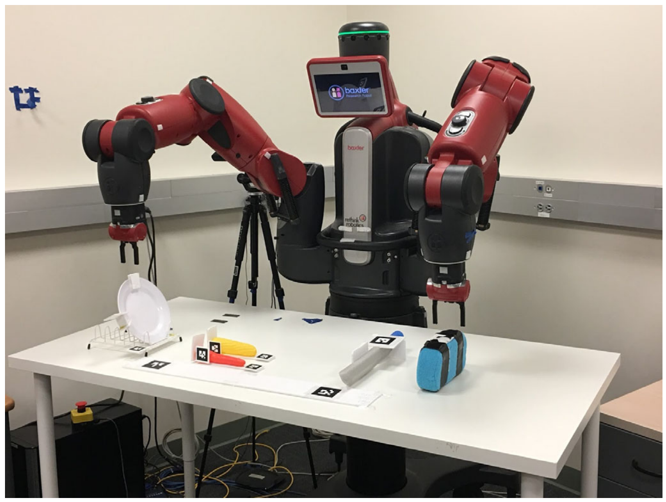


Figure 41: Environment of Baxter kitchen assistant

Identifying Objects

In order to locate items in the environment, objects were marked with AR tags and read by a camera facing the table. Since Baxter's arms or other items could interfere with the detection of an AR tags, AR bundles were used for robustness. An AR bundle is a grouping of AR tags which all reference the same position of a master AR tag. This ensures that occlusion won't be an issue. The ROS package that helped achieve this was AR_track_alvar. A visual representation of the bundles is shown in *Figure 42*.

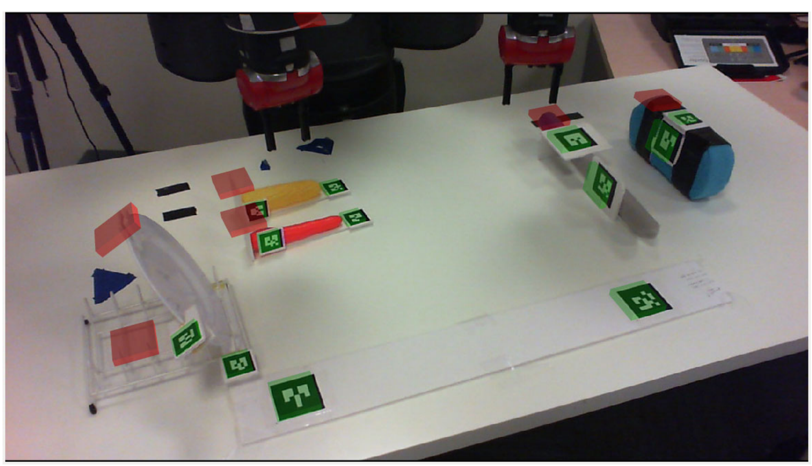


Figure 42: Visualizing the bundles

Avoiding Collisions

To improve robustness even more, collision avoidance was another challenge that was sought to be achieved. This was accomplished by using the Planning Scene Interface of moveit_commander to create a virtual representation of the physical environment that would then be used to by moveit_commander when computing the numerical inverse kinematics. A depiction of the physical environment in the Planning Scene is shown in *Figure 43*.

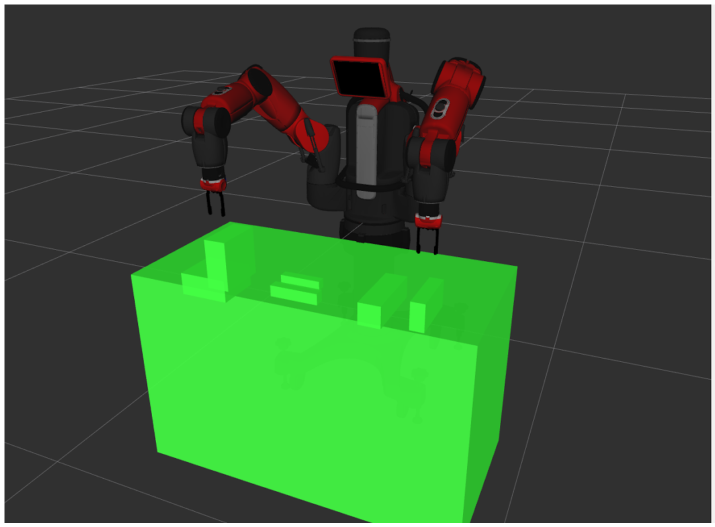


Figure 43: Representation of the environment in the obstacle world

Code: https://github.com/ych09041/ee206akitchen

Video: https://www.youtube.com/watch?v=RnBeRQ3_RMI