Autonomous Lawn Care Unit

PROJECT PLAN

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1 Introductory Material

1.1 Acknowledgement

If a client, an organization, or an individual has contributed or will contribute significant assistance in the form of technical advice, equipment, financial aid, etc., an acknowledgment of this contribution shall be included in a separate section of the project plan.

1.2 Problem Statement

The problem we intend to solve concerns the time and financial commitment required to upkeep a well-groomed lawn. There is a long list of reasons a certain individual may not be able to mow their lawn, ranging from lack of time to physical incapabilities. Someone who falls into this category does not have many options to get the job done, without hiring expensive, third-party help.

We intend to solve this problem by designing a safe, functional, and affordable autonomous lawn mower. This will give lawn-owners a relatively inexpensive, low-effort means of maintaining their lawn effectively. Our autonomous lawn mower will be able to mow any predefined area with maximum accuracy and efficiency safely.

1.3 Operating Environment

The general environment for our product will be a dry lawn. As with any lawnmower it, it would have trouble cutting wet grass. The wet lawn would also make it difficult for our lawnmower to retain traction and be able to travel up steeper terrain. Our mower will be spending most its time outside. Therefore, it must have some water and dust resistance. The electrical components are very susceptible to water, and they must be kept dry. Lots of dust could cause static electricity to build up, which could kill the components. The next thing we would have to worry about is the mower overheating. We will need to keep the electronic components out of direct sunlight. When we implement something to keep the components dry and dust free, it would also double as a shield from the sun.

1.4 Intended Users and Intended Uses

Our intended users are anyone who needs their lawn mowed. If you own a home, you most likely need to keep your lawn trimmed. There are many reasons why someone may not be able to d0 this. For example, some people do not have the time, and some people have physical incapabilities.

The uses for our product would be to mow a lawn. We picture it being used by residents and not corporations. The primary goal of our product will be to make the lives of the user's a little bit easier.

1.5 Assumptions and Limitations

- Assumptions
    - Residential, non commercial use.
    - Battery Powered
    - ⅕ Acre Lawn
    - Resident has wifi setup
- Limitations
    - Steep Terrain
    - Dry Conditions
    - Grass must not be overgrown
    - Must be under 45 pounds
    - Can only cut within specified parameters created by the wire

1.6 Expected End Product and Other Deliverables

- Safe and Affordable autonomous lawnmower.
    - Lawn mower can find and avoid hazards in lawn.
    - It is affordable compared to other mowers on the market.
    - Lawn mower can cut the entire lawn on 1 charge
    - Mower meets the basic safety standards set by IEEE
- Android App to control lawnmower.
    - This will tell the lawnmower when and where to mow. As well as view mower stats.
    - Android App will be able to control the mower via bluetooth
    - The app will also keep track of the mowers location via gps

We will have the mower completed before December of 2018.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The ultimate goal of our project is to deliver a safe, affordable autonomous lawn mowing system. The system includes the lawnmower device, perimeter mapping device, and software to control both of these.

2.2 Functional Requirements

- Algorithm to efficiently mow entirety of area given a mapped perimeter
  - Intelligent routes will ensure straight lines
- System to map perimeter of the lawn
  - Easy installation
  - Low power
- Object detection and avoidance
  - Use various sensors to accurately detect and avoid objects
  - Navigate around hazardous areas in a lawn
- Mobility through standard lawns
  - Drive up 30% grade
  - Lightweight
- Algorithm to detect and avoid safety concerns
  - Easy shutoff consistent with sensor stimuli
  - Indicate current state
- Power efficiency
  - Auto-charging feature
  - Charge and mowing time to fall between 60-90 minutes
- Streamlined interfacing
  - Android app for communication and diagnostics
- GPS module for directional guidance

2.3 Constraints Considerations

- Battery life to complete job or return to charging station
- Lightweight enough to be easily moved by hand
- Algorithm execution rate of 100Hz
- Design consists of affordable parts, and is reasonable for the domestic market
- 15% incline maximum
- 3.5 inch maximum grass height
- The motors will shut off if the mower is lifted off the ground
- Bump sensors to prevent unwanted mowing of objects

IEEE Standards that we will be following:

Safety:

IEEE C2: National Electrical Safety Code (2007)

Wireless/Mobile Connections:

IEEE 802.11p: WIFI this standard is part of the IEEE 802 family(LAN and MAN) networks. This standard is for information technology in lan and man networks for vehicular environments

IEEE 1609.2: Standard for Wireless Access in Vehicular Environments— Security Services for Applications and Management Messages(IEEE Std 1609.2): Make sure your wireless connection within a vehicle is secure.

IEEE 1609.3 IEEE S: The purpose of this standard is to provide addressing and data delivery services within a WAVE system, providing multiple higher layer entities access to WAVE communication services. Upper layer support includes in-vehicle applications offering safety and convenience to their users.

Hardware:

IEEE Std 1012-2016: Verification and validation (V&V) processes are used to determine whether the development products of a given activity conform to the requirements of that activity

2.4 Previous Work And Literature

There are several autonomous lawn mowers sold by lots of different companies available on the market. The majority of these lawn mowers are above 2000 dollars and resemble roombas. These lawn mowers use boundary wire, and the mower mows in random directions that are within the boundary wire perimeter. We conducted research of the current market to compare mowers from different companies. In this research, we compared the price and other variables which we believed is pertinent to our mower. This research is documented in the excel linked below. After conducting this research, we believe that our project will be cheaper than the majority of these products. Another thing our project will try to improve on is the mowing algorithm we will try to cut in an organized way and avoid cutting already cut grass rather than random movements within the wire perimeter.

Example of a mower which is expensive and uses a random mowing algorithm:

RS Model. (n.d.). Retrieved from https://www.robomow.com/en-GB/platform/rs/

Excel Sheet:

https://docs.google.com/spreadsheets/d/1waZLEHPhGPK-LqDRXmTi1eaSke41UbJOGq0iGLr6axQ/edit#gid=0

2.5 Proposed Design

Our lawn mower design is to create an RC chassis out of C channels, two caster wheels in the front, and two fixed wheels in the back. The two fixed wheels will each be powered by their own motor. We will use a microcontroller to read the sensors and control movement. For the blade, we decided on using a reel blade that will be attached towards the front of the mower. This blade will be powered by its motor. To make our mower autonomous, we will have boundary wire surrounding the portions of the lawn that will mowed. The mower will use the wire for guidance and mow within the desired perimeter. One design alternative was to modify an existing mower and make it autonomous using our microcontroller code.

Prototype Solidworks Design:
Refer to Figure 4.1, 4.2, and 4.3

2.6 Technology Considerations

Microcontrollers:

Arduino Mega

Pros

- Easy to program
- Many I/O ports
- Inexpensive (<$40)
- Prior team experience with Arduino
- Easy integration with GPS

Raspberry Pi 3

Pros

- Easy to program
- Has built in bluetooth and wireless modules
- Inexpensive(<$35)
- Easy to connect with Arduino

Deck:

Adapt an existing electric lawn mower

Pros

- Larger cutting radius

Cons

- Controller and wheels will draw power from battery
- Hard to move around and work on
- Larger mechanical component
- Add motors and caster wheels
- Bulky/ hard to navigate

DIY deck

Pros

- Inexpensive
- Wire, blade, or disk
- More leeway with size/ power
- Lightweight

Cons

- Less refined

Adapt trimmer

Pros

- Inexpensive
- Lightweight
- Low power

Cons

- Larger mechanical component
- Harder to integrate

Drivetrain:

Electric wheelchair wheels ($80-$200)

Pros

- Powerful (24V)
- Relatively inexpensive

Cons

- Better for full sized mower
- More current draw
- Heavier

RC wheels / tracks ($40-$150)

Pros

- Inexpensive
- More options
- Possibly include chassis
- Zero turn radius (tracks)

Cons

- Less powerful (9 - 12v)

Based on our collective research, we believe the best direction for this project is to create our own deck from scratch. Though creating the deck from scratch requires some initial mechanical engineering, it will ultimately require much less of a mechanical component than adapting an existing mower. This is due to the lack of existing mowers that meet our requirements. By creating our own deck, it will allow us to meet our design requirements and it will give us a lot more freedom in our other design choices.

A custom deck will be very inexpensive, lightweight, and provide us with more options. We can make this device very mobile and light, which will make testing much easier. An RC-scaled product gives us the ability to use less power, cut intricately, and realize the idea at a very low cost.

2.7 Safety Considerations

There are several safety concerns that should concern the consumer:

1. Young children should stay away from the mower at all times while running.
2. Stones, debris, and other large objects should be removed from the lawn prior to mowing to prevent injuries.

2.8 Task Approach

Our method has five parts to it: empathize, define, ideate, prototype, and test. For the empathize portion, we came up with a list of people which would need the mower. We had to understand why they needed an autonomous mower and what specific tasks the mower should perform. Regarding defining, we decided that an autonomous mower which is affordable and accessible to use. The ideate will help us think outside the box in our brainstorming and come up with more options that we see nothing like in the market. We looked at several competitors and mixed and matched their strengths. After researching many different possible prototypes, we finally created a prototype that was approved by our faculty advisor and ETG. This prototype meets all of our requirements such as weight, power, and efficiency. This prototype is also considerably under the budget that we were given. Once the prototype is created, we will be testing the mower to make sure it meets the standards we set for it. Some of these standards are: mow the whole lawn on one charge, mow the lawn thoroughly without missing any large sections, and making sure the mower can complete its task safely.

2.9 Possible Risks And Risk Management

- Finding the best components that fit the smaller scale design that we have for our mower.
- Having a lack of mechanical engineering knowledge.
- Cost could be high with the niche components that we are looking for.
- Purchasing and receiving the various components could take longer than expected.

2.10 Project Proposed Milestones and Evaluation Criteria

- Research and all options weighed
- Selection and purchase of parts for the mower

- Mower drivetrain is finished
- Have the microcontroller and sensors attached to the mower base
- Control the mowers movements using a remote
- Have the mower move autonomously
- Let the mower mow a lawn without human guidance

2.11 Project Tracking Procedures

We will be using gitlab issues and google docs to keep track of our project throughout the two semesters.

2.12 Expected Results and Validation

The desired outcome of our project is to provide a safe and affordable autonomous lawn mower. Our goal is to have this lawn mower sell for under $1500 and cover about ⅕ of an acre and be able to go on an incline up to 15%.

To validate our results, we will keep track of how far the mower has moved on one charge and calculate the total area covered. We will also test the mower on a grassy hill to make sure it has the power and traction necessary to move up an incline. Currently, with all our parts combined we are at $1100 which is considerably under the $3000 budget we were given.

2.13 Test Plan

Testing types:

Software:

1. Make sure that there is a good connection between the microcontrollers and the motors of the mower
2. Make sure that the mower is moving in the correct direction
3. Test if the arduino and the raspberry pi have a solid connection

Hardware:

1. All parts of the mower are connected securely and safely
2. All the sensors are receiving accurate data
3. The mower is operating at the correct speeds
4. Battery is charging correctly
5. The mower should be able to withstand certain conditions

Mobile:

1. The app should be connected to the mower correctly
2. Data from the mower should be shown to the user
3. Server for logging in should be working correctly
4. The app is able to control the mower wirelessly via bluetooth

Hardware Testing: PWM motor control and GPS data acquisition

We wrote Arduino code to generate a PWM signal on the digital pins and communicate with the motor controller. A 1ms pulse corresponds to full speed backward, and a 2ms pulse corresponds to full speed forward, and a 1.5 ms pulse stops the motor from moving. Initially, we tried using the Arduino analogWrite() function to generate the waveforms, but this only offers an 8-bit resolution, and we had considerable error. analogWrite() uses a 20ms period.

	Expected Pulse Width (ms)	Expected Duty Cycle (%)	analogWrite() Value	Measured Pulse Width (ms)	Measured Duty Cycle (%)	Error in Pulse Width (%)
Full Speed Backward	1	4.896	12 13 (12.48)	.974 1.056	4.765 5.141	2.6 5.6
Half Speed Backward	1.25	6.12	15 16 (15.606)	1.216 1.293	5.956 6.332	2.72 3.44
Stopped	1.5	7.344	18 19 (18.727)	1.456 1.533	7.085 7.461	2.93 2.2
Half Speed Forward	1.75	8.568	21 22 (21.848)	1.693 1.776	8.276 8.652	3.26 1.49
Full Speed Forward	2	9.792	25 (24.97)	2.008	9.812	0.4

Table 2.1: 8-bit resolution PWM using analogWrite()

To achieve 16-bit resolution, we modified the code to use the Arduinos built in timers and adjusted the prescalers to use a 4ms period. With 16-bit resolution, we got very insignificant error and were confident in the waveforms we would be sending to the motor controller.

	Expected Pulse Width (ms)	Expected Duty Cycle (%)	setMotor() value	Measured Pulse Width (ms)	Error in Pulse Width (%)
Full Speed Backward	1	24.414	16000 (15999.71)	.9991	0.09
Half Speed Backward	1.25	30.518	20000 (19999.97)	1.249	0.08
Stopped	1.5	36.621	24000 (23999.57)	1.499	0.06
Half Speed Forward	1.75	42.725	28000 (27999.83)	1.748	0.11
Full Speed Forward	2	48.828	32000 (31999.43)	1.998	0.1

Table 2.2: 16-bit resolution PWM using timers

Once we had valid PWM waveforms and our hardware, we set up the motor controller, battery, motor, and Arduino to test motor control. We wrote code to change the timer match values on the fly and test the motor with different speeds in each direction and calibrate the motor to be stopped. We got this working with very few issues, and are confident in our ability to control the drive motors. Our plan for future testing of the motors depends on setting up the device itself and adding the motors to determine values for desired speeds and turning capabilities.

We also used an Arduino library to handle GPS serial communication and parsing of GPS data. We setup the GPS module on a breadboard and are successfully receiving our desired GPS data including latitude, longitude, speed, time, and date. The next step is to configure and validate data using the WAAS capabilities of the chip and add it to the device to test the error in our application..

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

Spring Semester

Table 3.1 Spring Timeline

February	March	April	May
Hardware: Research the mower design Software: Order the arduino Mobile: Start App	Hardware: Find the parts needed for the lawn mower Software: Start testing the the basic functions of our microcontroller Mobile: Begin writing the ui for the app	Hardware: Order the parts needed for the lawn mower Software: Test the microcontroller with the motors Mobile: Connect the app with the microcontroller	Hardware: Assembly or test the parts we have ordered Software: Test the microcontroller on the mower Mobile: Connect the mower with the app

Fall Semester

September	October	November	December
Hardware: Test our mower and make adjustments Software: Continue improving our autonomous code Mobile: Connect a camera on the mower with the app	Hardware: Refine our mower Software: Continue improving our autonomous code Mobile: Move the mower with the app	Hardware: Make adjustments if needed Software: Continue improving our autonomous code Mobile: Add more functionality to the app	Hardware: Put finishing touches on the mower Software: Put finishing touches on the autonomous code Mobile: Put finishing touches on the app

Our project has three main parts. Each month we should try to set goals for all three parts. Obviously, some parts will be more important than others at different stages of our build process. These goals set in our timeline allow us to have a basic idea of how to proceed in the future. During the spring semester, our projected goal is to have our design completed, major parts working together, and the different microcontrollers able to communicate with each other. During the fall semester, we hope to have the mower mow a lawn by itself without error. If we reach our goals, we want to add a camera onto the front of the mower. We will use this camera to detect objects and other computer imaging tasks.

Gantt Chart: Refer to Figure 4.4

3.2 Feasibility Assessment

The end goal of this project is to have a mower that can mow a small residential lawn accurately and autonomously. Many challenges will appear when we start combining all of the pieces together. The parts we are buying do not come configured with what we want them to do. Some of these parts might not work together correctly right out of the box. We might have to make some customizations to the parts themselves. Another challenge which may arise will be creating code to make our mower autonomous. Our group has a lot of programming experience. However, making an autonomous mower will still be difficult despite that programming experience. We will have to combine many different systems and sensors to make our mower perform autonomously.

3.3 Personnel Effort Requirements

This is our estimate of basic time commitments we will need to finish our project.

Creating the mower	40 hours
Controlling the mower with a microcontroller	15 hours
Controlling and connecting the sensors	10 hours
Researching the what parts to use	15 hours
Autonomous mower code	80 hours
Mobile application	30 hours
Perfecting and adding possible changes	60 hours

3.4 Other Resource Requirements

Parts and cost spreadsheet: https://docs.google.com/spreadsheets/d/1CgmDwKo5UuJ-vxxP7mH8zM6wpVNLLWAvFZ_a-7ijMqk/edit#gid=0

3.5 Financial Requirements

This project will have an estimated cost of between $1000-$1500 USD. Our client has agreed to this number and will be providing our group with the funds.

4 Closure Materials

4.1 Conclusion

Mowing the lawn is something the majority of homeowners need to do on a semi-weekly basis. Sometimes they may not have the time or ability to mow it. With our project, we aim to solve this problem in an affordable and effective way. With our approach, we be able to make a device that is much cheaper than what the current market has to offer. Our mower will also have extra features such as a mobile app, lawn grooming, and automatic charging which should make it even more helpful to the consumer. Our end goal is to create a product that the every-day homeowner can use without any hassle.

4.2 References

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" ." *IEEE-SA - The IEEE Standards Association - Home*, standards.ieee.org/.

4.3 Appendices

Figure 4.1 SolidWorks model left plane of view

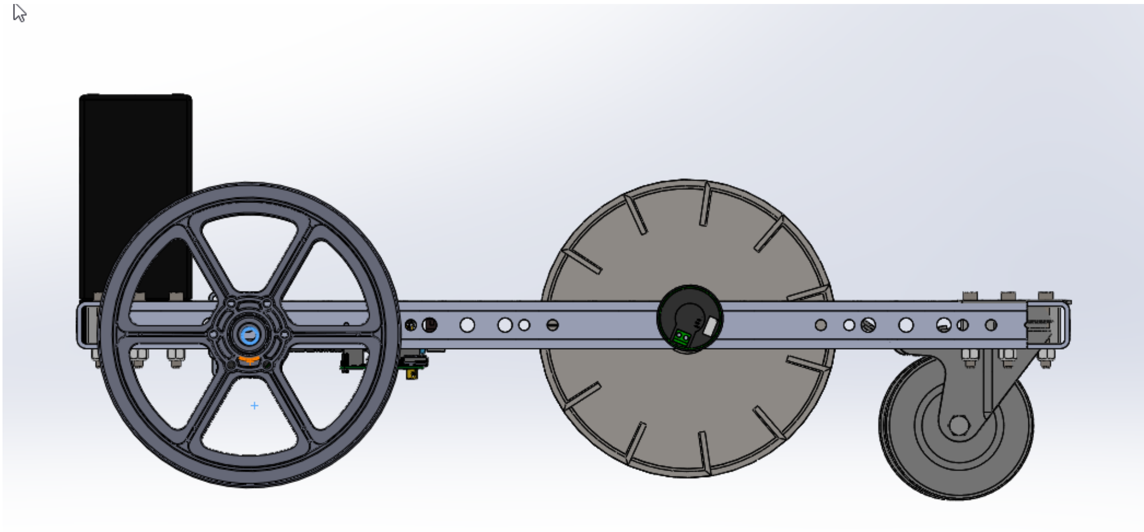

Figure 4.2 3-D view

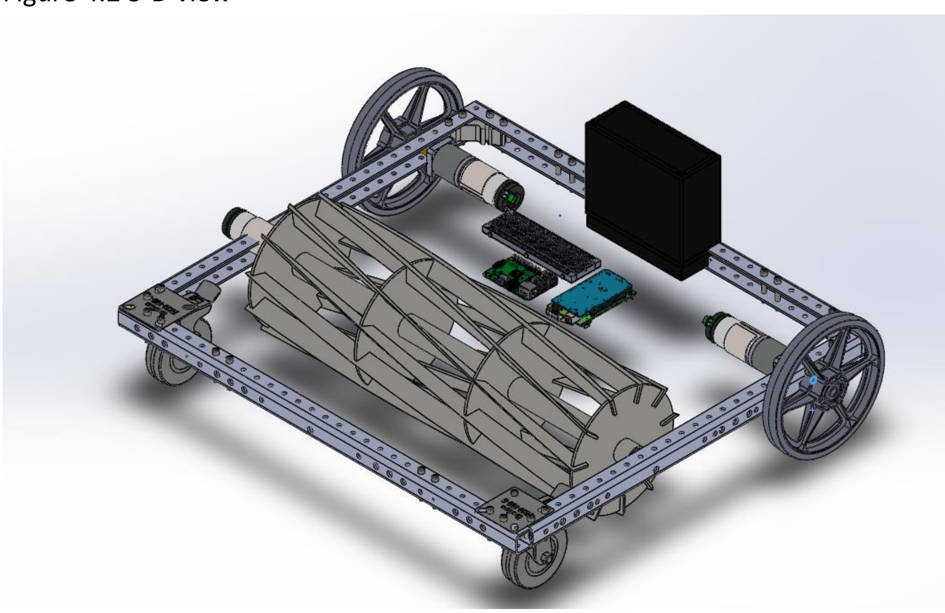

Figure 4.3 Wiring Diagram

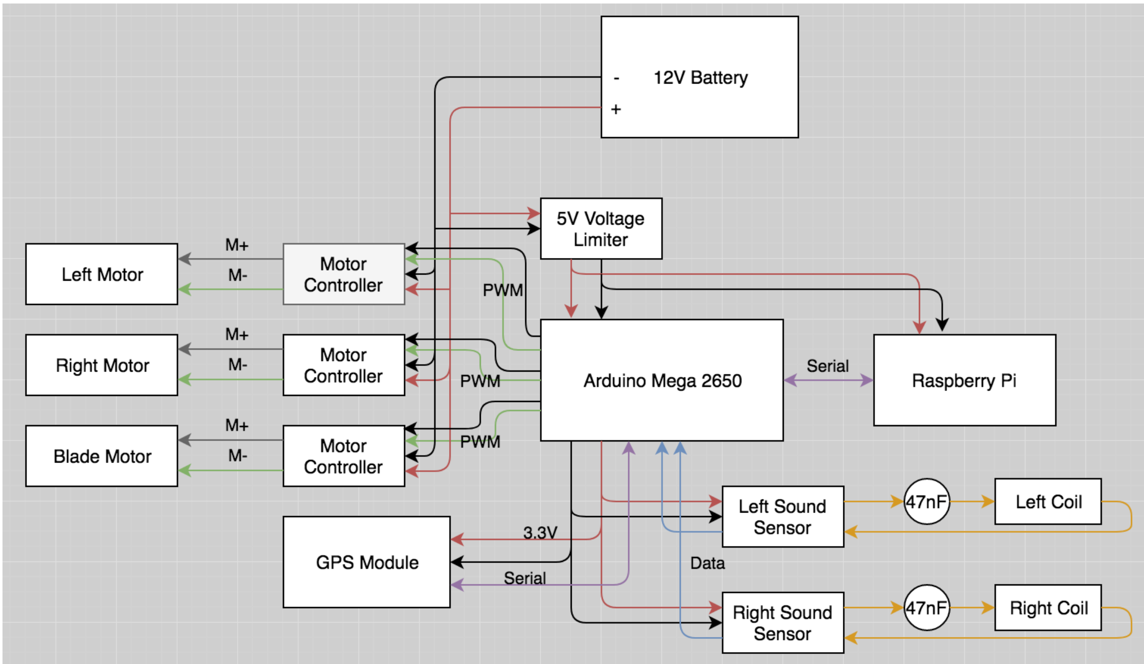

Figure 4.4 Gantt Chart

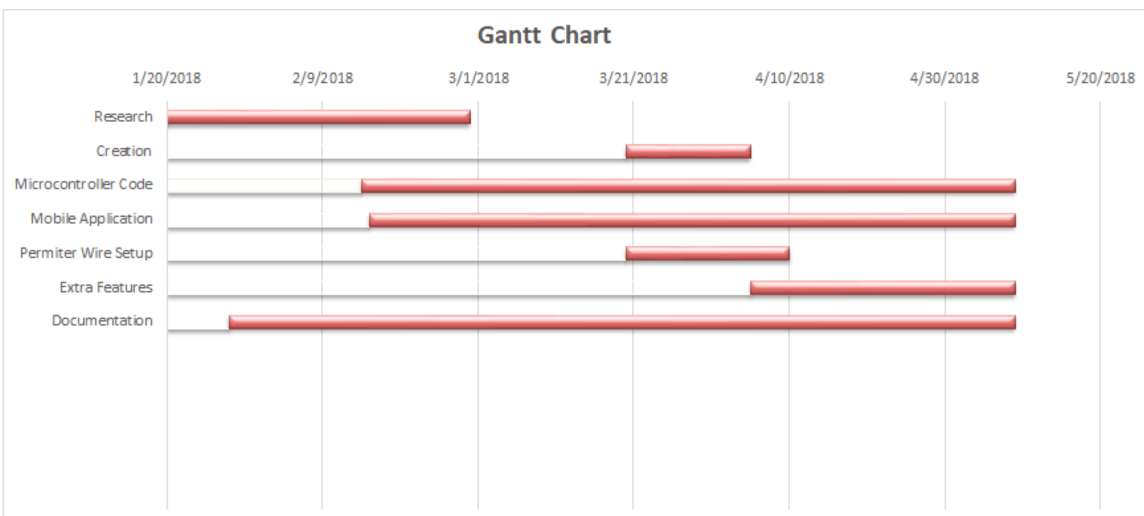

Figure 4.5: Motor control testing setup