Design and Development of Adjustable Halo coil for Non-Invasive Treatment of Brain Disorders

Second Project Plan

Group members:

Jessica Staley - jmstaley@iastate.edu

Saurabh Minocha - saurabh@iastate.edu

Anqi Deng - angel27@iastate.edu

Yixiao Shen - yixshen@iastate.edu

Client ad Advisor:

David Jiles - dcjiles@iastate.edu

Ravi Hadimani - hadimani@iastate.edu

Table of Contents

Introduction

A non-invasive, surgery-free treatment named Transcranial Magnetic Stimulation (TMS) has been using for many neurological diseases such as Parkinson's disease, Depression and Traumatic Brain Injury these years. This is a technology using a standard coil to simulate upper region of the brain with magnetic field. And another new coil has been developed in Jiles lab called as "Halo coil" is positioned around the head, aiming to be capable of simulating deeper region of the brain. With the combination of these two coils, an appropriate region can be located and simulated better.

Project summary

We need to design a helmet which can grasp the coil to stimulate different area of the brain, which means the coil can be moved up and down and rotated to a certain degree to locate at the target. After two groups' hard working, the fixture can move up and down precisely, but it still has some problems with the rotation because of the weight of the Halo coil. For this project, we are figuring out the problems and re-designing the structure of the helmet, trying to make sure it can translate and rotate well with the coil. In order to re-design and optimize our helmet, we need to learn the design and simulation software and knowledge about how the fields interact with the two coils to make sure everything will go well.

Concept Sketches

Figure 1: Concept Sketch

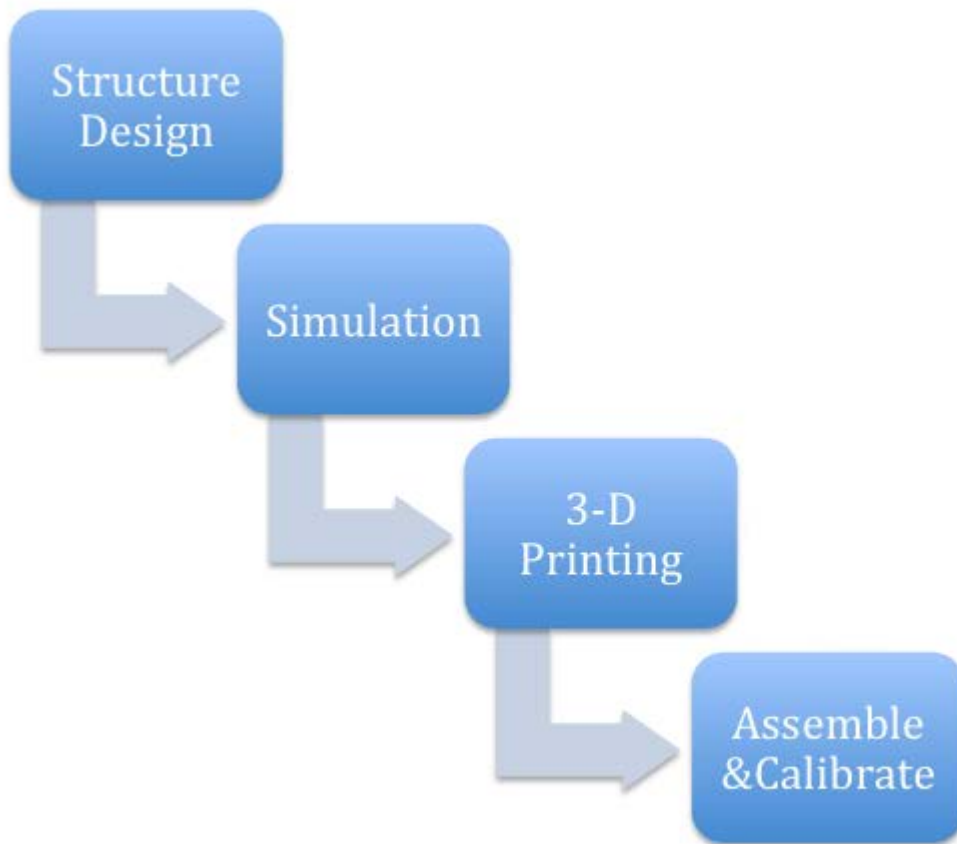**System Block Diagrams**

Figure 2: System Block Diagram

Process Description

There are mainly two aspects of this project: Simulations and Programming the hardware.

Simulations:

SEMCAD for electrical and magnetic simulations

Introduction-

The purpose of using simulations is to measure how electric and magnetic field generated by stimulating the halo coil, affects different parts of the brain. We will use SEMCAD for this purpose. After successfully completing simulations for desired results, the required halo coil can be designed.

Explanation-

In SEMCAD, we will use a standard head size, and two coils for stimulation. The top coil, which is to be stationary, is a single coil while the bottom one is a halo coil. The single coil is smaller, with a diameter of just 90mm as compared to 290 mm of the halo coil. The halo coil has 5 turns, whereas the single coil has 14. Since the single coil is stationary, it is kept at a distance of 5mm from the top of the head. The halo coil can be moved, and the distance between it and the single coil is 10mm. The movement is restricted to 30 degrees on either side of the axis.

While simulating for maximum electric and magnetic field, we rotate the coil by 5 degrees at a time and observe the collected 12 data points for the best result.
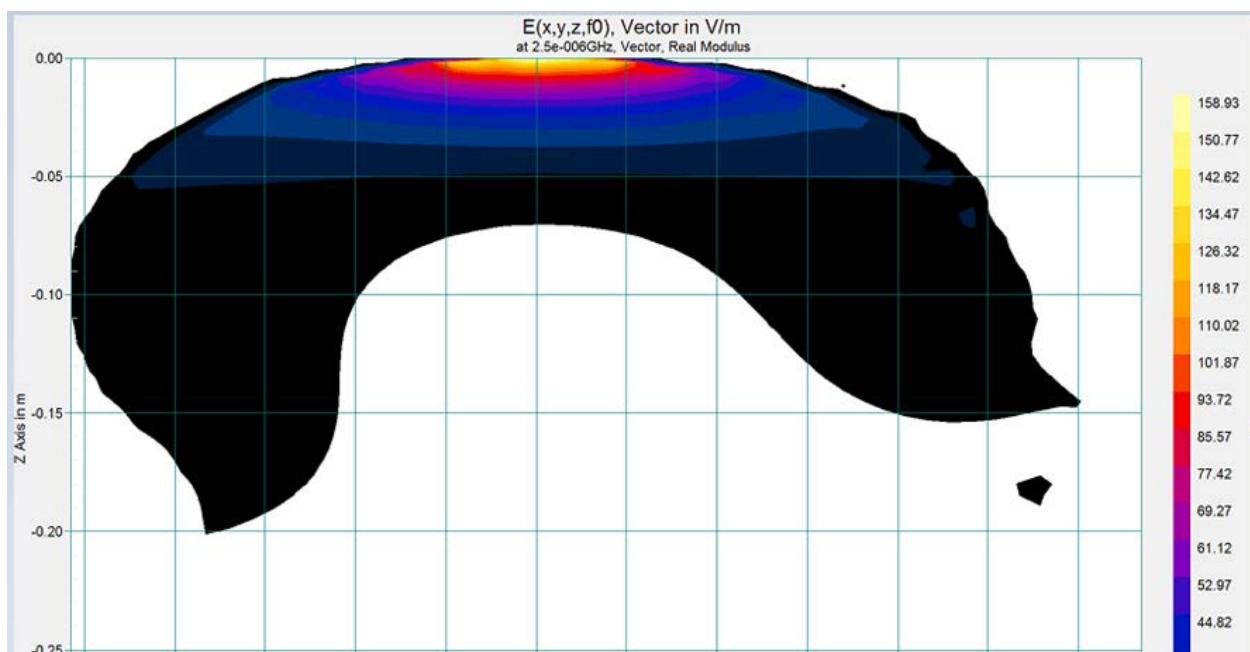

Figure 3: Result obtained for Electric Field along X axis for a Figure 8 coil bent at 60 degrees.
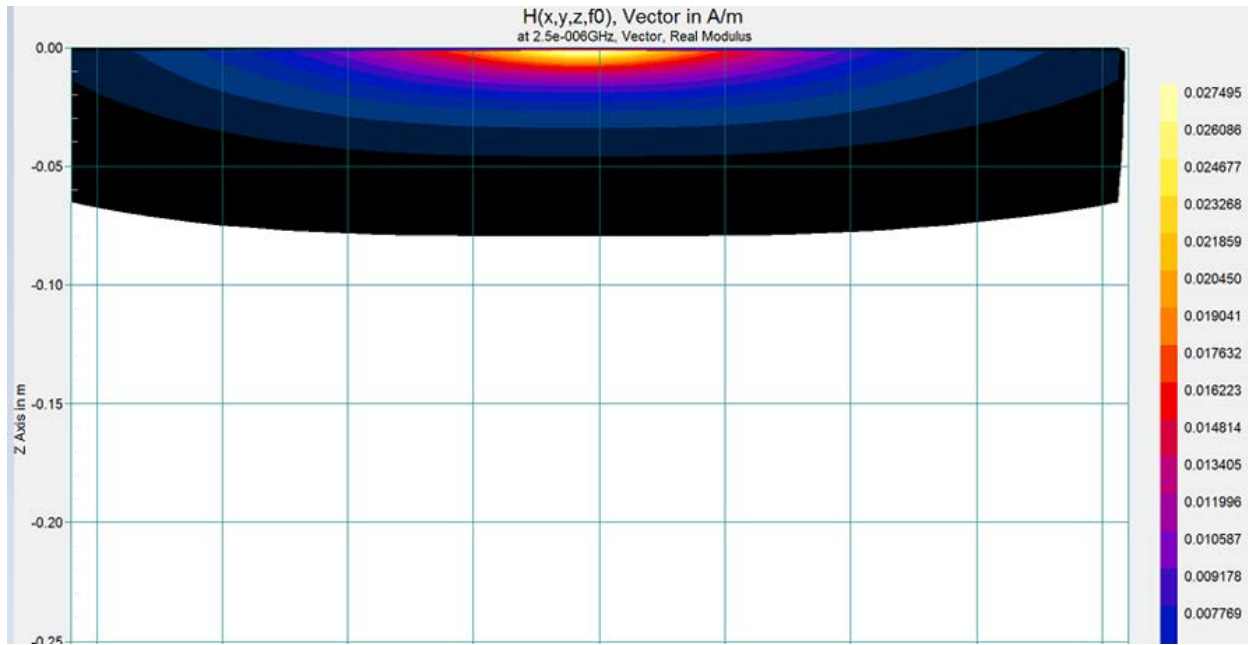
Figure 4: Results obtained for Magnetic field along Y axis for a figure 8 coil bent at 60 degrees.

As the color in the plot becomes lighter, the Electric or Magnetic field increases.

COMSOL for Electromagnetic Heat and Force simulations

Introduction:

Due to safety reasons and precautions, it is advised that the coils should not exceed a surface temperature of 98 degrees Fahrenheit, which is the human body temperature. Even though it is known that our body doesn't feel the harsh temperature unless it exceeds 120 degrees Fahrenheit, we have preferred to limit out design and experimental conditions to that of 98 degrees Fahrenheit.

Explanation:

Electromagnetic Heat & Lorentz Force Simulation

Coil model should be built properly at first by using COMSOL. In our project, there are two coils we are going to build the single coil and the halo coil. The signal from the biophasic

stimulator is a sinusoidal wave with a frequency of 2.5K Hz, and 5000A magnitude. So heat may be cumulate between the coils. So we need to obtain the power of that heat by using COMSOL simulation. Frequency-Transient analysis should be done in order to determine the time that the heat reaches human temperature.
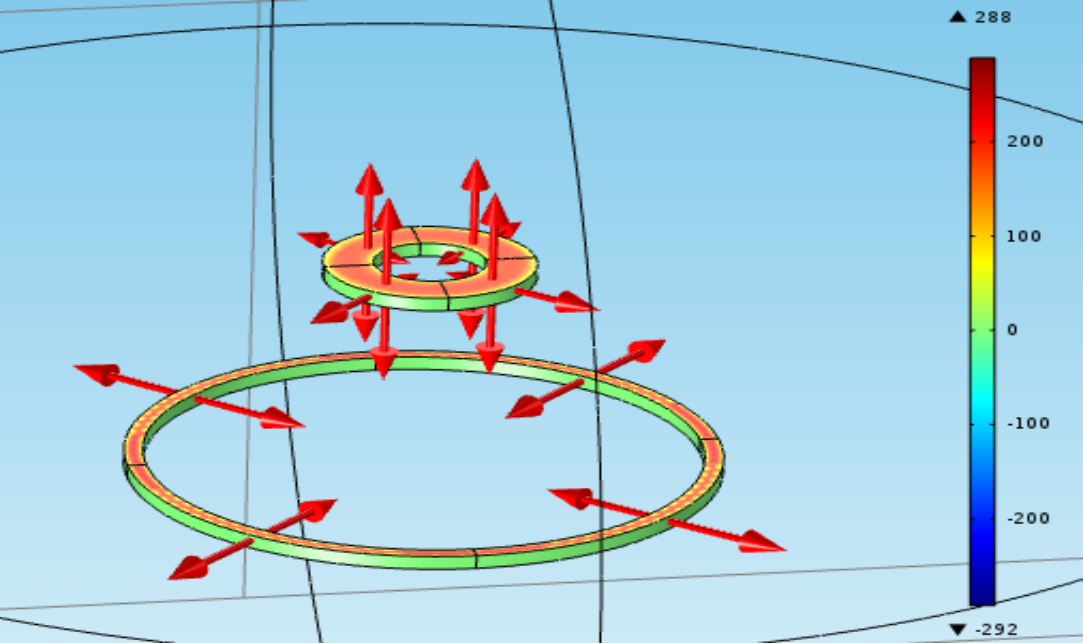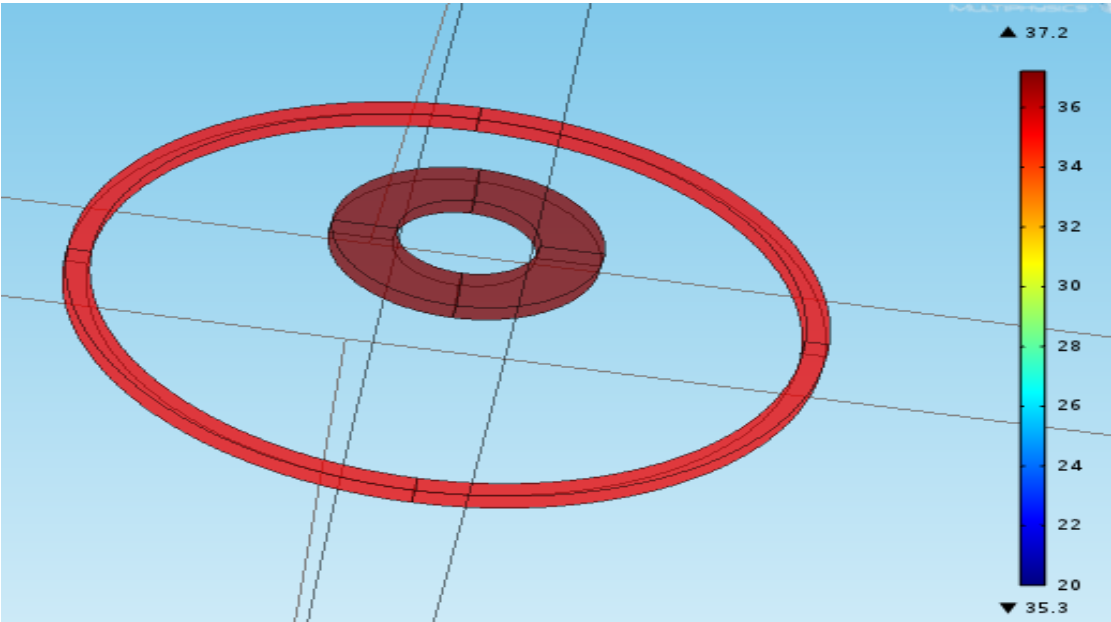

Figure 5: Magnetic Field Effect

Figure 5: Magnetic Field Effect

In terms of Electromagnetic Force, Lorentz force was generated by the magnetic field between the two metal coils. The force may affect the whole structure, so we have to determine the properly distance between the two coils as well as distance between coils and servo motor. In this situation, force simulation is necessary for us to do. The simulation also can be achieved by COMSOL. For COMSOL, we are going to apply electric current to the same coil model mentioned above so that we can get right distances between the parts in our TMS structure.

Programming the Hardware:

1. The GUI is the user interface. It will show the position of the coil as well as the electric and magnetic field images for the position. These images will be color coded using the color chart located at the left of the images. This is one of the most important part of our model, as the GUI will enable the user to move the coil around to stimulate different areas of the brain. The GUI will also be able to start the simulation by sending a pulse through a rs232 enabled port. The interface is where SEMCAD and COMSOL simulation results are used.
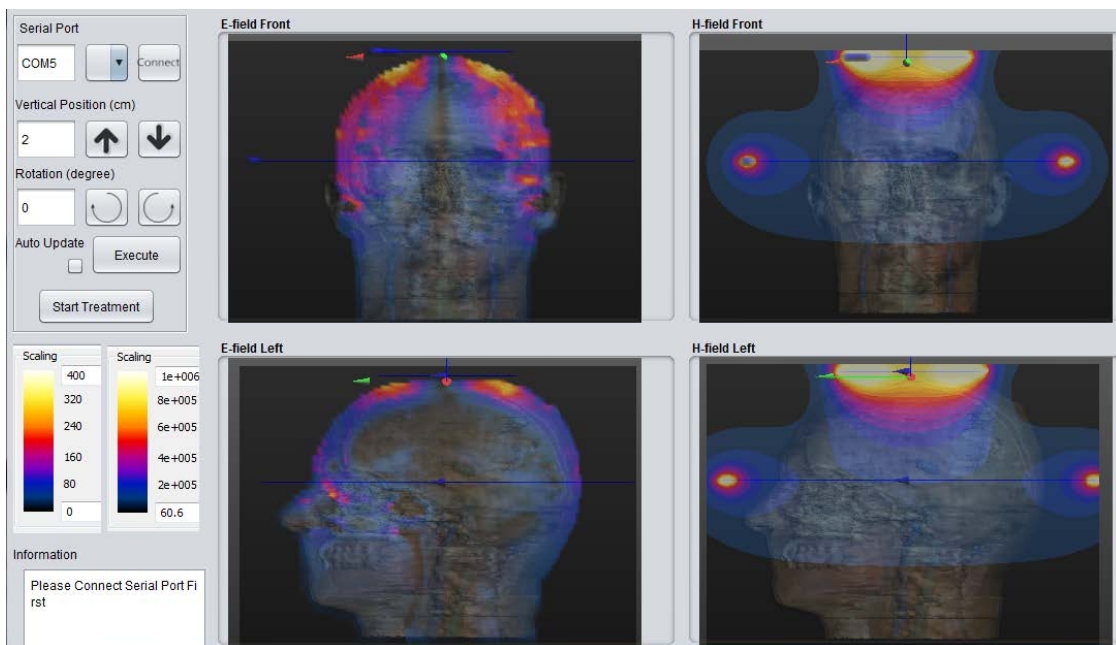

Figure 7: GUI Interface

2.   The Arduino board requires a signal, which is given through a computer via a USB cable. The arduino is programed using the Arduino program to make it easy to use. Its purpose is to control the movement of the coil and helmet based on signals sent from the GUI.

Helmet Design

Introduction-
Solidworks is a software to design an accurate 3D model using "parametric feature-based" method, once the design is done, it can be created to a 3D printable file which can be output to a real material part through 3D printing equipment.
Explanation-

To give a draft of the helmet, two things should be taken into account in the design, one is that all the dimensions to the new structure should be considered and confirmed, the other one is if it can work well in reality. And simulation results are also important in how to come up with the structure. The new structure will support the Halo coil to move up and down with the main linear actuator, and the rotatable function is controlled by a side linear actuator to locate the target. We will use the 3D modeling software Solidworks to finish the draft of the structure and input it into a 3D printer to implement our design, and the stand system should be manufactured by mechanical shop.

Figure 8: Helmet design with Halo coil

Operating Environment

The finished system is intended to operate in a hospital. The user interface and design has to be usable by people with little knowledge of electric and magnetic field, even though they are expected to have significant knowledge in the field of medicine. The system would be tested in laboratories and once the design and results are as desired, human brain testing would be the next step. Once we are entirely sure of it functionality and effectiveness, it will be good to be used on patients for treatment. It is to be noted that the experiments in laboratories as well as on the human brain is to be done under strict supervision and by experts only. Stimulating an incorrect region of the brain can be fatal. To aid professional handling this equipment, it is intended that GUI would make it easier for the coil to move and rotate as desired.

Requirements

- ➢ **Functional**
  - ○ **Rotation of Halo Coil** - The halo coil should be able to rotate between -30 and +30 degrees. The resolution of the rotation should be 1 degree to increase precision. This movement needs to be controlled by the GUI interface.
  - ○ **Long Term Usage** - The design needs to be able to run for extended periods of time without overheating the motors. The Halo coil weight needs to be recalculated to determine the correct support system.
  - ○ **Generate Appropriate Field** - The electromagnetic field generated must be 2 Tesla to stimulate the correct region of the brain. The current through the halo coil should be variable to stimulate closer to the skull?
  - ○ **Power the Design** -The entire design will need to be run using the electricity supplied from the walls. The power will have to be converted from an AC to DC signal to power the system.

- ➢ **Non-Functional**
  - ○ **Accuracy of Field** – Coil positions must provide correct stimulation every time.

○ **Adjustable Design** – Design should be easily upgraded if the coil technology changes.

Deliverables

First Semester – Halo coil rotation system prototype, completed simulation results, functioning user interface.

Second Semester – Finalized and tested design, functional user interface, possible improvement ideas.

Work plan

➢ **Member Roles**

　　○ Jessica Staley – GUI Programming

　　○ Saurabh Minocha – SEMCAD Simulations

　　○ Anqi Deng – 3D Modeling and Printing

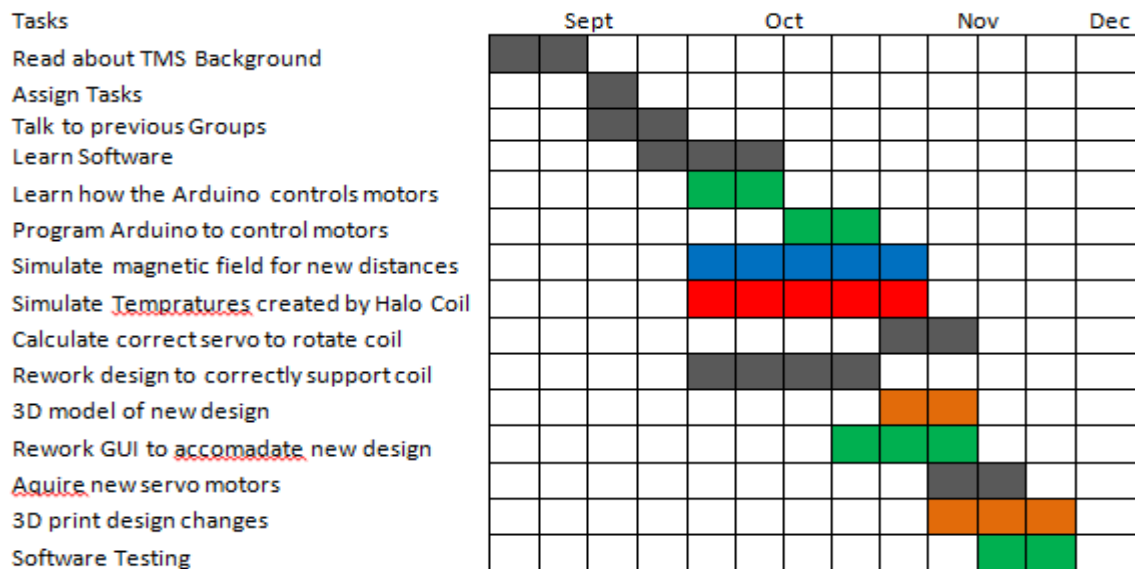　　○ Yixiau Shen – COMSOL Simulations

➢ **Timeline**

　　○ Fall Semester

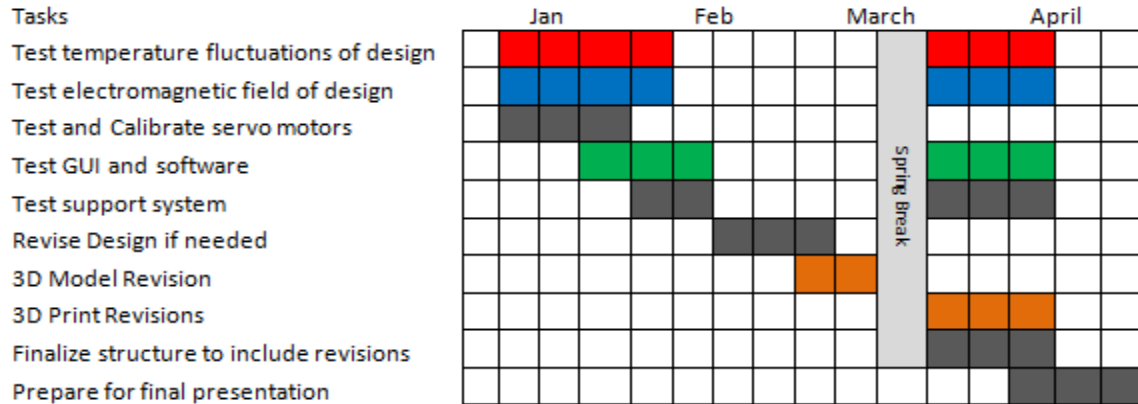| Tasks	Sept			Oct				Nov		Dec
Read about TMS Background	■	■								
Assign Tasks			■							
Talk to previous Groups			■	■						
Learn Software					■	■				
Learn how the Arduino controls motors					🟩	🟩				
Program Arduino to control motors							🟩	🟩		
Simulate magnetic field for new distances					🟦	🟦	🟦	🟦		
Simulate Tempratures created by Halo Coil					🟥	🟥	🟥	🟥		
Calculate correct servo to rotate coil								■	■	
Rework design to correctly support coil					■	■	■			
3D model of new design								🟧	🟧	
Rework GUI to accomadate new design							🟩	🟩	🟩	
Aquire new servo motors									■	■
3D print design changes									🟧	🟧 🟧
Software Testing										🟩 🟩

Figure 9: Fall semester Gantt Chart

Figure 10: Spring semester Gantt Chart

○ Color Assignments

Figure 11: Color Assignments

Limitations

1. Mastering the simulation software.

In this project, kings of simulation and design software will be heavily used to design and simulation the structure of helmet. Of course this is the biggest part of work in this project. Team members are going to read lots of document and user manual of related software and getting family with the software as soon as possible.

2. Achieve accuracy requirement

The most powerful motors have been used to this project but it seems does not work very perfect and the measurement result do not meet the require accuracy level. We may encounter same problems. So careful calibration is considered very essential for us.

3. 3-D printing Issue

In terms of 3-D printing, our team members had never touch 3-D equipment and 3- D printing software before. 3-D printing is quite a new technology release recently. Therefore, we need time and effort to understand how it can be used to print our needed element.