MAY2015 GROUP26

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

Final Project Plan

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2. Introduction

A non-invasive, surgery-free treatment named Transcranial Magnetic Stimulation (TMS) has been used 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. A 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, a specific region can be located and simulated better.

3. Project summary

The goal of this project is to design a helmet which can grasp the coil to stimulate different area of the brain, which means the halo coil can be 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.

4. Requirements

4.1 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 5 degree to increase precision. This movement needs to be controlled by the GUI interface.

- **Helmet Movemen**t **-** The halo coil helmet should accurately move up and down between 10 cm.
- **Controlled from Computer -** The entire system should move based on inputs into a user interface sent through serial communication.
- **Long Term Usage -** The design needs to be able to run for extended periods of time without overheating the motors.
- **Generate Appropriate Field** - The electromagnetic field generated inside the brain must be 150Volts per meter in the target area.
- **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.

4.2 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.

5. 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.

6. Market Survey

Magnetic coil

Transcranial magnetic stimulation is a relatively new treatment that was approved for medical use in 2008 (according to mayoclinic). The existing market only uses the top single or double coil to treat rather than using both top and side coil, which limit the range of simulation area of the brain. Without any secondary magnetic field, it is almost impossible to stimulate deep regions of the brain.

Figure 1: Current Medical TMS Setup

7. System Block Diagrams

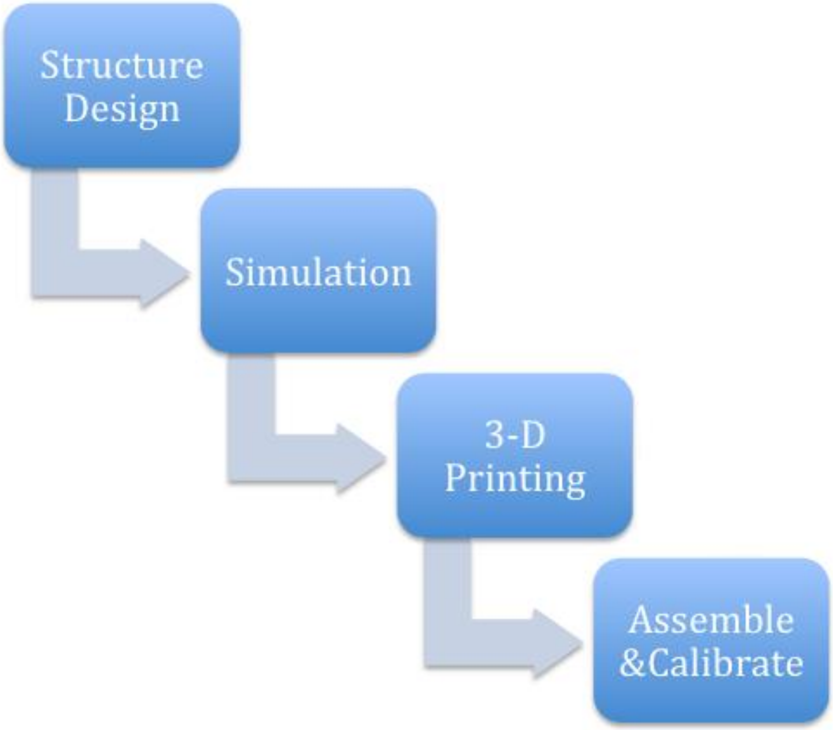

Figure 2: System Block Diagram

9. Interface/System Description

In order to make the previous group's design meet the accuracy and simplicity required, both the user interface and the structural design have to be modified.

User Interface

The user interface will be used to control all aspects of the design. It will move the halo coil helmet vertically up and down as well as rotating the coil using an arduino board. The interface will also be used to remotely start the treatment using RS232 serial communication. During the treatment the GUI will display images of the magnetic and electric fields created in the head in all three directions. The benefits of this design is that it decreases the complexity of the treatment by streamlining the process. Displaying the images on the screen will allow doctors to view the field from all angles. The downside of this design is the tabbed panes which causes the user to flip between screens to view all the images.

Structural Design

The structural design will handle rotation of the halo coil using a single linear actuator connected to the cord instead of two servo motors attached to the sides. Not only will this allow for long term use with better accuracy but it will also decrease the amount of helmet vibration during the rotation. The new design will allow for easier removal of the halo coil from the helmet by not connecting it directly to the moving parts. The downside of this design is the cost, in order to get a high resolution linear actuator of the correct size is much more expensive than two servo motors.

10. Concept Sketches

Figure 3: Helmet Concept Sketch

Figure 4: Halo Coil Rotation Concept Sketch

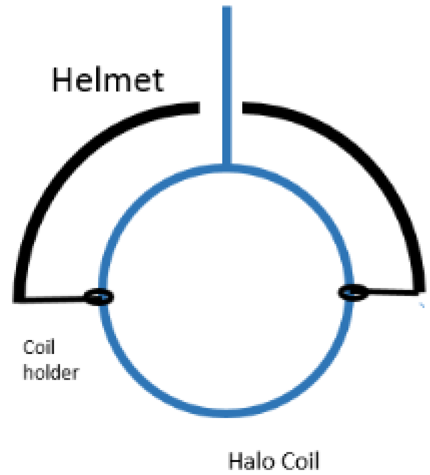

Figure 5: Top down Coil Support Structure Concept Sketch

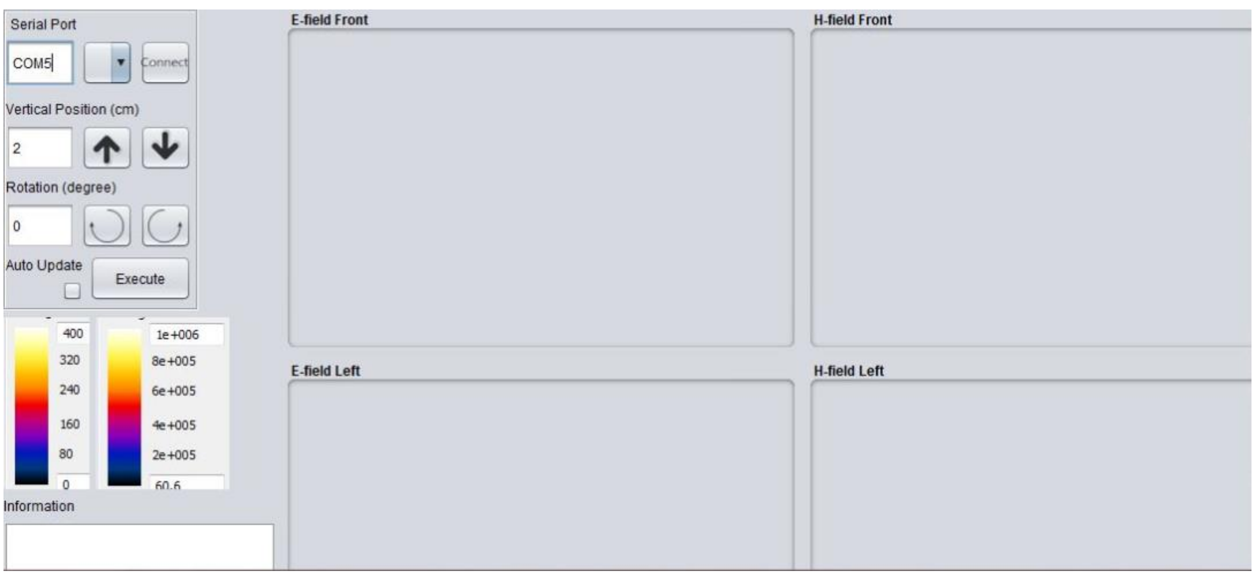

Figure 6: User Interface Concept Sketch

10. 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.

11.Testing

11.1 Coil Rotation

The testing of the halo coil rotation has two parts. The hybrid linear actuator vertical movement needs to be tested before it is attached to the helmet design. This can be accomplished using an accurate millimeter ruler. The actuator will have to be tested again after installed on the helmet to ensure that the resistance seen during rotation doesn’t affect the linear motion. The coil rotation can be tested using a simple protractor. The angle should be measured from the pivot neutral zero position. This measurement can be directly compared to the information in the computer interface.

11.2 Accuracy

The design needs to operate the same on the last treatment as it does on the first treatment. Both the actuator controlling the rotation and the actuator controlling the linear movement will have to be tested. This can be accomplished by positioning the helmet and halo coil hundreds of times. Not only will this test how well the design can withstand long term use, it will also give a basis on any possible recalibrations required for the actuators in later years.

11.3 Long Term Usage

Two separate tests are used to test long term usage of the machine. The first is the force measurements. These will be tested using the simulation software COMSOL. These simulations will ensure that the forces between the two coils remain stable for every rotational position of the halo coil. If they destabilize, electromagnetic field between them may start to fluctuate unexpectedly during treatment.

The second test used for long term use is a temperature test. In order for the design to be viable for long term use, the stimulating coils cannot exceed body temperature. Otherwise the patient will start to feel uncomfortable during the treatment. The temperature of the coil surface as well as the air temperature around the patient's head can be checked using a common thermometer.

11.4 Electromagnetic Field

The magnetic field is measured using a gaussmeter connected to an automatic control system. This can be set to read the field in many different locations. The field cannot exceed two Tesla at any point during the treatment. All readings need to be very accurate to ensure only a specific part of the brain is stimulated. The magnetic field must also be tested using the SIMCAD program.

SIMCAD simulations will be able to give an accurate visual of how the magnetic field travels through the human head. If the position of the coils and the gaussmeter magnetic field readings match up with the images displayed on the user interface at the surface of the coil, the SIMCAD simulations will accurately depict how the field is interacting with the human head.

11.5 Serial Communication

If any part of the serial communication isn't functioning the simulation will fail to start. If the code is working correctly then the Arduino and RS232 connectors need to be connected from the user interface. Once connected an Arduino test can be made by simply attempting to move the linear actuators. If for some reason the serial connection fails an error message will appear in the lower left hand side of the user interface.

The RS232 connection can be tested in the same fashion if the Magstim Super Rapid² stimulator isn't primed. If the connection is working properly a message stating "System Not Primed" will appear in the lower left hand corner of the user interface.

If all the serial connectors are properly attached to the computer running the user interface but a connection isn't achieved, there is a problem with the connection hardware that needs to be addressed.

11.6 Powered by outlet

The AC-DC converter used must be tested before it is connected to the design. This is done by connecting the AC side to a small transformer set up to mimic the output from an outlet. A voltage and current reading are then taken from the DC side. The voltage will have to be 12Vdc to power the linear actuators. The current emitted through the AC-DC converter needs to be small enough that it doesn't damage the parts. Once the converter has been tested on a transformer, it should be tested in the same fashion in an outlet. Only when it passes both parts of the test can it be attached to the halo coil motion circuit. Without this testing the parts used in the design could be ruined if they receive too much current or voltage.

12. Work plan

12.1 Timeline

- Fall Semester

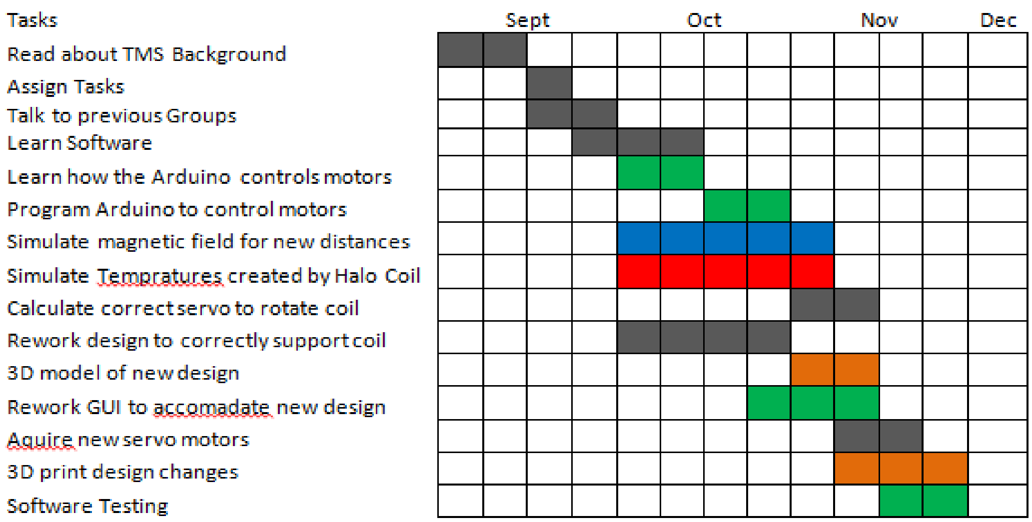

Figure 7: Fall semester Gantt Chart

- Spring Semester

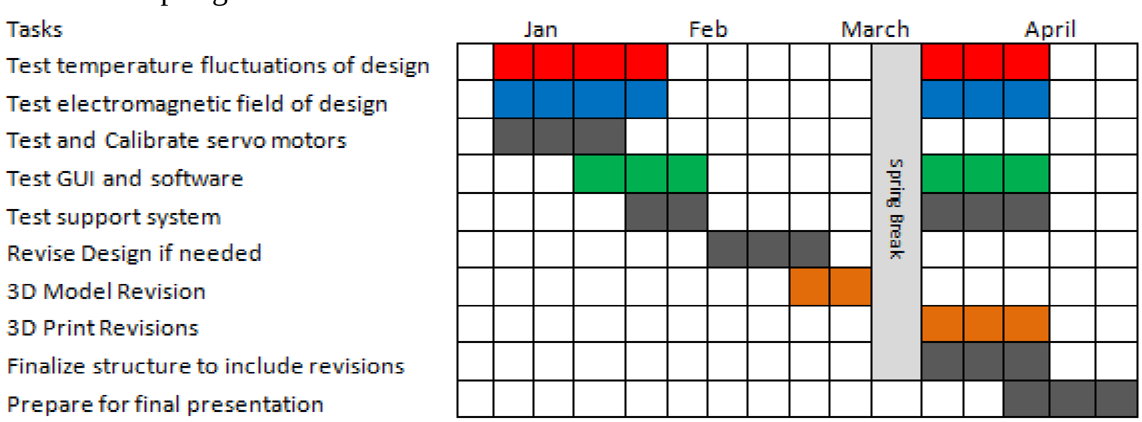

Figure 8: Spring semester Gantt Chart

- Color Assignments

Figure 9: Color Assignments

12.2 Cost Estimate

- 3D printing: $420
- Linear actuator: $141.57
- Pivot structure: $14

12.3 Limitations

Simulation software

In this project, simulation and design software will be heavily used. They are used to create the advanced tests used throughout the simulation process. The values calculated in these programs directly influence the length of stimulation. If these simulations are off in any way the doctors will run the risk of injuring the patient.

Accuracy

The movement of the coil and the helmet rely solely on the linear actuators. Finding an actuator of the right size with high resolution is essential for the rotation. If the linear actuator used isn't reliable in its movements it could cause the entire electromagnetic field to become distorted. If the actuator used for the vertical movements isn't consistent in the distance traveled as it extends the top coil could be located the wrong distance from the patients head which would weaken the magnetic field on the human skull. These could potentially cause the field to focus in the wrong part of the brain.

Materials

Parts of our final design will be fabricated using the 3D printing facilities on campus. That limits the materials to plastic. This material will be beneficial in the design because they won't interfere with the electromagnetic field produced. The problem is that they will also dictate the thickness of the design because of their limited strength. If the calculations for these pieces are wrong, the plastic may break under the stress.

Assembly

The final assembly of the design will be limited by the types of actuators purchased. The actuator used for rotating the halo coil is a non-captive screw type actuator. Both the motor and one end of the actuator will have to be connected. The motor can be connected to the main structure in a simple fashion but the screw will cause problems. This screw will need to be securely fixed to the halo coil cord or it will disconnect during the movement. A tight connection will have to be chosen that prevents the screw from turning

13. Conclusion

During this semester, we came up with a couple of design ideas and finally we decided to use the linear actuator to control the Halo coil rather than motors, for which can load much more force to make sure the coil can rotate desired degree. The support helmet structure, which will hold the Halo coil above the ground and has a pair of pivot structure to passively lead the coil's rotation, has been 3D printed. In next semester, we need to modify the structure and make tests to ensure the whole system will work well.

14. Sources

TMS market survey
http://braintreatmentcenter.asia/english/sleep/MRT.php

http://www.mayoclinic.org/tests-procedures/transcranial-magnetic-stimulation/basics/definition/prc-20020555