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

Design Document

OCTOBER 28, 2014

MAY 2015 GROUP 26
Iowa State University

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1. Project Overview

1.1 Introduction

Transcranial Magnetic Stimulation (TMS) is a technique in modern medical treatment for brain neurological disorders. By causing depolarization and hyperpolarization in the neurons of human brain, Transcranial Magnetic Stimulation can treat disease such as Parkinson’s disease, post-traumatic stress disorder, as well as depression. The principal of TMS is that it uses electromagnetic induction to induce faint electric current in magnetic field to cause some activities of parts of brain.

The last halo coil research groups have already done some major part of this project. But the problem is that they cannot let the coil move up and down to 30 degrees. Also they did not achieve the accuracy requirement.

1.2 Purpose

The purpose of this project is that we are supposed to design and test a whole new structure of the helmet as well as the motion in order to make the coil move up and down freely within 30 degrees. Also, after we finish design the machine, we will carefully calibrate the functional accuracy to make the result as accurate as possible and meets the requirement.

1.3 Deliverables

The whole new structure of the TMS system will include changes as follow:

i. Remove the two servo motors that placed between the coils

ii. Add a vertical serve motor to hold the handle of the coil

iii. New structure that link the new sever motor to the main vertical sever motor in order that they can move together.

2. Requirements

2.1 Functional Requirements

Generate 2T magnetic field in particular place.

Helmet can be placed easily though machine.

System can receives command from computer

Move the helmet up and down freely

Display the magnetic field and movement of helmet at PC interface

2.2 Non-Functional Requirements

Accuracy-Must provide consistent results

Comfort- Must below the patient’s body temperature

Variability- Must be able to fit all different size and height of human brain.

Extensibility- Source code for UI are supposed to be written in a way that function can be easily added or removed.

3. System Description

3.1 Concept Sketches

Figure 1: Concept Sketch

3.2 Block Diagrams

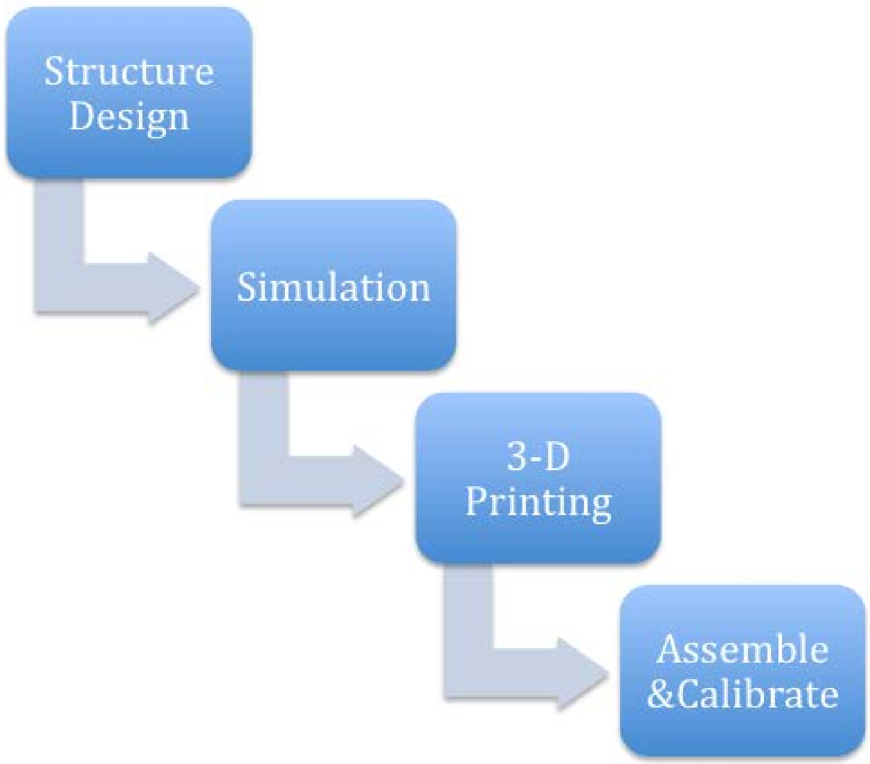

Figure 2: Block Diagram

3.3 Component Specifications

Coil Dimensions

Single Coil

- Average diameter :9 cm
- Number of turns: 14

Double Coil

- Inner diameter: 32mm

- Outer diameter: 48 mm
- Number of turns: 9 turns
- Space between turns: 1 mm
- Turn width: 1 mm
- Winding dimension: 1 mm*5 mm

Halo Coil

- Inner diameter: 277 mm
- Outer diameter: 299 mm
- Number of turns: 5 turns
- Space between turns: 1 mm
- Turn width: 6 mm
- Winding dimension: 1 mm*5 mm

Helmet dimension

Helmet

- Half circle average diameter: 33.9 cm (29.9cm + 4 cm)
- Coil holder diameter: 22mm

Stand system

- Number of linear actuator: 2

4. Design Process

4.1 Simulations

4.1.1 Electric and Magnetic

Introduction-

We use a software called SEMCAD to find the impact of electric current and magnetic field in deeper regions of the brain. Using SEMCAD we can run various simulations which can help identify the region where the current is maximum due a certain position of the halo coil.

Procedure-

A heterogeneous model of a simple human head is used for simulations. Two coils are placed above it, a single coil and a halo coil. The standard coil, is at the top and is stationary, while the halo coil can be moved and rotated to a certain extent for reaching deeper regions of the brain. The single coil is 90mm in diameter, having 14 turns. The halo coil has a diameter of 290mm and has 5 turns. The single coil is placed at a distance of 5mm over the head and the distance between both the coils is 10cm. The movement of halo coil is restricted to 30 degrees upwards as well as downwards. The simulations give us data points using which we can identify the area where electric field is maximum as desired.

4.1.2 Electromagnetic Heat

Introduction-

These simulations are very important as the coil should not get very hot as it can cause discomfort and much worse. The temperature should not exceed 37 degrees Celsius which is the human body temperature. The simulations are done in order to find the maximum time our coil can be used before it reaches this temperature and the treatment has to be stopped.

Procedure-

We use COMSOL for heat simulations. In COMSOL we use joules heating model for electromagnetic heating. Once we have created our coils and placed them correctly, the frequency of the sinusoidal wave is set to 2.5 KHz and magnitude is 5000 A. We then run the simulations and check till the temperature reaches the 37 degree mark.

4.1.3 Magnetic Force

Introduction-

We need to simulate for the force as well because the two coils can apply some force on the whole system. We are dealing with very sensitive instruments and designs and need to ensure precision. The force simulations are done so we know how far the coils must be placed from one another so the forces generated do not impact the helmet during the treatment as it could cause major issues. Also stability needs to be ensured, which is why all acting forces must be taken into account.

Procedure-

COMSOL is used for these simulations as well. Electromagnetic Force is chosen this time. Using the same coil design as earlier, we move the coils to find the distance at which the acting force is minimum.

4.2 Materials

3D Printing Locations

a. Boyd Lab (Iowa State University Hoover Hall 1260)

i. Dimension uPrint Plus 3D Printer

Maximum Size: 8” x 6” x 6”

Materials: ABSplus Thermoplastic (Support plastic dissolved during printing)

ii. Fortus 250 3D Printer

Maximum Size: 10” x 10” x 12”

Materials: ABSplus Thermoplastic (Support plastic dissolved during printing)

iii. ZPrinter 450 3D Printer

Maximum Size: 8” x 10” x 8”

Materials: Colored Plastic

b. **Prototyping & Fabrication Service Center (Iowa State University Howe Hall 1380)**
   i. **Alaris 30U**
      Maximum Size: 7.12” x 11.57” x 5.9”

      Materials: Colored (black, white or grey) hard Plastic

   ii. **Connex 260**
      Maximum Size: 10.2” x 10.2” x 7.9”

      Materials: Colored (black, white, grey or clear) hard Plastic

3D Printing Materials

NYLON: (Polyamide)

- Also called White, strong & flexible / Durable plastic / White plastic
- Strong and flexible plastic
- 1mm minimum wall thickness
- Naturally white, but you can get it colored
- About 10 layers per 1mm
- Made from powder
- Alumide = Polyamide + Aluminum
- Interlocking, moving parts possible (Chain)

ABSplus Thermoplastic:

- Strong plastic
- Made from spaghetti like filament

- Many color options
- About 3 layers per 1mm
- 1mm minimum wall thickness

5. Detailed Design

5.1 Helmet Design

The purpose of this helmet is to hold the halo Coil above the ground and support it up and down and rotate with the help of linear actuator. The shape of the helmet is like a half circle, consisting of two parts which are the circle and the coil holder. And these two parts are made of plastic and will be fabricated through 3D printing method.

5.1.1 Stand System

The helmet support structure will stand behind the patient's seat and carry the weight of the coil to make sure there is no danger to the patient. There are two linear actuators in this system, aiming to stimulate different parts of brain by controlling these two pieces. By this means, the coil will up and down when the big main linear actuator moves up and down, and when the small side linear actuator moves up and down without moving the main actuator, the coil will rotate as desired.

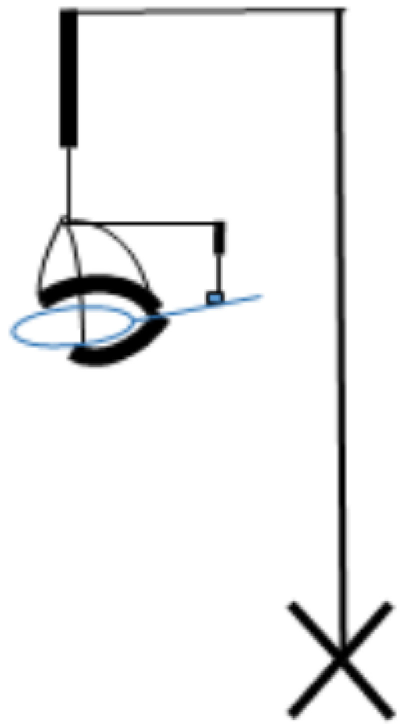

Figure 3: Full Helmet Stand

The figure shows the rotation system which is consist of a side linear actuator and the Halo coil.

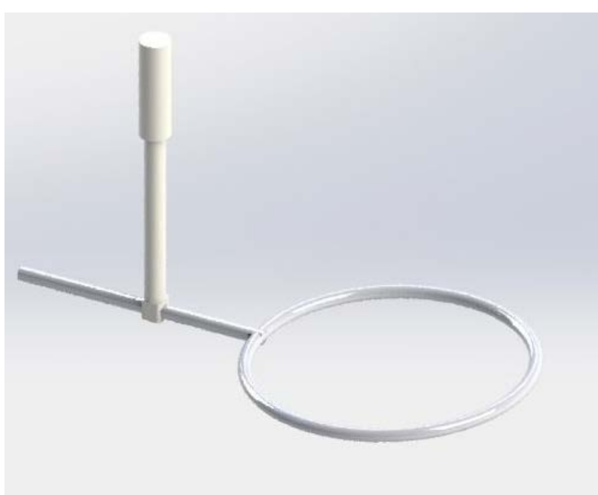

Figure 4: Halo Coil 3D Rotation System

5.1.2 Halo Coil Support System

We use the software Solidworks to model the plastic part and a printable file will be created into the 3D printer whenever it is finished. The plastic part is shaped with half circle surround with the Halo coil, it goes with the coil up and down.

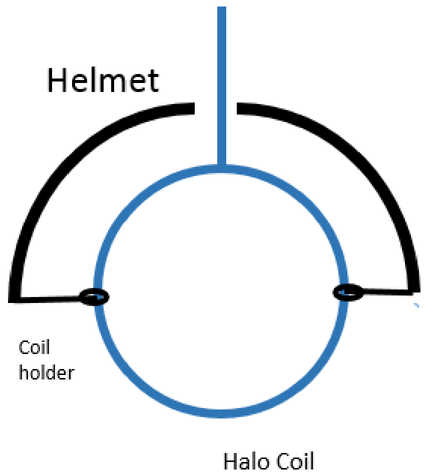

Figure 5: Top down Coil Support Structure

Figure 6: 3D Coil Support Structure

The coil holder can be rotated when some forces are pushed, in this case, when the small linear actuator above the cord moves without the main linear actuator moves, there are some vertical forces to the coil, leading the coil holder rotate.

Figure 7: Halo Coil Rotation Fixture

5.2 Control System

The PC interface is used to control the movement of the halo coil and start the procedure. The vertical position and rotation data are displayed and updated on this interface. The magnetic treatment is also started from this interface. Images that display the maximum magnetic field locations are changed based on the coil position.

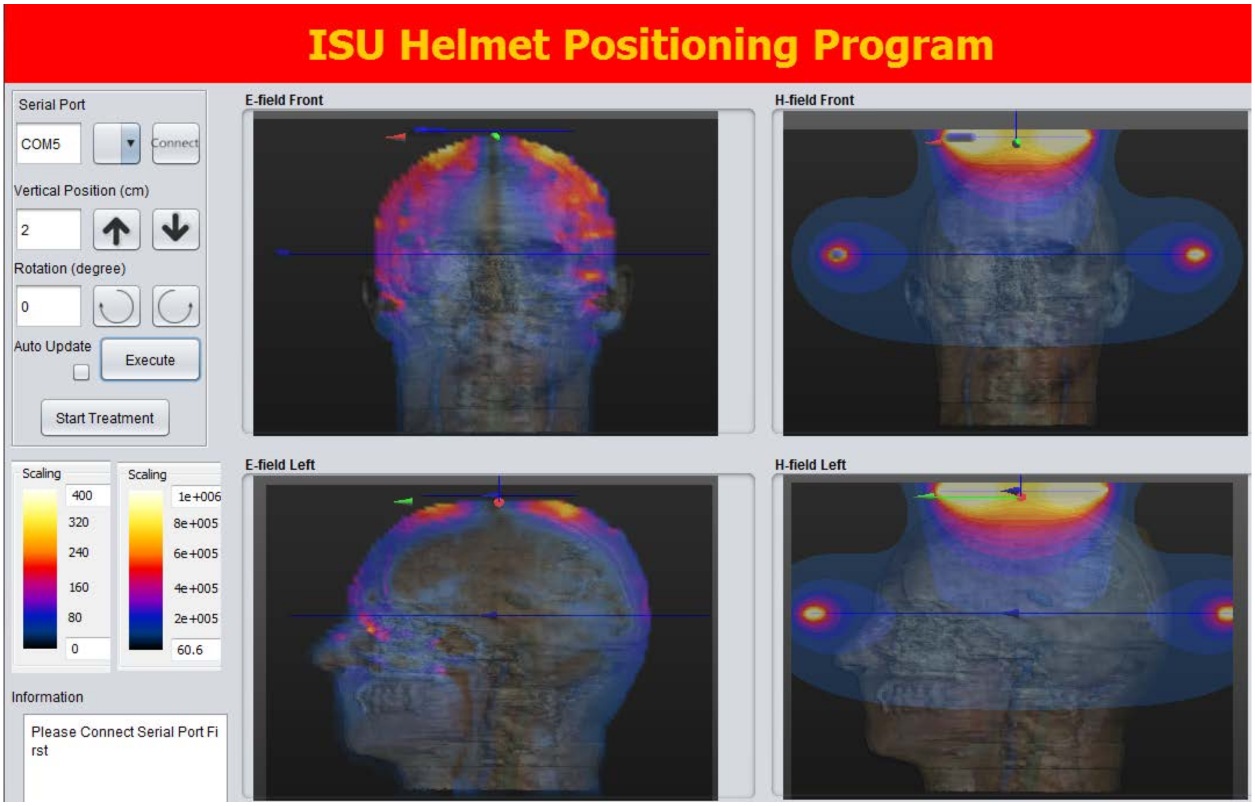

Figure 8: GUI Interface

6. Testing

6.1 Magnetic Field

The magnetic field is measured using a guassmeter connected to an automatic control system. This can be set to read the field in many different locations. The results need to be very accurate to ensure only a specific part of the brain is stimulated. These readings must be compared against the simulation results to verify that the images used in the GUI are accurate.

6.2 Helmet & Coil Position

Testing the vertical movement of the helmet is done using a ruler with centimeter markings. The position of the structure can be compared to the information in the computer interface.

The testing of the halo coil rotation can be accomplished using a simple protractor. The angle should be measured from the neutral zero position. This measurement can be directly compared to the information in the computer interface.

6.3 Temperature

The actual temperature of the coil will be measured using thermometer. These thermometers are already integrated into the coil itself. In order to ensure safe functionality the temperature must never exceed 37 degrees Celsius otherwise the coil will heat up and start melting the plastic cover.