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Project Proposal

Team Members: Ganesh Arvapalli

Mentors:

- VOR lab: Dr. Amir Kheradmand, Dr. David S. Zee
- BIGSS lab: Farshid Alambeigi, Dr. Mehran Armand

Topic: Our objective is to assess subjective visual vertical (SVV) perception via eye tracking and the relationship between SVV and the supramarginal gyrus (SMGp).

Goal: Create a robotic tool that can perform transcranial magnetic stimulation (TMS) automatically to measure areas of activity around the brain.

Relevance:

The subjective visual vertical (SVV) is defined as a person's ability to perceive vertical lines and identify them.[1] Impairment of this measurement has previously been correlated with Parkinson's disease, Pisa syndrome, and otolith injury.[1][2][3] The SVV has been linked to activity in the posterior aspect of the supramarginal gyrus (SMGp), a region of the brain that has been shown in neuroimaging studies to analyze vestibular inputs and combine them with visual perception.[4] In order to investigate this relationship further, eye tracking technology has been developed that can measure ocular torsion, in which the eye twists within its socket to align with perceived verticality, thereby quantifying the SVV further.[5] Thus, forcibly inducing changes in the activity of the SMGp could be used to affect SVV perception that can consequently be measured using eye tracking software.

Approach:

Currently, Transcranial Magnetic Stimulation (TMS) is used to induce the required changes in the activity of different regions of the brain.[4] This process involves a continuous theta burst stimulation that creates a cortical stimulation in a targeted area.[6] TMS can be applied over the SMGp through specific points of interest on the cortex, however this process can be arduous for experimentation due to the need to apply TMS repetitively for extended periods of time. Our solution is to automate the application of TMS through robotic control via a UR5 or Kuka robot. Current concerns include keeping the TMS coil close to the site of application, which is tangent to the head, while also addressing the safety concerns of moving a robot so close to a subject. For this reason, force feedback will be implemented to ensure the pressure applied is kept to a minimum. A diagram of the robot control scheme is shown below.

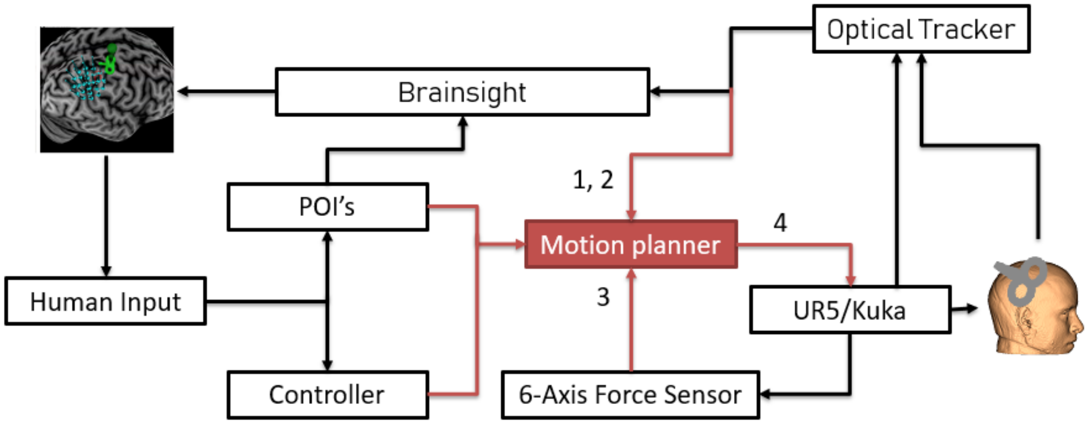

Figure 1. A diagram showing the intended solution setup, where the red components have yet to be implemented.

A general list of steps is listed below:

1. Define points of interest prior to setup on MRI reconstruction.
2. Position the optical tracker with the tool and head in view.
3. Complete registration of the head to the MRI reconstruction and skin and find the initial position of the TMS coil with respect to the head using pivot calibration.
4. Calculate the vector of motion to the first point of interest.
5. Move the TMS coil into position very slowly and stop.
6. Measure the force feedback and adjust TMS coil position accordingly.
7. Conduct the experiment while keeping the tool stationary.
8. Repeat steps 4-7 as needed.

Deliverables:

Minimum Goals:

- Develop control algorithms to move the TMS coil in simulation reliably between given points
- No consideration of safety concerns
- Documentation of control algorithm and motion planning

Expected Goal:

- Complete motion planning between given points on phantom head generated by MRI scans
- Add safety constraints to robot path planning to ensure patient
- Documentation of safety constraint code and motion adjustments
- Add interface with MRI visualization software

Maximum Goal:

- Move the TMS coil reliably between many head locations on the physical robotic system

Timeline

Task	***Deadline***	***Status***	***Assessment***
Get relevant dimensions of all components	3/2	Completed	Record numbers – 2/23
Set up simulation software	3/2	Ongoing	Successfully run – 3/2
Construct 3D models of relevant environment parts	**3/2**	Upcoming	Create environment – 3/2
Write motion algorithm w/o force feedback	3/15	Upcoming	Test algorithm base cases – 3/16
Document motion algorithm and registration	**3/16**	Upcoming	Document Assessment 1 – 3/16
Compute head registration based on MRI scans	3/28	Upcoming	
Compute tool registration	**4/6**	Upcoming	Run in simulation - 4/12
Gather POI's and position relative to CAD model	4/7	Upcoming	
Research safety constraints and implementation of force feedback	4/12	Upcoming	Present findings – 4/12
Write force feedback algorithm and integrate into existing code	**4/20**	Upcoming	Run in simulation – 4/26
Document safety constraint algorithm	4/21	Upcoming	Document Assessment 2 – 4/21
Understand Brainsight software usage and interface	**4/27**	Upcoming	Testing in VOR Lab – 5/10
Port code into existing robotic system	**5/4**	Upcoming	
Document all code used in portability	5/5	Upcoming	Document Assessment 3 – 5/5

Table 1. A basic timeline showing deadlines and assessment dates as well as the mode of assessment.

Key Dates

Goal	***Complete Date***	***Assessment Date***	***Overall Status***
Recreate experiment environment in simulation without motion	3/2	3/8	
Registration of all environment elements to optical tracker	3/16	3/29	

Calculating TMS tool vector to targeted POI's on scalp in real time	4/6	4/12	Minimum Goal
Constraining robotic motion to remain tangent to head (within safety constraints)	4/20	4/26	Expected Goal
Interface motion data with brain visualization software	4/27	5/10	
Converting simulated motion data into actual robotic movement	5/4	5/10	Maximum Goal
Complete documentation reassessment (ongoing for each part)	5/11	5/17	

Table 2. A list of important dates that also lists milestones along the left side column. These milestones align closely with the goals and expectations for this project.

Dependencies

Item	***Reasoning***	***Status***	***Deadline***	***Backup Plan***
Lab access	To work in focused environment with simulation software (from Farshid)	Received	2/23	-
Simulation software	Model motion of robot before testing on actual system (from Farshid)	In progress	3/2	Use lab computers to work instead.
Brain visualization software	Construct 3D model of head based on MRI scans and show tool relative to brain (from Amir)	Received	-	-
Defined safety constraints	Lower tool pressure against head (from Farshid and Amir)	In progress	3/1	Restrict robot speed
Robotic system in Homewood lab	Achieve maximum goal of performing experiments (from Farshid and Amir)	In progress	4/1	Minimal testing will be done in lab on medical campus

Table 3. A current list of dependencies including those that have recently been received.

Management Plan

My current plan is to schedule weekly meetings with Farshid on Thursdays before class at 12:30 PM. I will also schedule bi-weekly meetings with Amir and Jorge at the Vestibular and Ocular motor Research (VOR) Lab on the medical campus although the timing on these meetings will vary. All coding will be accomplished on either my personal computer or on a computer in the BIGSS Lab with version control through Bitbucket.

Reading List

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2. Pereira, C. B., Kanashiro, A. K., Maia, F. M., & Barbosa, E. R. (2014). Correlation of impaired subjective visual vertical and postural instability in Parkinson's disease. Journal of the Neurological Sciences, 346(1–2), 60–65. https://doi.org/10.1016/j.jns.2014.07.057
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10. Pereira, C. B., Kanashiro, A. K., Maia, F. M., & Barbosa, E. R. (2014). Correlation of impaired subjective visual vertical and postural instability in Parkinson's disease. *Journal of the Neurological Sciences*, *346*(1–2), 60–65. https://doi.org/10.1016/j.jns.2014.07.057
11. Rossi, S., Hallett, M., Rossini, P. M., & Pascual-Leone, A. (n.d.). Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. *Clinical Neurophysiology*, *120*(12), 2008–2039. https://doi.org/10.1016/j.clinph.2009.08.016