

Robot-Assisted Transcranial Magnetic Stimulation (RA-TMS)

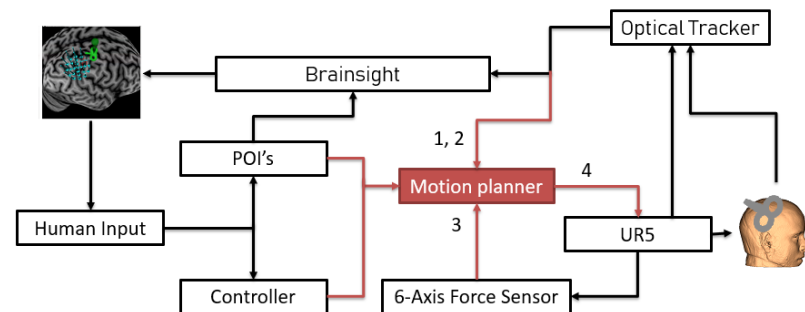
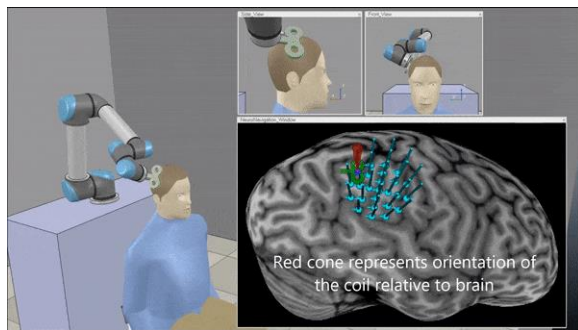
Name: Ganesh Arvapalli

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

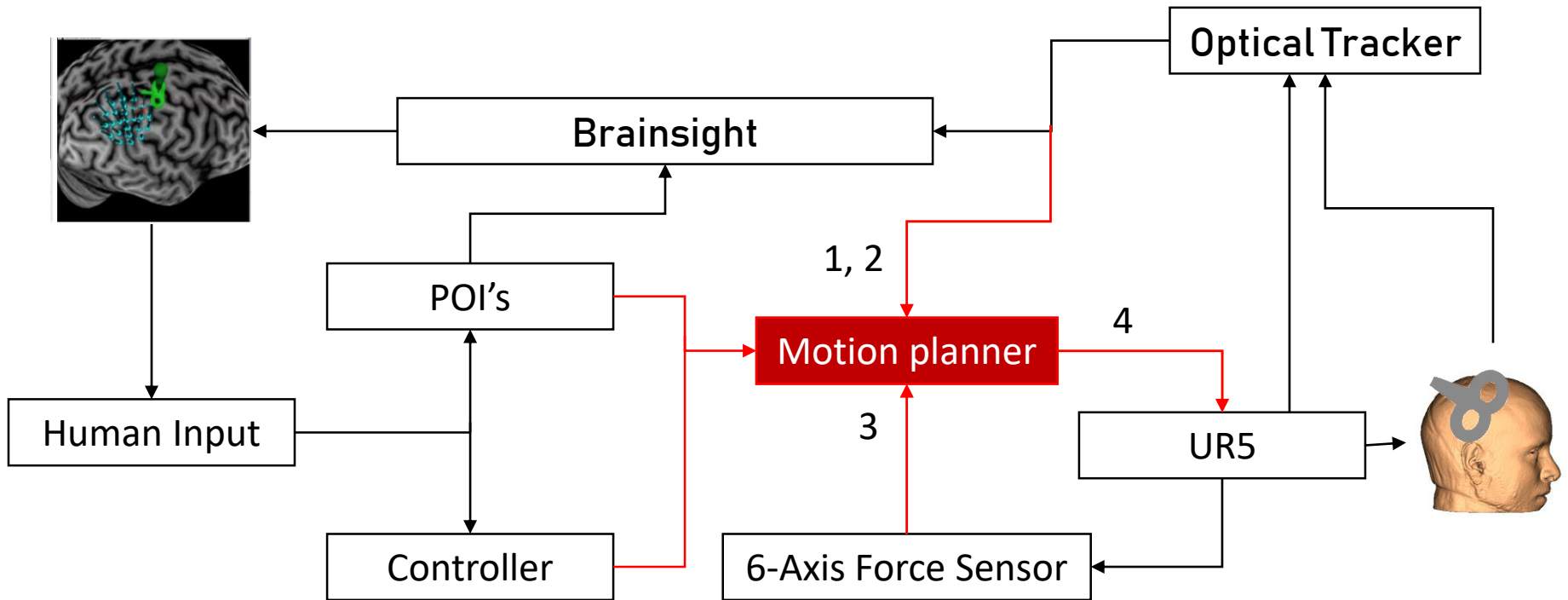
Project Summary

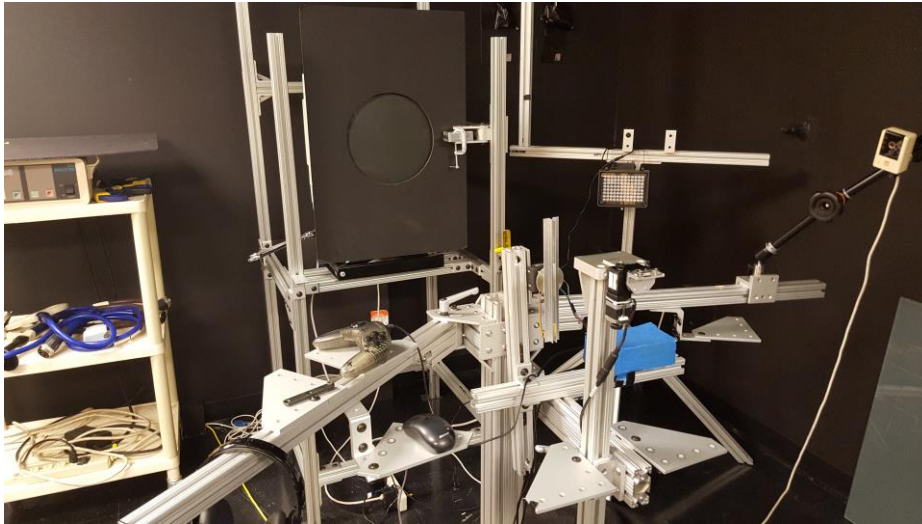
Topic: Assess subjective visual vertical (SVV) perception via eye tracking and relationship between SVV and the SMGp.

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



Solution Setup





Completed Tasks

- Created 3D CAD model for TMS coil, received model for robot and head
- Set up environment in 3D Slicer
- Calibrated force sensor and linked to computer
- Wrote program to move robot linearly from one point to another (no force feedback, no curvature)
- Began writing point map generator for curved surface
- Wrote instruction manual for installation and setup

Next Steps

- Design rigid holder for TMS coil and interface with six-axis force sensor

Previous Deliverables

- **Minimum: (Expected by 4/12)**
 - Develop control algorithms to move the TMS coil in simulation reliably between given points (ignoring safety concerns and using only linear motion).
 - Documentation of control algorithm and motion planning
- **Expected: (Expected by 4/26)**
 - Complete motion planning between given points on phantom head generated by MRI scans
 - Add safety constraints to robot path planning to ensure patient
 - Add interface with MRI visualization software
 - Documentation of safety constraint code and motion adjustments
- **Maximum: (Expected by 5/10)**
 - Move the TMS coil reliably between many head locations on the physical robotic system
 - Document implementation in full robotic system, including installation instructions

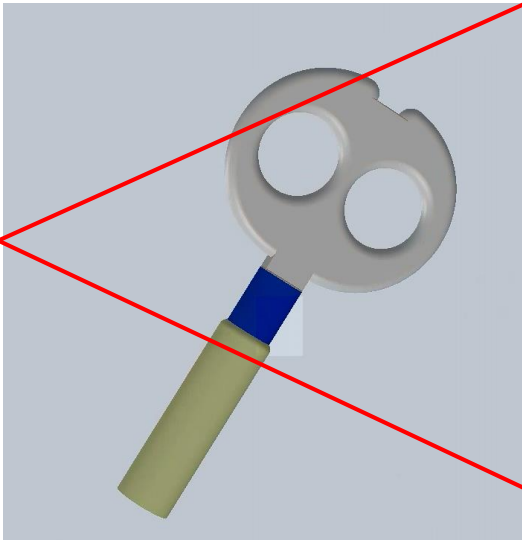
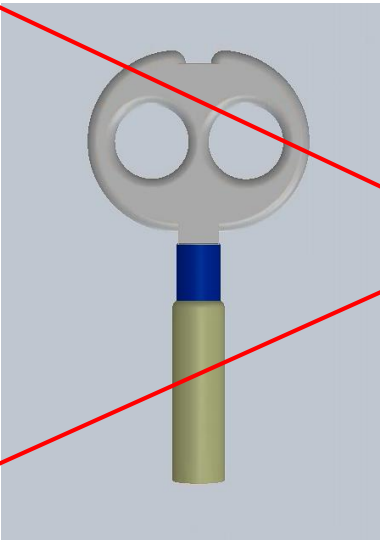
Updated Deliverables

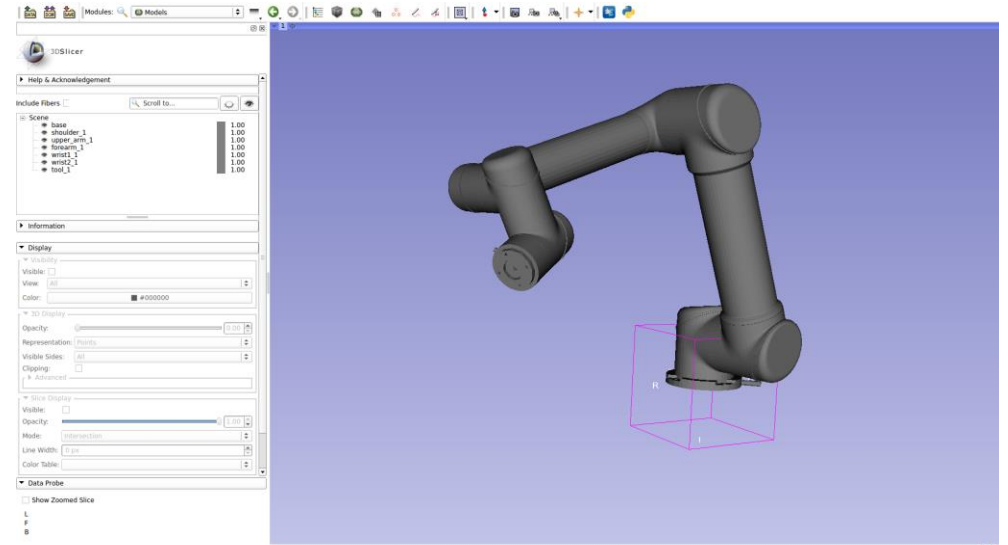
- **Minimum: (Expected by 4/12)**
 - Develop control algorithms to move the TMS coil in simulation reliably between given points (ignoring safety concerns and using only linear motion).
 - Documentation of control algorithm and motion planning
- **Expected: (Expected by 4/26)**
 - Complete motion planning between given points on phantom head generated by MRI scans
 - Add safety constraints to robot path planning to ensure patient
 - ~~– Add interface with MRI visualization software~~
 - Documentation of safety constraint code and motion adjustments
- **Maximum: (Expected by 5/10)**
 - ~~– Move the TMS coil reliably between many head locations on the physical robotic system~~
 - Measure force interactions between TMS tool and robot on physical system and record acceptable limits
 - Document implementation in full robotic system, including installation instructions

Updated Dependencies

Item	Reasoning	Status	Deadline	Backup Plan
Lab access*	To work-in focused environment with simulation software (from Farshid)	Received	2/23	Work off personal laptop or computers in other labs
Simulation software*	Model motion of robot before testing on actual system (from Farshid)	Received	2/23	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	Ensure tool pressure against head is not dangerous (from Farshid and Amir)	In progress	5/4	Restrict movement of robot to very slow speeds
Robotic system in Homewood lab	Achieve maximum goal of performing experiments on real-world system (from Farshid and Amir)	Updated	4/28	Minimal testing will be done in lab on medical campus

CAD Models





Documentation

- Installation Manual + Setup Instructions for Ubuntu 16.04 environment
- LCSR common code kept on GitLab:
<https://git.lcsr.jhu.edu/>
- Authored code is on Bitbucket:
https://bitbucket.org/garvapa1/ra_tms_control

Updated Timeline

Task	Deadline	Status	Assessment
Set up simulation software	2/23	Completed	Successfully run — 2/23
Get relevant dimensions of all components	2/23	Completed	Record numbers — 2/23
Construct 3D models of relevant environment parts	<u>3/2</u>	Completed	Create environment — 3/2
Compute head registration based on MRI scans	3/9	Completed	Run simulation with tracker w/ highlighted POI's — 3/29
Compute tool registration	<u>3/16</u>	Updated	
Gather POI's and position relative to CAD model	3/28	Updated	
Write motion algorithm w/o force feedback	<u>4/6</u>	Completed	Run in simulation — 4/12
Document motion algorithm and registration	4/7	Completed	Document Assessment 1 — 4/7
Research safety constraints and implementation of force feedback (with tool holder)	4/12 4/20	Upcoming	Present findings — 4/17
Write force feedback algorithm and integrate into existing code	<u>4/26</u>	Upcoming	Run in simulation — 4/26
Document safety constraint algorithm	4/26	Upcoming	Document Assessment 2 — 4/21
Understand Brainsight software usage and interface	<u>4/27</u>	Updated	Testing in VOR Lab — 5/10
Port code into existing robotic system	<u>5/4</u>	Upcoming	
Document all code used in portability	5/5	Upcoming	Document Assessment 3 — 5/5

*Total assessment will be done on 5/11, including documentation

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)	4/26	4/26	Expected Goal
Interface motion data with brain visualization software	4/27	5/10	
Construct tool holder to interface force sensor and coil	5/2	5/10	
Converting simulated motion data into actual robotic movement (with force feedback measurements)	5/4	5/10	Maximum Goal
Complete documentation reassessment (ongoing for each part)	5/11	5/17	

Management Plan

- Continue weekly Meetings with Farshid (Day varies week to week, no longer Thursdays)
- Bi-weekly meetings with Amir/Jorge + VOR Lab
 - At end, will convene group to take force measurements

Reading List

1. Brodsky, M. C., & Holmes, J. M. (2012). Torsional augmentation for the treatment of lateropulsion and torticollis in partial ocular tilt reaction. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, 16(2), 141–144. <https://doi.org/10.1016/j.jaapos.2011.11.009>
2. Gorelick, D. A., Zangen, A., & George, M. S. (2014). Transcranial magnetic stimulation in the treatment of substance addiction: TMS as addiction treatment. *Annals of the New York Academy of Sciences*, n/a-n/a. <https://doi.org/10.1111/nyas.12479>
3. Kheradmand, A., Lasker, A., & Zee, D. S. (2015). Transcranial Magnetic Stimulation (TMS) of the Supramarginal Gyrus: A Window to Perception of Upright. *Cerebral Cortex*, 25(3), 765–771. <https://doi.org/10.1093/cercor/bht267>
4. Narayana, S., Papanicolaou, A. C., McGregor, A., Boop, F. A., & Wheless, J. W. (2015). Clinical Applications of Transcranial Magnetic Stimulation in Pediatric Neurology. *Journal of Child Neurology*, 30(9), 1111–1124. <https://doi.org/10.1177/0883073814553274>
5. 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>
6. 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>
7. Scocco, D. H., Wagner, J. N., Racosta, J., Chade, A., & Gershanik, O. S. (2014). Subjective visual vertical in Pisa syndrome. *Parkinsonism & Related Disorders*, 20(8), 878–883. <https://doi.org/10.1016/j.parkreldis.2014.04.030>