Robot-Assisted Transcranial Magnetic Stimulation (RA-TMS)

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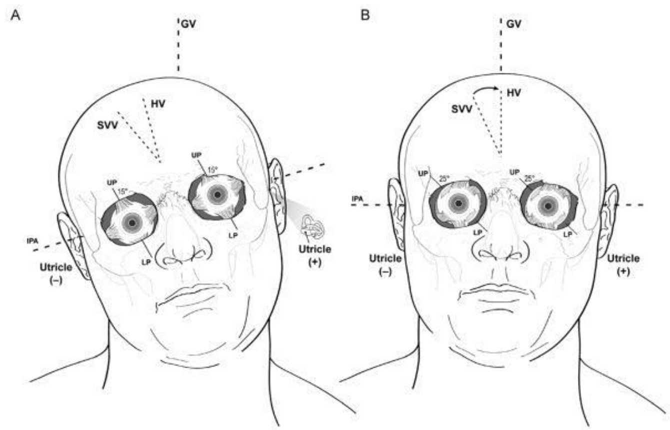
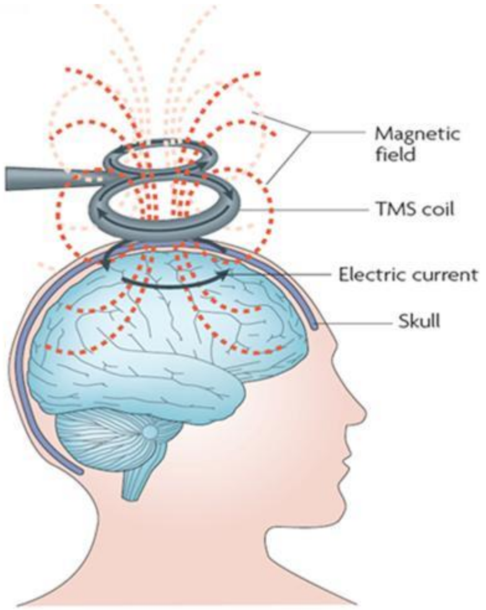
Background and Relevance

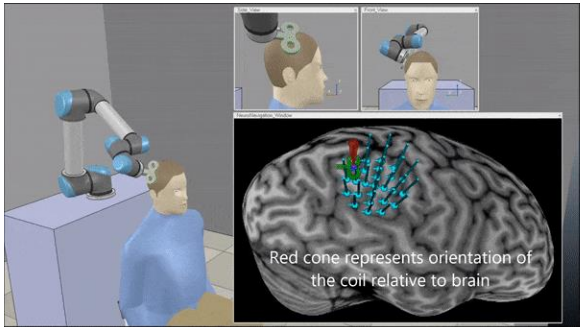
- Subjective Visual Vertical (SVV)
  - Eye tracking
  - Torsional motion
- Supramarginal gyrus (SMGp)
  - Perception of space
- Vestibular feedback and Perception

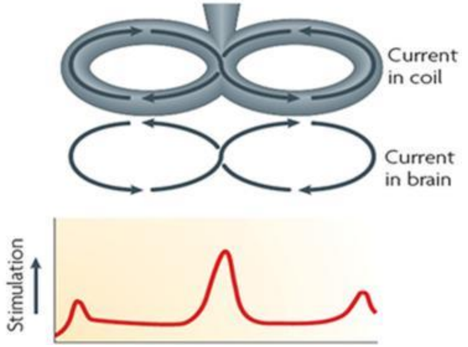


Current Approach

- Transcranial Magnetic Stimulation (TMS)
- Points of Interest (POI's)
- UR5/Kuka control
- Safety concerns
  - Force feedback







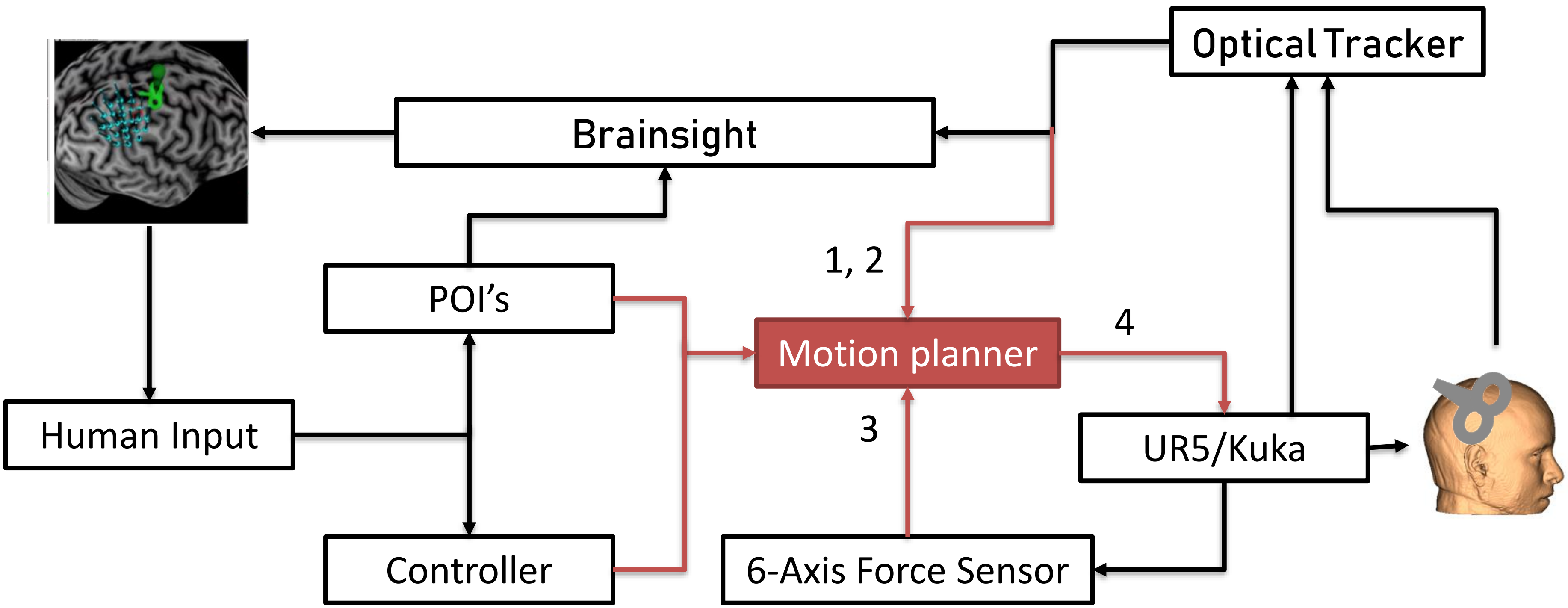
Topic: Assess subjective visual vertical (SVV) perception via eye tracking and relationship between SVV and the SMGp.

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

Sub-goals

1. Registration of subject's head to MRI reconstruction of head based on cortex
2. Calculating TMS tool vector to targeted POI's on scalp in real time.
3. Constraining robotic motion to remain tangent to head (within safety constraints)
4. Converting simulated motion data into actual robotic movement

Solution Setup



Solution Steps

1. Define POI's prior to setup on MRI reconstruction
2. Position optical tracker with tool and head in view
3. Complete registration of head to MRI reconstruction + skin and find initial position of tool w.r.t. head using pivot calibration
4. Calculate vector of motion to first POI
5. Move coil to position very slowly and stop
6. (Optional: Measure force feedback from tool and adjust position accordingly)
7. Conduct experiment while keeping the tool stationary
8. Repeat steps 4-7 as needed.

Deliverables

- **Minimum Goals:**
  - Developing control algorithms to move the TMS coil **in simulation** reliably between some **given** points on a phantom's head without considering the safety concerns.
- **Expected Goal:**
  - Repeating the minimum goal task with additional safety constraints in **simulation.**
- **Maximum Goal:**
  - Move the TMS coil reliably between a number of different cortical locations **on the physical robotic system**

Dependencies

Item	Reasoning	Status	Deadline	Backup Plan
Lab access*	To work in focused environment with simulation software (from Farshid)	In progress	2/23	Work off personal laptop or computers in other labs
Simulation software*	Model motion of robot before testing on actual system (from Farshid)	In progress	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	3/1	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)	In progress	4/1	Minimal testing will be done in lab on medical campus

Timeline

Task	Deadline	Status	Assessment
Set up simulation software	2/23	Ongoing	Successfully run – 2/23
Get relevant dimensions of all components	2/23	Ongoing	Record numbers – 2/23
Construct 3D models of relevant environment parts	**3/2**	Upcoming	Create environment – 3/2
Compute head registration based on MRI scans	3/9	Upcoming	Run simulation with tracker w/ highlighted POI's – 3/29
Compute tool registration	**3/16**	Upcoming	
Gather POI's and position relative to CAD model	3/28	Upcoming	
Write motion algorithm w/o force feedback	**4/6**	Upcoming	Run in simulation - 4/12
Document motion algorithm and registration	4/7	Upcoming	Document Assessment 1 – 4/7
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

*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)	4/20	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	

Management Plan

- Weekly Meetings with Farshid
  - Thursdays before class
- Bi-weekly meetings with Amir/Jorge + VOR Lab

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