HMD-Based Navigation for Ventriculostomy

Maia Stiber

CIS II Project Proposal
***Mentors**: Ehsan Azimi, Peter Kazanzides, Chien-Ming Huang, Dr. Judy Huang, and Dr. Camilo Molina*

Introduction

A *Ventriculostomy* is a procedure conducted by neurosurgeons bedside to relieve pressure in the brain. This procedure is done by drilling a burr hole and inserting a catheter into a ventricle to drain cerebrospinal fluid. The target of this procedure is the Foramen of Monro.

Relevance/Importance: Surgeons largely rely on spatial temporal reasoning, because they look at a CT scan to guide this procedure, and experience. In addition, because patients have various anatomies, the Foramen can be shifted. This results in misses in about a third of insertion attempts. That's not ideal because generally this procedure is time sensitive as pressure in the brain continues to build during failed attempts. There needs to be a way to eliminate the additional attempts.

There already has been a HMD system created, by my mentors on this project, which provides a voice-activated navigational system that overlays the target ventricle on the patient's head and also a planned path of catheter insertion customizable by the user. This system uses Hololens to project all of the visualization.

The overall workflow of this current system is calculating the wearer's interpupillary distance (provided by Hololens), register the CT scan to the patient's head, and then plan the path at which the surgeon would insert the catheter along. The process of registering involves touching a tracked pointer to the fiducials and then recording the location using voice commands. The spheres in the hololens turn green to show that the fiducials are registered. The next step in the registration process is to use the commands "align" and "register" so that the visualization is exact overlay of the patient's anatomy. The path planning process involves recording the desired start location of insertion and then the system will project a path from that start point to the target. The voice commands used for this step are "plan" and "complete."

To test this system, a phantom was created. The phantom has registration fiducials on the front of the skull, a sample burr hole on the top of the head, and openings on the side for horoscope cameras to look in. Inside the plastic skull is the "brain of the phantom. The "brain" is made out of gelatin and there are three balls embedded in it, where are the possible shifts/locations of the foramen. These balls are the sample targets for this procedure. In order to use this phantom, a CT scan has been taken and then doctored so that the foramen is at each one of those balls.

Goal and Aims

The goal of this project is to evaluate the current AR-Guided Ventriculostomy System, to improve upon the guide line visualization, and to create a training module for the catheter insertion using this system that provides additional multi-modal feedback.

The aims of my project are to see if the AR-guided ventriculotomy is preferred by neurosurgeons, aiding in catheter alignment. We foresee issues, during the user study, with lining up the catheter with the red guide line because even though this guide line is in 3D space it is hard to tell depth. Another issue is that this system doesn't provide any feedback on how well the catheter is aligned and if the catheter has hit the target. Currently, this system relies on the intuition of the surgeon to assess insertion path and to know that they should only insert the catheter 6cm in. So the third aim, is to provide a training module so that surgeons would get catheter tracking information and feedback on whether they hit the target and also about their alignment.

Technical Approach Summary

This project is divided into two major sections: user study and training module.

User Study

Hypothesis: AR-Guided Ventriculostomy increases accuracy, efficiency, and decreases mental task load.

The users will be neurosurgery residents of varying expertise. It is a within-subject study meaning that they will be doing catheter insertions with and without the AR system. There are three targets in the phantom and the participants will do each of them in a randomized order for both conditions. Data will be recorded through video of the attempts and a questionnaire. The questionnaire would contain such measurements as the System Usability Scale (SUS), Demographics, and NASA Task Load Index. SUS is a well-established 10-question scale that determines how usable the system is. Demographics are important because experience, as mentioned above, is a crucial factor in the success of this procedure. NASA TLX is another well-established scale used to measure mental load of the workflow. Two borescope cameras implanted in the skull will determine accuracy. These cameras have an average error of 0.3mm. Video coding will also determine the efficiency of the procedure as annotations can be added as well feedback from the user.

Training Module

As mentioned before, one of the aims is to provide catheter feedback and better visualization of the catheter to aid in insertion and training using the system. As of right now, we have installed borescope cameras that can measure the distance between the catheter tip and the target. However, this is not in real-time. The goal of the training model would be using the borescope in real time to provide a current visualization of the catheter with respect to the patient and the guide line. In addition, the module would provide feedback, such as sound, to let the user know when the catheter has hit the target, as depth is hard to visualize.

Deliverables

Minimum:	• User Study Results and Analysis of Data • Edited UI that has improved visual perception of line
Expected:	• User Study Results and Analysis of Data • Script that provides feedback to surgeons on how well aligned and how close catheter is to the target in training
Maximum	• User Study Results and Analysis of Data • Script that provides feedback to surgeons on how well aligned and how close catheter is to the target during actual procedure

Milestones

Milestone	Expected Date Done By	Status
User Study Conducted	**3/13/20**	**In Progress**
• Questionnaire Created	2/21/20	Completed
• Video Tutorial Created	2/19/20	Completed
• IRB Approval	2/17/20	Completed
• Neurosurgeon Approval of User Study Questionnaire and Tutorial	2/24/20	Completed
• Pilot Study Conducted	2/29/20	In Progress
• Actual User Study Conducted	3/13/20	Not Started
Data Analysis of the User Study	**3/20/20**	**Not Started**
• Video Coding Conducted	3/20/20	Not Started
• SUS/NASA TLX scales analyzed	3/20/20	Not Started
Reading Preliminary Papers	**3/17/20**	**In Progress**
Editing AR UI	3/20/20	**In Progress**
• Learn Unity	3/4/20	In Progress
• Improved visualization of the guide line	3/20/20	Not Started
Training Script for AR-Guided Ventriculostomy	**3/31/20**	**Not Started**
• Real-time measurements of catheter distance from target	3/20/20	Not Started
• Add 3D line to represent catheter in UI with real-time orientation	3/30/20	Not Started
• Add multi-modal feedback for catheter alignment and target distance	3/31/20	Not Started
Tracking Catheter Script during Procedure	**4/30/20**	**Not Started**
• Prototype various Catheter Tracking Systems	4/15/20	Not Started
• Pick one and implement that system	4/25/20	Not Started
• Edit UI to provide feedback to the surgeons using the catheter tracking	4/30/20	Not Started
Poster Presentation/Report	**5/5/20**	**Not Started**

This plan has few "built-in" delays. For example, extra time was allotted to the user study section and data analysis section because the length of that depends on the availability and schedules of neurosurgery residents.

Dependencies

Dependency	Contact	Solution	Alternative Plan	Milestone Effect	Completed?
Hololens	Peter Kazanzides	Get one from lab.	Ask around for another one.	All	✓
Computer	N/A	Lab Computer	My laptop	All	✓
Catheter	Ehsan Azimi	Get one from Ehsan	Buy a catheter	All	✓
Cameras	N/A	Camcorder from Lab	Iphone camera	User study	✓
Skull Phantom	Ehsan Azimi	Get the one built in lab	N/A	All	✓
Neurosurgeon Availability	Dr. Judy Huang and Dr. Camilo Molina	Email and schedule neurosurgery residents.	Use people from the local community	User study	In Progress will be done by 3/6/20
Data/Code Backup	N/A	Github	External HD	All	✓
SD Card Reader	N/A	My laptop's SD card reader	USB SD card reader	User study	✓
IRB	Peter Kazanzides	Get added to the IRB.	N/A	User study	✓
Doctored CT images	Ruby Liu	CT scan of skull, doctored, so that the balls in phantom are vesicle.	N/A	User study	✓

Management Plan

During the term, I will have weekly meeting with Chien-Ming Huang on Monday from 2:00PM to 2:30PM and biweekly meetings on Wednesday with Chien-Ming Huang, Ehsan Azimi, and Peter Kazanzides at 4PM. Otherwise, my mentors can be reached by Slack and email.

Reading List and References

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- Yudkowsky, Rachel, et al. “Practice on an Augmented Reality/Haptic Simulator and Library of Virtual Brains Improves Residents’ Ability to Perform a Ventriculostomy.” Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare, vol. 8, no. 1, 2013, pp. 25–31.