Augmentation of Haptic Guidance into Virtual-Reality Surgical Simulators

Group 14
Eric Cao
Vipul Bhat
Brett Wolfinger

Mentors
Dr. Jeremy Brown
Dr. Mahya Shahbazi
Guido Caccianiga
Clinical Relevance

The number of robotic minimally invasive surgeries performed annually is increasing rapidly.

Surgeons must achieve proficiency with robotic surgical systems before performing these surgeries.

Training takes time and is lacking in real-time feedback.
Status Quo and Shortcomings

Trainees complete a practice task and are given observational feedback on metrics like force applied, smoothness, etc.

There is no real-time feedback, so trainees can develop bad practices during training.

Expensive Equipment

“Observational” Feedback

No Corrective Guidance
Prior Work

Experimental setup and virtual task implemented on dVRK

Provides 2 degrees of visual feedback on deviations from optimal path
Project Goal

Create haptic force feedback using guidance and repulsive force fields

Integrate force fields into existing dVRK experimental setup

Evaluate approach in pilot user studies

Evaluate effect of brain stimulation on training in pilot user studies
Technical Summary Overview

Pre Study
- Define force parameters based on task space error

During Study
- User begins training task
- Read position of surgical tool
- Data Collection Scripts
- Apply force according to force fields

Post Study
- Change force parameters based on user feedback and metrics

More details next slide
Technical Summary - Force Field Terminology

Repulsive: spring damper pointing towards optimal path

Guidance: forces pointing along optimal path

More details next slide
Technical Summary - Force Field Parameters

- $k_{\text{repulsive, guidance}}$: spring constant
- $\eta_{\text{repulsive, guidance}}$: damper constant
- $r_{\text{repulsive, guidance}}$: radius of allowable region
- Scaling on $x$ (linear, quadratic, etc)
- Repulsive, Guidance mixing strategy

\[ F = kx + \eta x' \]
Technical Summary - Force Study Outline

**What?** Evaluate different approaches and parameters for force fields

**Why?** To determine which approach/set of parameters results in most accurate guidance to optimal path and is least disruptive to the operator

**How?** Collect user feedback survey data and performance metrics

**Who?** Internal lab members
Technical Summary - Stimulation Study Outline

What? Evaluate effect of brain stimulation on robotics surgery training

Why? Brain stimulation could have a significant positive effect on training

How? Use existing brain stimulation setup while collecting user feedback survey data and performance metrics

Who? Novice undergrad / grad students
# Dependencies

<table>
<thead>
<tr>
<th>Dependency</th>
<th>Estimated Resolve Date</th>
<th>Needed Resolve Date</th>
<th>Resolution Plan</th>
<th>Fallback Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Existing GitLab</td>
<td>2/20</td>
<td>2/22</td>
<td>Contact Guido.</td>
<td>Can begin planning code without access, but will need access before we can test or check integration</td>
</tr>
<tr>
<td>Availability of dVRK</td>
<td>3/1</td>
<td>3/1</td>
<td>Create LCSR dVRK schedule</td>
<td>Move project onto a different dVRK or surgical robot.</td>
</tr>
<tr>
<td>Availability of accessories</td>
<td>3/1</td>
<td>4/5</td>
<td>Coordinate with HAMR lab for access to brain stimulation measurement tool</td>
<td>Use the brain stimulation tool when other lab members do not need it</td>
</tr>
<tr>
<td>IRB update</td>
<td>3/1</td>
<td>4/12</td>
<td>Dr. Brown has previously approved IRB. Add us and dVRK to it</td>
<td>If there is an issue with updating the IRB, we will have to write and submit a new one</td>
</tr>
<tr>
<td>Subjects Scheduling</td>
<td>4/5</td>
<td>4/12</td>
<td>Schedule mutually available times with subjects.</td>
<td>If unavailable, we can find more subjects (perhaps in a different population if acceptable to goal of study)</td>
</tr>
</tbody>
</table>
## Deliverables

| Minimum: (4/12) | ● C++ code for measuring, computing, and applying force fields to dVRK manipulators while in simulation stored in GitLab  
● Documentation of environment including operation, maintenance, and future |
| Expected: (4/19) | ● Report on user study evaluating the approach(es) taken to implement force field (Goal n = 10)  
● Data collection protocol and scripts for study extendability stored in GitLab |
| Maximum: (5/10) | ● Report on user study evaluating the effectiveness of the haptic guidance in the absence and presence of brain stimulation (Goal n = 10)  
● C++ code for integrating brain stimulation into data collection  
● Data collection protocol and scripts for study extendability stored in GitLab |

More details next slide
Timeline - Overview

More details next slide
## Timeline Details - Development

<table>
<thead>
<tr>
<th>Minimum Tasks: Implementing repulsive and guidance force fields for the needle-driving task on the dVRK system</th>
<th>Expected Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete ROS Tutorials from Clearpath Robotics</td>
<td>2/22</td>
</tr>
<tr>
<td>Generate a movement on the existing dVRK setup</td>
<td>3/1</td>
</tr>
<tr>
<td>Control movement to follow simple translation and rotation commands with controllable forces and torques</td>
<td>3/8</td>
</tr>
<tr>
<td>Refine movement to follow given 3D curve with human interference</td>
<td>3/15</td>
</tr>
<tr>
<td>Create repulsive force fields when deviated from given curve</td>
<td>3/29</td>
</tr>
<tr>
<td>Refine integration of curve following into dVRK</td>
<td>4/5</td>
</tr>
<tr>
<td>Edit / create documentation. Create documentation write up.</td>
<td>4/12</td>
</tr>
</tbody>
</table>
## Timeline - Evaluation

<table>
<thead>
<tr>
<th>Expected Tasks: Evaluating the approaches in a pilot user study</th>
<th>Expected Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create procedures for conducting study</td>
<td>4/5</td>
</tr>
<tr>
<td>Create data collection code</td>
<td>4/5</td>
</tr>
<tr>
<td>Complete pilot testing</td>
<td>4/12</td>
</tr>
<tr>
<td>Create write up and edit procedures document</td>
<td>4/19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Tasks: Evaluating the effectiveness of haptic guidance in the absence and presence of brain stimulation in a pilot user study</th>
<th>Expected Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add brain stimulation controls into experimental setup (work with Guido throughout this process)</td>
<td>4/26</td>
</tr>
<tr>
<td>Complete pilot testing</td>
<td>5/3</td>
</tr>
<tr>
<td>Create write up and edit procedures document</td>
<td>5/10</td>
</tr>
</tbody>
</table>
Management Plan - Overview

Weekly Meeting with full mentor team - Fridays 9am-10am
Weekly Check-Ins with mentor Guido - Tuesdays 12pm
Biweekly Team Check-Ins - Sundays 3pm-6pm, Thursdays 8pm-11pm

Communication: Instant Messaging (Slack), JHU Email
Code Storage: Fork of Existing GitLab
Documentation Storage: Google Drive, JHBox

More details next slide
Management Plan - Work Breakdown

We will all work on all parts of project. Members will take leads on different sections.

Vipul: Create and implement force field models.

Brett: Integration with VR environment. Creating user study procedures.

Eric: Set up brain stimulation with mentor Guido.
Reading List