Augmentation of Haptic Guidance into Virtual-Reality Surgical Simulators

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Summary

- Problem: Robotic Minimally Invasive Surgery (RMIS) trainees currently lack a means for real time feedback while performing practice tasks and can ingrain bad habits as a result
- Goal: Develop and evaluate the effectiveness of real-time haptic feedback and corrective guidance in surgical task simulators of complex trajectories (ie. suturing task)
  - Two Methods of Haptics:
    - Guidance: Persistent force encouraging user along an optimal 3D path
    - Forbidden Region: Forces applied only upon navigating into region
- Status: Delayed but catching up!
  - Issues with provided force interface to DVRK set us back a week
  - Minimal deliverable to be complete in the next week
  - Dependency update: IRB approved - go ahead to run study!
  - Dependency update: Brain stimulation tool may not be ready for our use - will impact maximum deliverable

Updates

Update: Dependencies

Dependency	Estimated Resolve Date	Needed Resolve Date	Resolution Plan	Status	Fallback Plan
Access to Existing GitLab	2/20	2/22 	Contact Guido.	**Received GitLab and setup our own branch**	Can begin planning code without access, but will need access before we can test or check integration
Availability of dVRK	3/1	3/1 	Create LCSR dVRK schedule	**Project is on both dVRKs, reserved one during our meeting times**	Move project onto a different dVRK or surgical robot.
Availability of accessories **(Brain stimulation tool)**	3/1	~~4/5~~ **4/19** 	Coordinate with HAMR lab for access to brain stimulation measurement tool	**Guido does not think the brain stimulation tool will be ready for our use**	~~Use the brain stimulation tool when other lab members do not need it~~ **Develop protocol and necessary code for running brain stimulation**
IRB update	3/1	4/12 	Dr. Brown has previously approved IRB. Add us and dVRK to it	**IRB approved and encompasses everything we need for our study**	If there is an issue with updating the IRB, we will have to write and submit a new one
Subjects Scheduling	~~4/12~~ **4/19**	~~4/12~~ **4/19** 	Schedule mutually available times with subjects.	**Pushed back a week due to delays, will start this week as pilot testing wraps up**	If unavailable, we can find more subjects (perhaps in a different population if acceptable to goal of study)

Update: Deliverables

Minimum: (~~4/12~~ **4/19**)	• Documentation of environment including operation, maintenance, and future • C++ code for measuring, computing, and applying ~~force fields~~ **guidance forces** to dVRK manipulators while in simulation stored in GitLab • **Same as above for forbidden regions**
Expected: (~~4/19~~ **5/4**)	• Data, study protocol and scripts for study extendability stored in GitLab • Report on user study evaluating the ~~approach(es) taken to implement force field~~ **effect of haptic feedback and our chosen approach(es)** (Goal n = 15)
Maximum: (5/10)	• C++ code for integrating brain stimulation into data collection • Data collection protocol and scripts for study extendability stored in GitLab • Report on user study evaluating the effectiveness of the haptic guidance in the absence and presence of brain stimulation (Goal n = 15)

More details next slide

Update: Timeline Details - Development

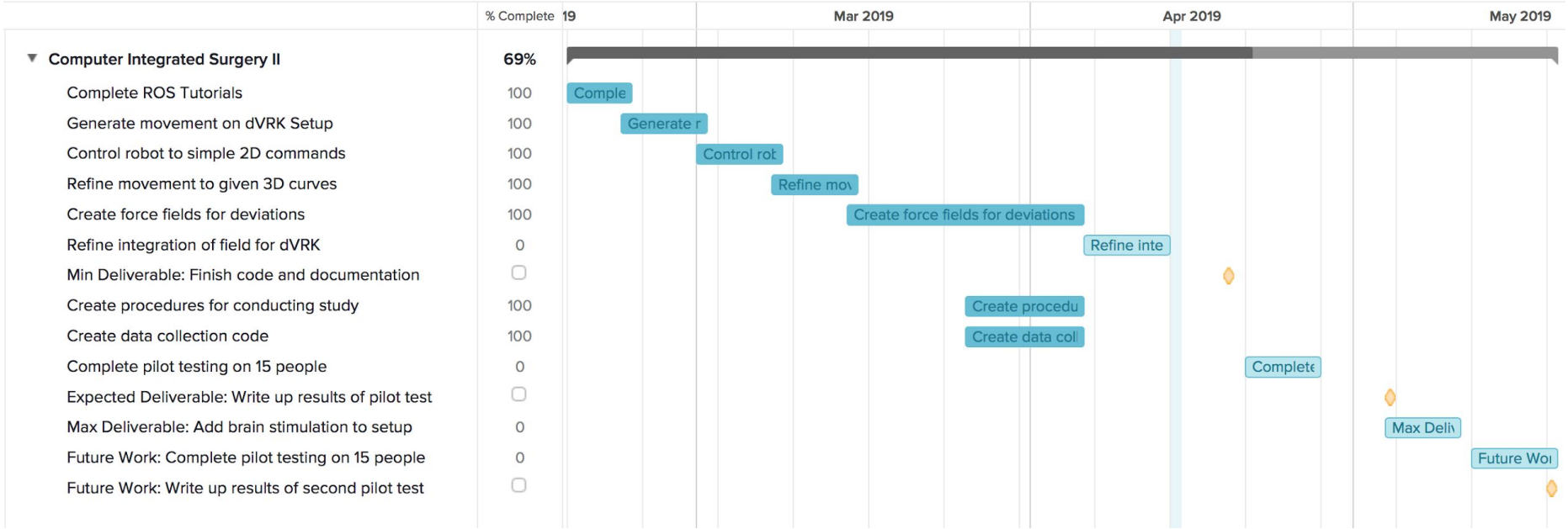
Minimum Tasks: Implementing repulsive and guidance force fields for the needle-driving task on the dVRK system	**Expected Date**
Complete ROS Tutorials from Clearpath Robotics	2/22
Generate a movement on the existing dVRK setup	3/1
Control movement to follow simple translation and rotation commands with controllable forces and torques	3/8
Refine movement to follow given 3D curve with human interference	3/15
Create repulsive force fields when deviated from given curve **(Guidance Force)**	~~3/29~~ **4/5**
Refine integration of curve following **(Guidance force)** into dVRK	~~4/5~~ **4/12**
Edit documentation. **Finish Forbidden Regions**	~~4/12~~ **4/19**

Update: Timeline Details - Evaluation

Expected Tasks: Evaluating the approaches in a user study	**Expected Date**
Create procedures for conducting study	4/5
Create data collection code	4/5
Run study on n=15 participants	~~4/12~~ **4/26**
Create write up and edit procedures document	~~4/19~~ **5/4**

Maximum Tasks: Evaluating the effectiveness of haptic guidance in the absence and presence of brain stimulation in a user study	**Expected Date**
Add brain stimulation controls into experimental setup (work with Guido throughout this process)	~~4/26~~ **5/10**
Run study on n=15 participants	~~5/3~~ **Future Work**
Create write up and edit procedures document	~~5/10~~ **Future Work**

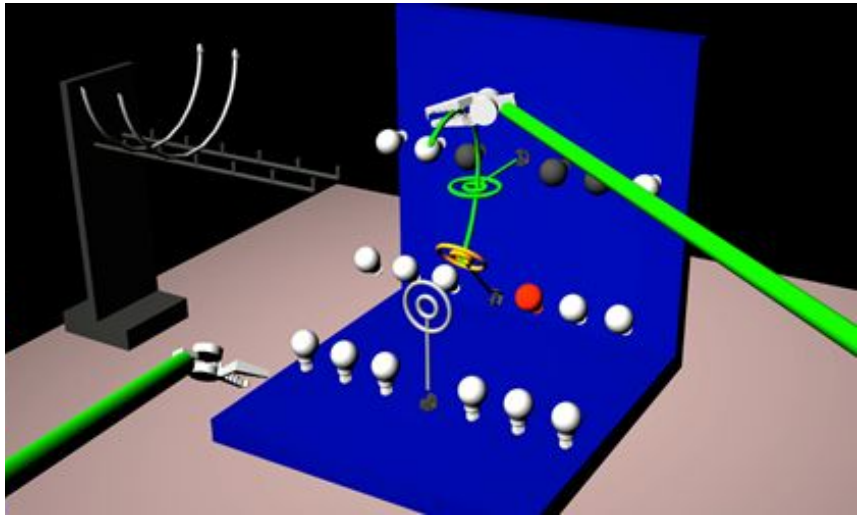
Update: Activity Timeline



Work to Date

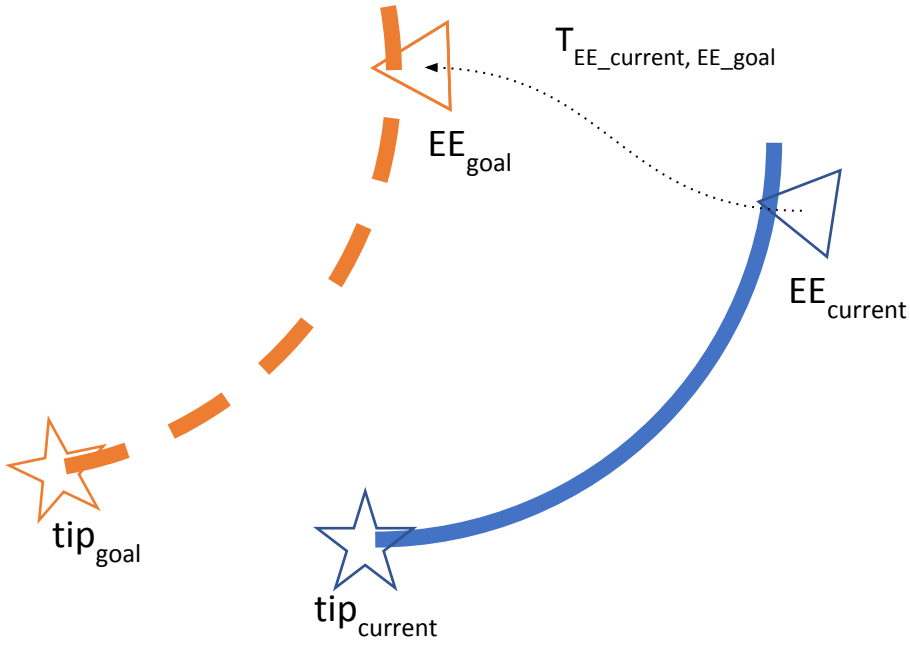
Task Overview

- Want to implement Haptic Feedback
- Need to find Task Space Error
  - Difference between where End Effector (EE) is and where EE should be



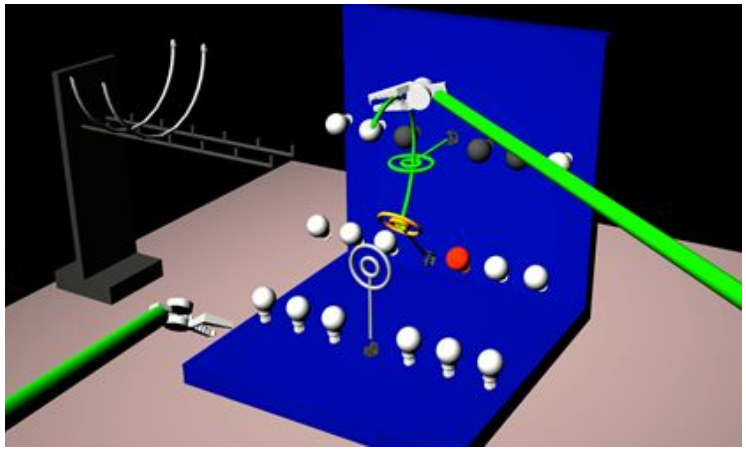
Calculating Task Space Error

1. Read $tip_{current}$, $EE_{current}$
2. Calculate $T_{tip,EE} = EE_{current} * tip_{current}^{-1}$
3. Find tip_{goal} (details later)
4. Calculate $EE_{goal} = T_{tip,EE} * tip_{goal}$
5. Calculate $T_{EE\_current,\ EE\_goal} = EE_{goal} * EE_{current}^{-1}$
6. $T_{EE\_current,\ EE\_goal}$ is task space error



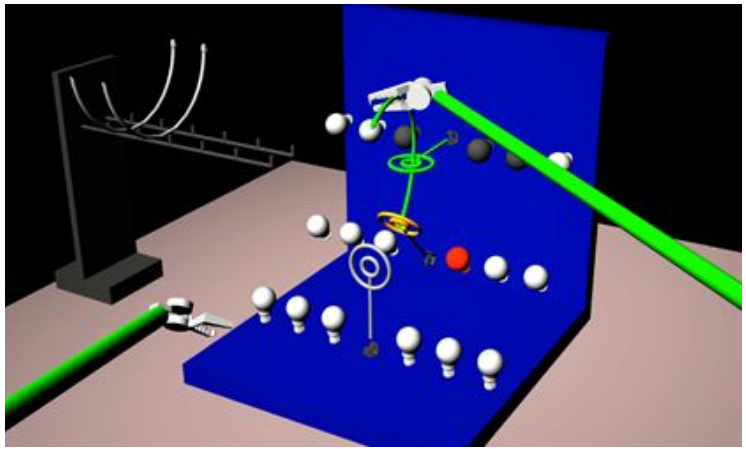
Haptic Feedback Methods: Guidance

- Guidance: Persistent force encouraging user along an optimal 3D path
- Tip_{goal} : Closeby candidate point taking into account current and desired velocity
- Spring, Damper



Haptic Feedback Methods: Forbidden Region

- Forbidden Region: Forces applied only upon navigating into region
- Tip_{goal} : Closest point in region
- Spring, Damper, Allowable region



Roadblocks We've Overcome

- dVRK Availability
  - Solution: switch systems
- Small Bug in dVRK Cartesian Impedance Optimizer
  - Plane optimizer not taking into account simulation frame transformation
  - Solution: Apply a correcting transformation in the background
- Small Bug in No_Joint_Limit Client
  - Solution: Anton fixed it and pushed an update

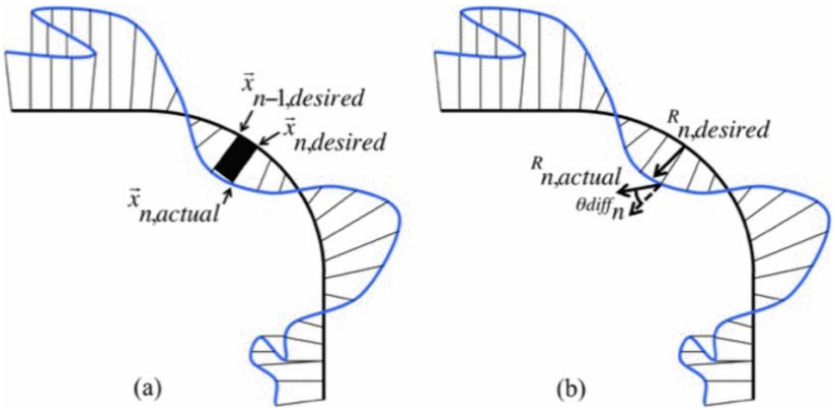
Looking Forward

User Study

- Question we are seeking to answer:
  - Does Haptic Feedback improve performance and/or learning on surgical tasks involving complex trajectories (ie. suturing)
- Experimental Setup
  - Subjects: Novices on the DaVinci (n = 15, 5 in each group)
  - Control group: No haptics
  - Two Experimental Groups: Guidance and Forbidden Regions
- IRB has been approved

User Study Metrics

- Metrics collected
  - Time to completion, level of forces applied, path taken by needle, translational and rotational error, subject survey data



[1] M. M. Coad et al., “Training in divergent and convergent force fields during 6-dof teleoperation with a robot-assisted surgical system,” IEEE World Haptics Conf., 2017, pp. 195–200.

Citations

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Reading List

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