Project Proposal - Collateral Control Systems for Surgical Training

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Background:

Robotic surgical systems have become increasingly popular around the world as a tool for surgeons to be able to perform increasingly effective and minimally invasive procedures. The integration of these systems allow them not only to be more efficient, but they also decrease lessen the toll of recovery on patients.[1] With more than 5,500 Da Vinci surgical systems installed around the world and more than 7.2 million procedures having been performed as of 2019,[2] the necessity of efficient training and educational tools for using such advanced machines is paramount. As recent studies have shown, many licensed operators for these systems still lack the hands-on experience necessary to be proficient in utilizing these machines.[3] This is primarily due to lack of hands-on experience with the robot since their number is limited and so is their availability for training.[4] Due to this lack of training and access to these machines alternatives for developing the necessary skills for the operation of these machines is crucial for the proliferation of their use, and improvement of their effectiveness as powerful surgical instruments.

Goal:

The goal of this project is to develop shared control systems for the AMBF (Asynchronous Multibody Framework) simulator which is a program capable of simulating virtual environments and tools that are integrable with a dVrk. This simulator allows users to practice using consoles similar to those used to operate da Vinci surgical machines in a 3D, totally modular environment. In doing so, different puzzles, procedures, and manipulations can be tested, practiced and mastered with little to no risk or pressure to the user. By integrating such a system with dual console control schemes, we hope to be able to create new training conventions for using dVrk and AMBF as training tools for da Vinci operators. The objective for us is to determine how users most effectively learn how to use the control console with the least amount of frustration and time consumption.

In addition, we hope to develop a new set of puzzles within the AMBF simulator in order to prove the robustness of the simulator as a potential training tool. Creating easily decipherable puzzles which put different skills and manipulations to the test will ideally help users build confidence in their ability to use the control console with precision, while also making the experience engaging. Making these puzzles easily understandable, but interesting enough to put users to the test should help show the universality of systems such as these for instruction across many different programs and skill levels.

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[1] "Minimally Invasive Robotic Surgery." *Grand View Health*, www.gvh.org/minimally-invasive-robotic-surgery/.
[2] *Intuitive.com*, www.intuitive.com/en-us/about-us/company.
[3] "Human Surgeons Are 'Barely Trained' on Operating Room Robots." *Futurism*, The Byte, 17 Mar. 2019, futurism.com/the-byte/surgeons-barely-trained-operating-robots.
[4] Ibid.

Importance:

The significance of this project is to improve the efficiency of widely distributable surgical training platforms in education and proficiency building activities. Already, VR systems for surgical training have shown to be effective tools in assessing and developing proficiency with the da Vinci robot.[5] Since precedent already exists for using such systems as training platforms for surgeons, and it is already understood that training programs for using these machines must be based on demonstration of proficiency and safety in using these machines,[6] the question then becomes how can we improve on these systems to make mastery of these skills more efficient? This project is a first step in developing these new systems. By designing new potentially very effective dual control training schemes and correlated puzzles to test them, this project could help pave the way for creating new standards in already existing -however not fully standardized- robotic training curricula.

Technical Approach:

The technical approach for this project is three-fold: development of dual console control schemes, creation of a set of puzzles in AMBF simulator, and the undertaking of a user study to test the effectiveness of these newly developed collateral control systems when compared to traditional learn methodologies. The first is development of the dual console control schemes. This will be done directly in the AMBF simulator code base which already includes, albeit very basic, collateral control protocols. This is all coded in C++ and already has an interface to integrate new shared control schemes. Approximately 6 new puzzles plan to be developed of varying difficulty (two easy, two medium, two hard) and will all be designed in Blender™, which can have 3D models quickly imported into the simulator. The difficulty of these tasks will be judged subjectively by us, based on some general criteria (duration, complexity of manipulations, required precision, difficulty to solve etc.), but ultimately are not crucial for the user study. Finally, conducting the user study for this experiment using our developed control systems and new set of puzzles is crucial for testing and analyzing the effectiveness of our collateral control systems as well as gather potentially informative data on the puzzles we developed. For conducting this study, IRB approval is currently being acquired and the estimated size of this study will consist approximately 30 participants. Along with these users, 2 experts will be needed for the study as well to serve as the "teachers" while testing the dual control systems. The plan is to get control data for user performance after self-teaching versus user performance after collateral control instruction from an expert. Data for this user study will be gathered through an already existing python script, which will be modified to include data collection in time taken, precision of movements, and efficiency of manipulations. Along with

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[5] Bric, Justin D, et al. "Current State of Virtual Reality Simulation in Robotic Surgery Training: a Review." *Surgical Endoscopy*, U.S. National Library of Medicine, 30 June 2016, www.ncbi.nlm.nih.gov/pubmed/26304107.

[6] Sridhar, Ashwin N, et al. "Training in Robotic Surgery-an Overview." *Current Urology Reports*, Springer US, 24 June 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5486586/.

this data, video footage of their virtual environment will be collected for qualitative analysis as well.

Deliverables:

- Minimum: At the very minimum, we intend to develop and implement dual console control in the AMBF simulator along with designing approximately 6 puzzles of varying difficulty to be used alongside the dual control system. In addition, we intend to develop a user study to be conducted along with collecting some mock data by ourselves to determine which metrics would be most valuable to test for in the user study.
- Expected: In addition to our minimum deliverable, we expect to be able to recruit surgeons and/or trainees with experience using the dVRK consoles to participate in our designed user study using the AMBF simulator and dual console control system.
- Maximum: If all goes well with project timing, we plan on writing and submitting an academic paper based on the results of the user study in addition to the other deliverables described previously.

Dependencies:

Currently, our unresolved dependencies for this project are as follows:

Dependency	**Description**	**Effect if not Resolved**	**Needed By**	**Alternatives**	**Contact(s)**
Homewood IRB approval	Approval to conduct user study	Inability to complete expected deliverable.	4/17	Use mock data to prove concept	Dr. Russ Taylor, Dr. Adnan Munawar, Dr. Peter Kazanzides
J-Card Access to JHU Robotarium	For access to dVRK consoles	Limits our access to dVRK consoles in Robotarium	3/6	Arrange times with Adnan to be let into Robotarium	Dr. Adnan Munawar
Subjects for user study	Consenting surgeons and/or trainees to participate in study	Inability to complete expected deliverable.	4/10	Generate mock user data for proof of concept	Dr .Peter Kazanzides

Notable dependencies that have been resolved include access to Blender™ and the AMBF simulator source code, a Git repository for version control and backups, and computers to use for development and testing.

Timeline:

Note that bolded items in our timeline are project milestones listed along with their expected achievement date:

Task	**Planned Start Date**	**Expected Finish Date**	**Status**
Familiarization with AMBF simulator and dVRK environment	2/12	2/28	Complete
Complete request for Homewood IRB approval	2/22	3/12	In progress
Milestone 1: IRB approval request submitted		**3/12**	
Implementing dual-console control in AMBF simulator	3/9	3/27	Not started
Design puzzles for user study	3/6	3/27	Not started
Documentation for dual control system in AMBF	3/16	3/27	Not started
Testing dual-console collateral control with dVRK	3/9	3/27	Not started
Milestone 2: Dual console control with dVRK and AMBF simulator		**3/27**	
Write and test data acquisition script	3/30	4/10	Not started
Milestone 3: Data acquisition script for user study (Minimum Deliverable)		**4/10**	
Finalize procedure for user study	3/30	4/17	Not started
Conduct user study	4/20	5/1	Not started
Milestone 4: User study complete (Expected deliverable)		**5/1**	

Write final report/paper/poster	5/1	5/5	Not started
Milestone 5: Final project report and poster		**5/5**	
Write user study paper	5/5	5/13	Not started
Milestone 6: Academic paper (Maximum deliverable)		**5/13**	

<u>Team Management:</u>

In order to work successfully as a group, we have set up weekly times to meet and discuss our progress, determine questions that could be asked when meeting with our mentor, and determine plans for future action. We have also arranged to meet with our main mentor, Dr. Adnan Munawar on a weekly basis for project updates though our existing group Slack workspace. We have also discussed with Dr. Munawar procedure for securing access to the dVRK consoles as needed.

Reading List

Bric, Justin D, et al. “Current State of Virtual Reality Simulation in Robotic Surgery Training: a Review.” *Surgical Endoscopy*, U.S. National Library of Medicine, June 2016, www.ncbi.nlm.nih.gov/pubmed/26304107.

Bric, Justin, et al. “Proficiency Training on a Virtual Reality Robotic Surgical Skills Curriculum.” *Surgical Endoscopy*, U.S. National Library of Medicine, Dec. 2014, www.ncbi.nlm.nih.gov/pubmed/24946742.

Lerner, Michelle & Ayalew, Mikias & Peine, William & Sundaram, Chandru. (2010). Does Training on a Virtual Reality Robotic Simulator Improve Performance on the da Vinci (R) Surgical System?. Journal of endourology / Endourological Society. 24. 467-72. 10.1089/end.2009.0190.

Moit, Harley, et al. “A Standardized Robotic Training Curriculum in a General Surgery Program.” *JSLS : Journal of the Society of Laparoendoscopic Surgeons*, Society of Laparoendoscopic Surgeons, 2019, www.ncbi.nlm.nih.gov/pmc/articles/PMC6924504/.

Sridhar, Ashwin N, et al. “Training in Robotic Surgery-an Overview.” *Current Urology Reports*, Springer US, Aug. 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5486586/.