Group 14: Vipul Bhat

Seminar Paper Critical Review

Project Summary

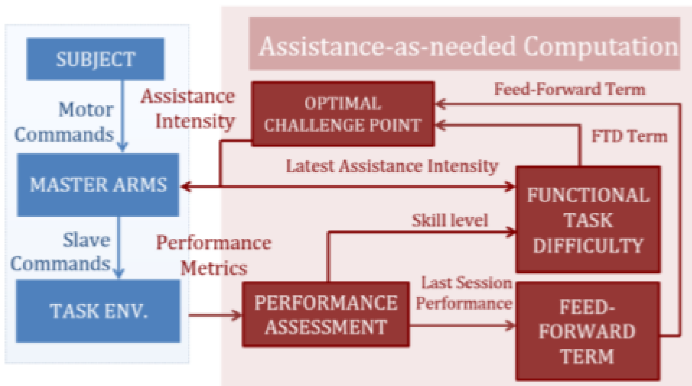
My group is investigating the effects of haptic feedback onto motor learning using virtual reality surgical simulators. We are implementing both a guidance method and a forbidden region active constraint and testing their effects on learning a skill through a user study.

Paper Selection

For my seminar presentation and report, I have chosen the paper titled "Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study," as I believe it is very relevant to the goals of our project. This paper explored the effects of a viscoelastic active constraint on the motor learning of a specified task and involves a similar experimental setup and software environment as our project. The experiments were run on the daVinci Research Kit (dVRK) and the Assisted Teleoperation with Augmented Reality (ATAR) framework was utilized for the virtual reality simulation. Due to these similarities, this paper was a good starting point as a model for our forbidden region, user study, and the project as a whole.

Summary and Background

The primary question addressed by the paper is whether robotic assisted training (haptic feedback using an active constraint) can help trainees gain skills faster. There have been previous studies done on this topic, but this paper attempts to tackle some of the shortcomings of past reviews. One of these shortcomings is that the tasks in previous paper have often been too simple, and this study uses a complex task that requires both manual dexterity and hand-eye coordination to ensure the presence of a learning curve. Another problem encountered by past studies is that trainees often become reliant on the haptic feedback, and this paper also utilizes a mathematical model to decrease the haptic feedback as the trainee learns the task to prevent such dependence. This method, which is often referred to as robot assistance-as-needed in teleoperated surgical robotics training, allows users to stay at an Optimal Challenge Point (OCP) so that learning is constantly promoted.



Methods

The task used for the study was a classic steady-hand game, which involves the user moving a ring along a curved wire path with the goals of preventing contact between the wire and ring and maintaining the plane of the ring perpendicular to the wire. The task inherently provided some visual feedback during the trials, as the color of ring changed from yellow to red if the ring approached the wire. This provided some intuitive feedback for the control group during the study. For the study, 16 non-medical participants were divided into two groups of 8, a null group and an assisted group. Each participant completed two sessions of eight repetitions each day for five days for a total of ten sessions. In order to prevent fatigue and keep the subjects motivated, frequent breaks and rests were provided.

The haptic feedback was provided using a simple viscoelastic active constraint. Given a desired pose T_d: [$\boldsymbol{p}_d$, $\boldsymbol{q}_d$] and a current pose T_c : [$\boldsymbol{p}_c$, $\boldsymbol{q}_c$], where $\boldsymbol{p}_x$ is the position vector in $\mathbb{R}^3$ and $\boldsymbol{q}x$ is a unit quaternion in $\mathbb{R}^4$, the formulas generate a force $\boldsymbol{f} \in \mathbb{R}^3$ and a torque $\boldsymbol{\tau} \in \mathbb{R}^3$.[1] K_T and K_R refer to the elastic coefficients, B_T and B_R refer to the viscosity coefficients, and ω_c refers to the current angular velocity.

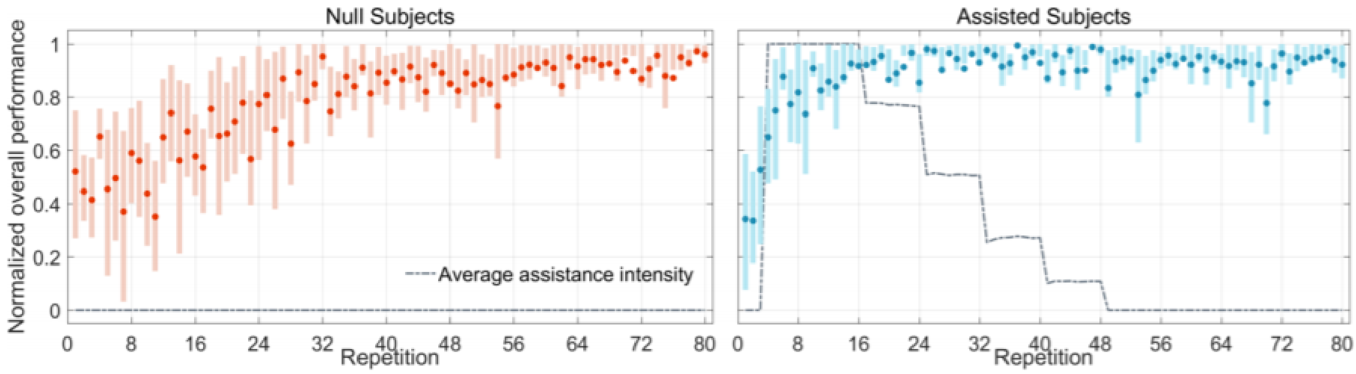
$$\boldsymbol{f} = K_T(\boldsymbol{p}_d - \boldsymbol{p}_c) - B_T\,\dot{\boldsymbol{p}}_c$$

$$\boldsymbol{\tau} = K_R[\boldsymbol{q}_c^*\boldsymbol{q}_d]_{rpy} - B_R\,\boldsymbol{\omega}_c$$

As stated earlier, the haptic feedback was also reduced for the assisted group as the trainee learned the task, a key point from Challenge Point Theory, which states that optimal learning corresponds to a specific Functional Task Difficulty (FTD), determined by the skill level of the trainee and the task. Maximum feedback was provided for the first two sessions and then slowly reduced until no feedback was provided. Metrics such as performance on previous sessions and repetitions were used in order to calculate the assistance intensity.

Results

Four main metrics were collected to analyze the effect of the haptic feedback on learning. The RMS of completion time, RMS of translational error, RMS of rotational error, and maximum translational error were normalized between 0 and 1, and then used to calculate a final normalized performance value also between 0 and 1. The results seemed to depict a slight decrease in learning time for the robotic assisted group, but there was no difference in the final performance values between both groups at the end of the study. When robotic assistance was decreased, subjects' performance initially decreased, but peak performance was re-achieved quickly.



Overall Assessment

This paper does a great job of addressing variables that have been lacking in many previous studies in order to provide thorough insight into whether haptic feedback can aid in motor learning for surgical systems. The combination of intuitive visual feedback and haptic feedback as well as comparing the base skill level of the two groups ensured that a difference in the learning curves arose from the haptic feedback. Adequate and frequent breaks prevented fatigue among the subjects and allowed for productive trials among all sessions. The paper also provided good descriptions and explanations for the approach and methods utilized in the study.

Although the paper had many positive components, I also have some critiques about the study. They conducted all the trials on the same path, which is more likely to teach the trainees the path as opposed to the skill. Adding more variability in the curvature of the path would help train the dexterity and coordination of the subjects rather than the muscle memory involved to complete the single path in the study. Another improvement that could be made to the study is the timing of the sessions during the day. It was observed during the later sessions that subjects in both groups showed better performance improvement from a morning session to an afternoon session compared to an afternoon session to the next morning session. Analysis of session to session improvement may be less variable if sessions were only conducted at one time of the day.

Conclusions

Although the results of the study showed a small decrease in learning time for the robotic assisted group, these results were not substantial enough to make definitive conclusions. However, the results are promising for future studies in this topic. The next steps to be taken after this study are to increase the sample size of participants and to test different paths throughout the sessions. The study also serves as a good model for our own user study since we will be using the same experimental setup and a simulation framework with a slightly different task. The overall layout seemed to work well for this study, but we will try to run our study on a larger sample size and test on different paths to tackle the shortcomings of this study.

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References

1. Enayati, Nima, et al. “Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study.” 2018 IEEE International Conference on Robotics and Automation (ICRA), May 2018, doi:10.1109/icra.2018.8463168