Augmentation of Haptic Guidance into Virtual-Reality Surgical Simulators

Computer Integrated Surgery II

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Introduction

- We have developed and integrated haptic and visual real-time feedback systems into a pre-existing virtual simulator for a needle suturing task using the daVinci Research Kit (dVRK).
- These guidance systems lay the groundwork for a comprehensive study on the benefits of visual and haptic feedback to Robotic Minimally Invasive Surgery (RMIS) trainees
- RMIS surgical training is currently lacking real-time feedback – our goal with this project is to identify, develop, and validate feedback systems which will provide the most benefit to trainees.

The Problem

- The number of RMIS surgeries is rapidly increasing and requires trained surgeons in order to perform them.
- In the current standard, training is time-consuming and requires observational feedback from other trained surgeons. During the time it takes to get feedback, trainees may be ingraining bad habits
- By providing real-time feedback, surgical trainees can learn from their mistakes immediately, avoiding the lengthy waits for observational feedback. Ideally, this will speed up training and improve quality of learning.

The Solution

- In order to provide this real-time feedback to surgical trainees, we implemented several haptic and visual feedback systems on a virtual surgical skill training simulator (Figure 1).

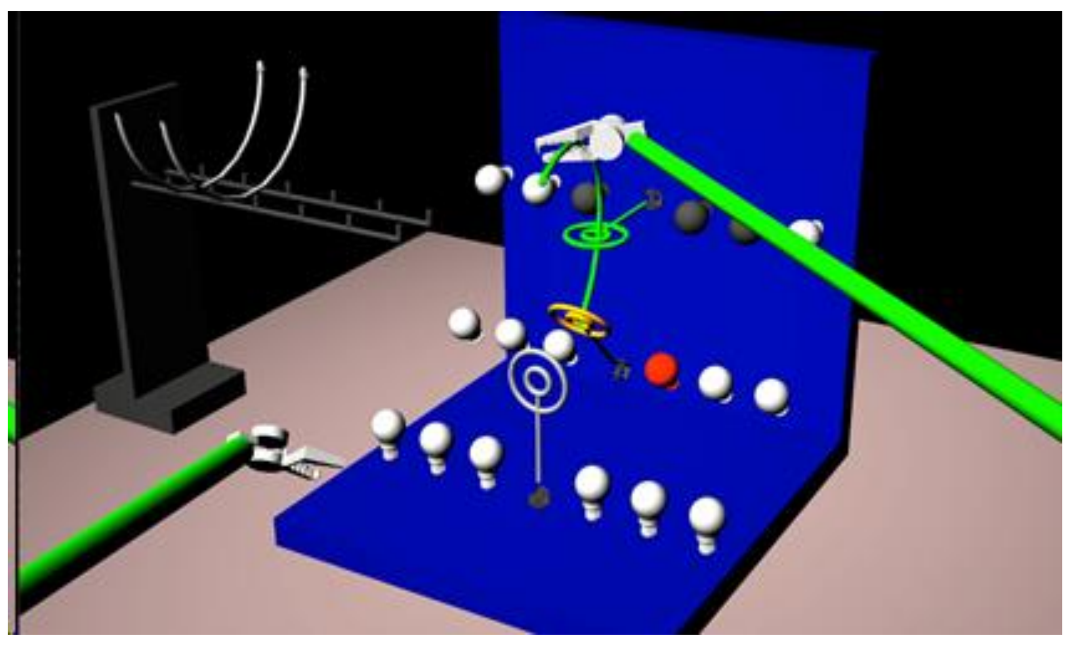

Figure 1: Virtual needle suturing simulator (a)

- Feedback systems we implemented fall into the following categories:
  - Haptics (forces implemented using a spring and damper model) :
    - Forbidden Regions – Navigation of the needle outside of the tube created by the rings provides forces pushing the needle back into the allowable region
    - Ideal Path Guidance – Divergence of the needle from a preset ideal path through the task results in forces to correct the needle position
  - Visual:
    - Current and Ideal Frames - 6 DoF frames located on the suture tip to be matched with ideal suture pick-up location, entrance position, and ideal path
  - Armed with these systems, we have designed a definitive study structure of the effect of haptic and visual feedback systems in virtual surgical simulators (Figure 2).

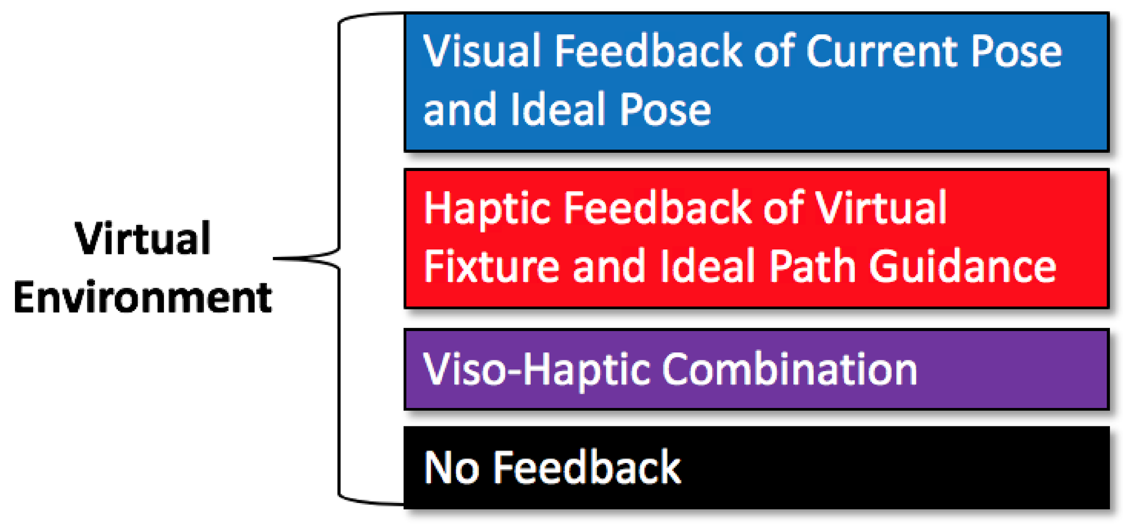

Figure 2: Future study structure utilizing the feedback systems we have implemented this semester.

Outcomes and Results

- We analyzed pilot data over 21 trials each with n=3 novices to determine which metrics to focus on during a full user study (63 trials total)
- This small pilot study gave us valuable feedback in tuning the force parameters and guiding development towards the full user study

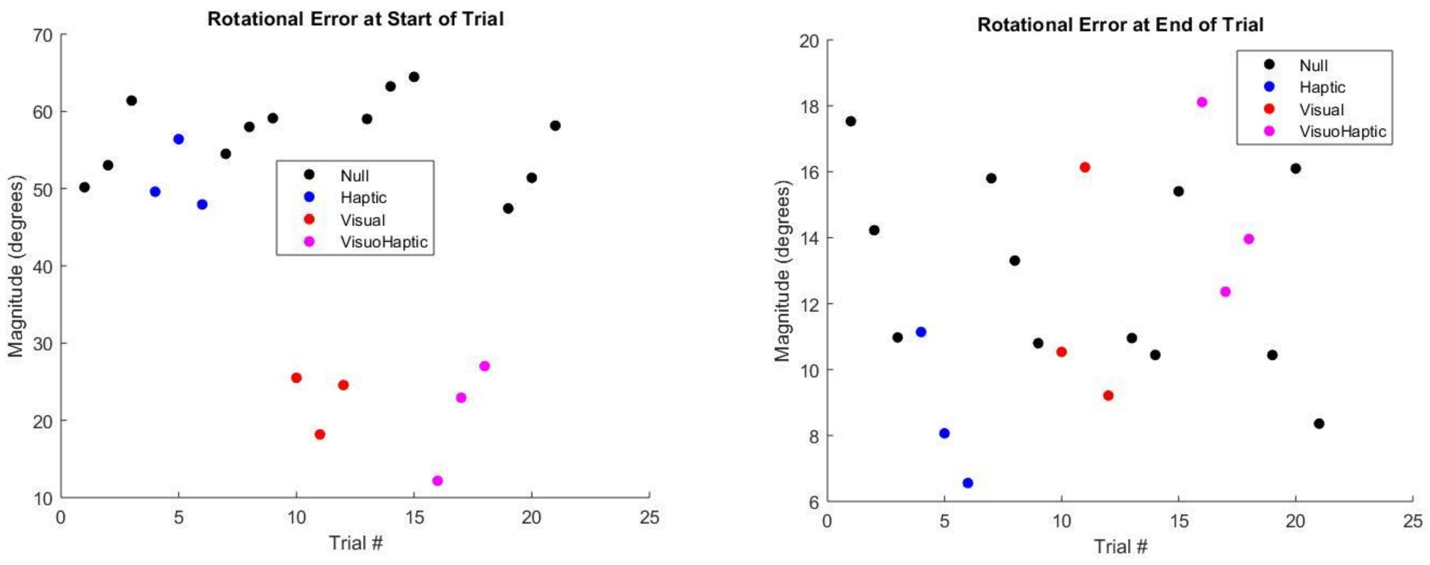

Figure 3: Selected statistics of pilot trials. Blue represents visual feedback groups, red haptic feedback, and purple visuo-haptics.

Future Work

- Preparations and documentation have been made to pass on this work to further student researchers but current team members may continue in Fall 2019
- To fund future work, we are considering submitting this project to an Intuitive Technology Research Grant. With that money, we would conduct user studies comparing visual and haptic feedback in the virtual and realistic environments.

Lessons Learned

- Rigorously defining connections between software as well as the mathematical approach before implementation can be time consuming but reduces likelihood of errors
- When implementing haptic functions, getting feedback from others outside the development team on feel can give key new insights

Credits

- Team members worked together, but leading roles were:
  - Eric – Code structure, code review, documentation
  - Vipul - Code implementation, pilot study data collection
  - Brett - Mathematical formulations, presentations

Support by and Acknowledgements

- Thank you to our mentors for guiding us through this process, your feedback was invaluable
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