Seminar Presentation

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Group 14: Augmentation of Haptic Guidance into Virtual-Reality Surgical Simulators

• 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.
Paper Selection

• **Evaluation of Haptic and Visual Cues for Repulsive or Attractive Guidance in Nonholonomic Steering Tasks**
  - doi: 10.1109/THMS.2016.2561625

• Reasons:
  - Implemented methods of Haptic Feedback (repulsive and attractive) heavily influenced the design of our two methods
  - Interesting to see a setup so similar to ours with a different application (virtual steering of vehicle vs. virtual surgical task simulator)
  - Thorough user study collecting a variety of metrics which can help us determine what metrics are important for our own study
Summary of Problem

• Teleoperation is more difficult than direct manipulation due to limited sensory feedback of the task
  • To combat this, add artificial task-related feedback
• Goal: Evaluate several approaches to feedback (support systems) and compare their efficacy in assisting the task
  • Repulsive Haptic and Visual
  • Attractive Haptic and Visual

• Hypotheses:
  • Due to quick reflexes, haptics will result in improved performance compared to visual
  • The more difficult the task, the more useful the additional information
Key Results

• Predicted trajectory of the vehicle and suggested path information improved task performance
  • No difference was found between haptically or visually reflected information
• Reflection of predicted trajectory resulted in improved performance visually but not haptically
• More difficult environments resulted in larger benefits for all support systems
Significance of Key Results

- Indicate that in general, additional information improves performance, especially when difficulty is high.
- If both types of information (haptic and visual) are available, it is beneficial to reflect them both.
  - In general, it is more important to evaluate the task and application in order to choose how to present information.
Necessary Background

• Basic understanding of forbidden regions, forces and torques
  • Explained well in the paper

• Comfortability with statistics and RM-ANOVA to interpret several large results tables
  • Tables provided with easier to understand graphs
Technical Approach

• Repulsive Haptic Guidance around Obstacles
  • Virtual Potential fields around obstacles (and an attractor around goal)
  • Generated based on predicted position of the slave after translation of $L_p = .01m$
  • Gain $k_p = 6 \text{ N/m}$, penetration depth $d_p$, slave distance $d_s$
  • Forces only reflected when with angle $\alpha = 90^\circ$
  • Parameters tuned to be over-ruizable

$$
\tau_{HR,i} = \begin{cases} 
  k_p L_p (d_p - d_{si}), & \text{if } d_{si} \leq d_p \text{ and } |\theta_i| \leq \alpha \\
  0, & \text{else.}
\end{cases}
$$

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Technical Approach

• Attractive Haptic Guidance to a Suggested Path
  • Guide toward predefined suggested path
  • Torques computed from virtual guidance force acting on arm $L_p = .01m$
  • Gain $k = 5$ N/m
  • Distance $d$ between suggested path and predicted position of slave
  • Presented to subjects as torsional stiffness on master

\[ \tau_{HA} = k L_p d. \]
Technical Approach

- Visual Equivalent Support Systems
  - Designed to be similar to corresponding haptic system
  - Repulsive is based on predicted path, so in repulsive visual that is shown only
  - Attractive is based on predicted location and optimal path, so both are shown
Experimental Design

- A user study involving 15 subjects
- Subjects controlled a three DOF planar parallel master device
  - Forward translation coupled to translation of the slave.
  - Rotation of the master was coupled to steering
- 5 blocks (one each experimental condition) of 8 trials
  - 4 different environments shown twice (regular and mirrored)
  - Additional catch trial on difficult environment to investigate dependency on support

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Markers are 300ms time intervals.

EoDt – easy obstacle
difficult target reaching

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Collected Metrics

• Task Completion Time
• Targeting Accuracy
• Number of slave Retractions
• Total duration of retractions
• Number of collisions
• Minimum time to obstacle collision
• Distance to obstacles
Results

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Assessment

• Importance
  • Provides support that haptic AND visual feedback is beneficial in task, especially as they become more difficult
  • Fails to convince me that haptics alone is useful

• Relevance
  • Provides basis for evaluating visual and haptic cues in a simulated environment
Assessment

• Good points
  • Thorough explanation of approach, experimental design
  • A very complete look at haptics and visual cues
  • Changing environment helped to teach user a skill not memorize a path

• Bad Points
  • Collected a lot of metrics and the presentation on these was dense
  • Tested for a lot of things and many variables were changed (every user experienced every possibility)

• Further Work Suggestion
  • An attempt to model the operator (ie through brain stimulation) could help generalize the results to other tasks
Conclusions

• Presented a refreshing view on haptic and visual cues in a simulated environment

• Indicated that providing additional information to the user is beneficial especially in tasks with greater difficulty (a seemingly obvious result)

• Cast more doubt on my personal belief in the efficacy of haptics as a sole provider of feedback
Questions?