Paper Seminar Presentation

Group 14

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Project Summary

Goal: Investigate the effect of haptic feedback on motor learning using VR surgical simulators

- Implement haptic guidance
- Implement forbidden region
- Test effects in a user study

Paper Selection

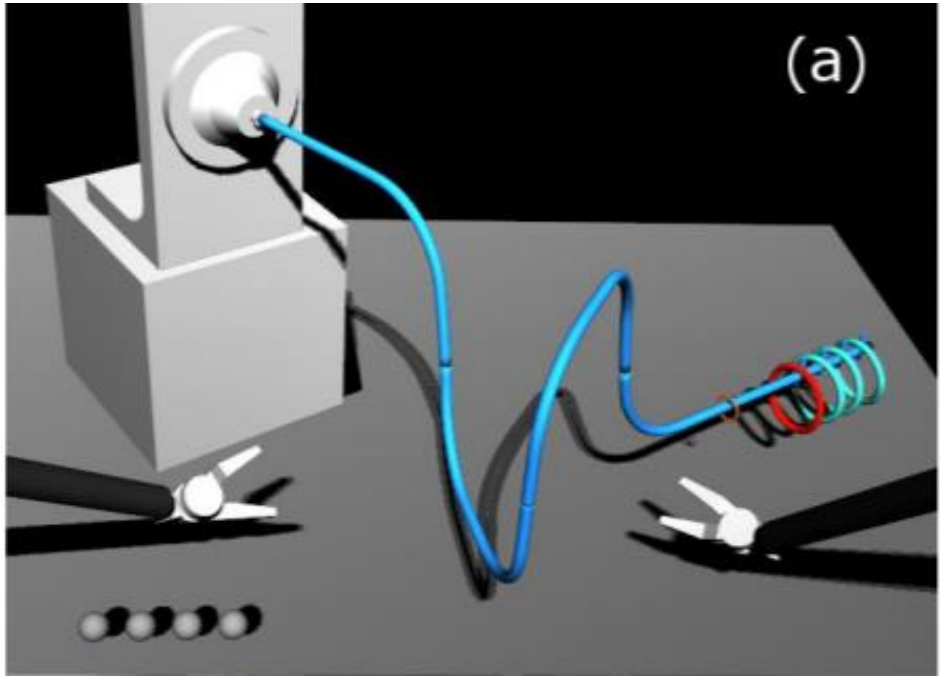
- Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study
  - Enayati, Nima, et al. “Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study.” 2018 IEEE International Conference on Robotics and Automation (ICRA), May 2018, doi:10.1109/icra.2018.8463168
- Similar experimental setup and environment
  - Uses the dVRK and Assisted Teleoperation with Augmented Reality (ATAR) framework for the VR environment
- Investigates the effect of haptic feedback on learning

Summary

- Addresses the question of whether robotic assisted training (haptic feedback with a virtual fixture) can help trainees gain skills faster
- Tries to tackle shortcomings of previous studies
  - Complex task to ensure learning curve
  - Decreasing guidance as user learns prevents dependence
    - Robotic assistance-as-needed

Task

- Moving a ring along a curved wire path
  - Prevent contact between wire and ring
- Visual feedback was provided
  - Ring color ranged from yellow to red based on performance of the user
- Overall performance also reported once task was complete



Robotic Haptic Assistance

- Viscoelastic active constraint
  - Desired pose – T_d: [p_d, q_d]
  - Current pose - T_c: [p_c, q_c]
  - Elastic coefficients – K_T, K_R
  - Viscosity coefficients - B_T, B_R
  - Current angular velocity - ω_c

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

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

Robotic Haptic Assistance (cont)

- Challenge Point Theory – optimal learning corresponds to a specific Functional Task Difficulty (FTD), determined by the skill level of the trainee and the task
- $\sigma_{r,s}$: User's skill level
- α : Assistance intensity
- FFA_s : Feed Forward term
- Δ_s : $FFA_s - FFA_{s-1}$
- M = 2, number of sessions with maximum assistance

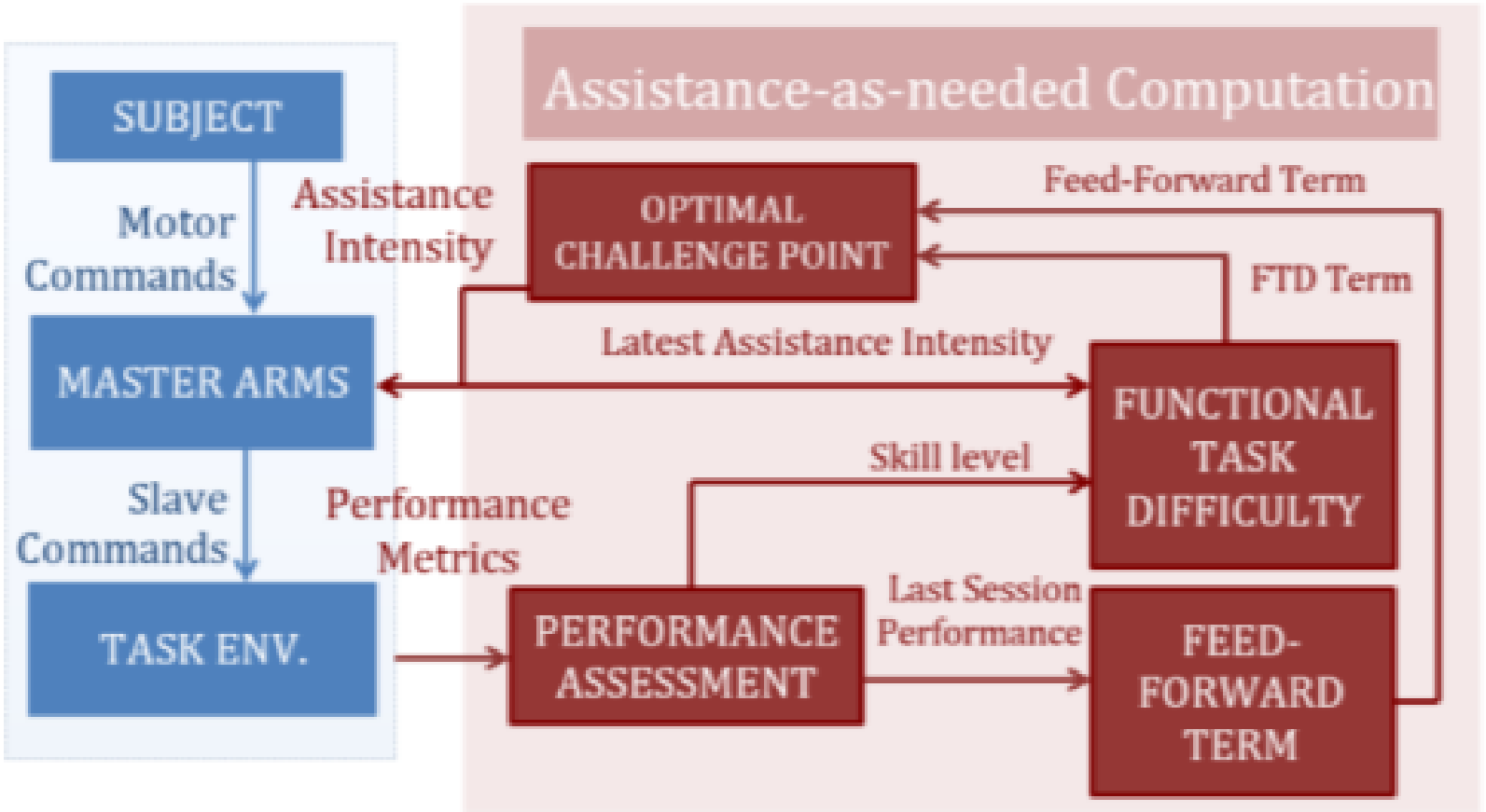
$$FTD_{r,s} = 1 - \lambda\,\sigma_{r,s} - (1-\lambda)\,\alpha_{r-1,s}$$

$$\sigma_{r,s} = \frac{N\,\overline{p_{s-1}} + 2(r-1)\overline{p_s}}{N + 2(r-1)} \in [0,1]$$

$$FFA_s = 1 - \frac{s - M}{S_{max} - \overline{p_{s-1}}(S_{max} - S_{min}) - M}$$

$$\alpha_{r,s} = \begin{cases} 1 & if\ s \le M \\ \max(0,\ FFA_s - \Delta_s(2FTD_{r,s} - 1)) & if\ s > M \end{cases}$$

Robotic Haptic Assistance (cont)



User Study

- 16 non-medical participants divided into 2 groups of 8
  - Null group
  - Assistance group
- 10 sessions of 8 repetitions each
  - 2 sessions per day (1 morning and 1 afternoon)
  - Lots of breaks to ensure no fatigue
  - First session of assisted group started with 3 null repetitions

Performance Metrics

- Calculated 4 metrics
  - RMS of completion time
  - RMS of translational error
  - RMS of rotational error
  - Maximum translational error
- Normalized and saturated between 0 and 1
  - sat(a, x, b) – saturates input x between values a and b
  - x_{best} and x_{worst} – constant values selected based on learning curve of the null group

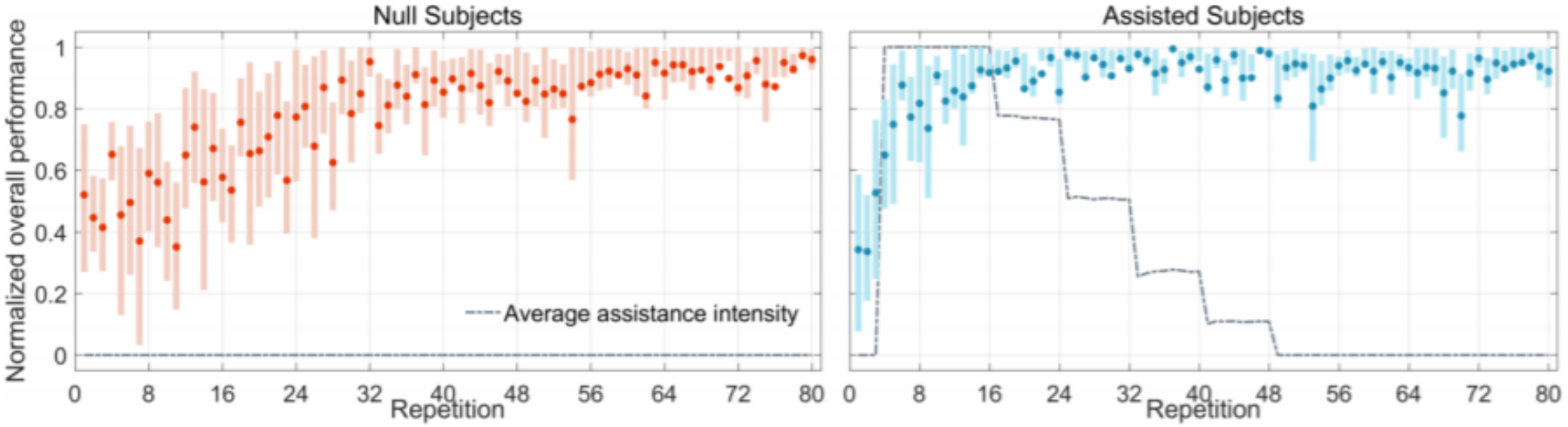
$$x^*_{repetition} = sat(0, \frac{x_{best} - x_{repetition}}{x_{best} - x_{worst}}, 1)$$

Results

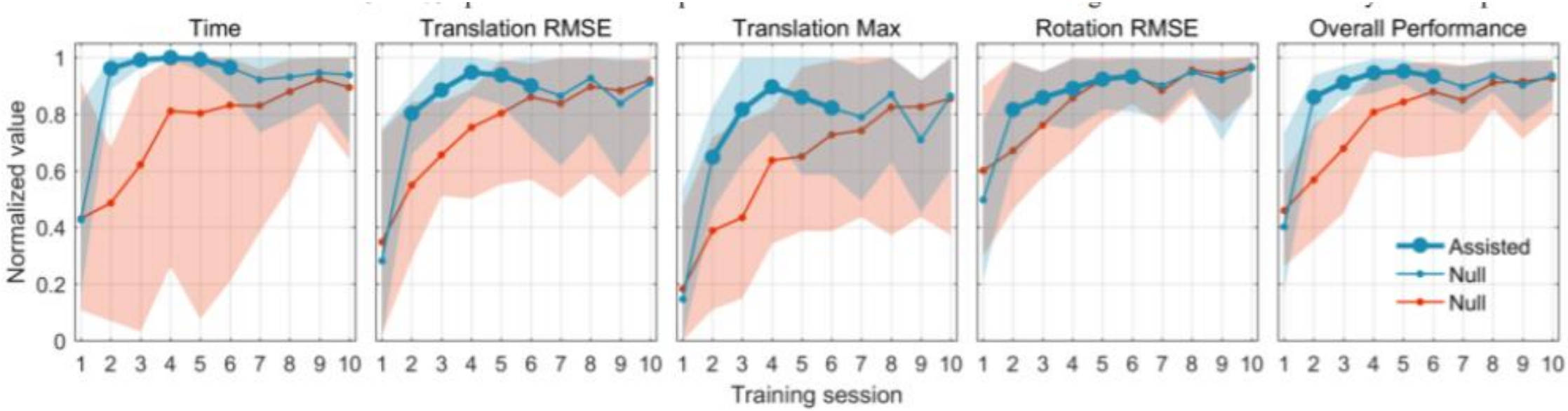
- As expected, the two groups had different learning curves
- Assisted subjects seemed to learn at a faster rate, but not substantial enough to make conclusions – needs further study
- Final performance was about equal for both groups
- As assistance was decreased for the assisted group, performance declined slightly but was recovered quickly
- In the later sessions, subjects showed improvement from a morning to afternoon session of the same day, but not from afternoon to next morning.

Results (cont.)

Graphs below depict performance as the sessions progress with an indicator of assistance received for both groups.



Results (cont.)



Paper Assessment

- Good
  - Visual feedback for null group and visual + haptic feedback for assisted group
  - Good description and explanation of their approach, methods, and results
  - Breaks to prevent fatigue and ensure subjects are motivated
- Improvements
  - Same path used for all trials so it is difficult to tell if trainees were taught the skill or the path
  - Morning vs afternoon sessions caused discrepancy in results

Paper Assessment (cont.)

- Relevance
  - We are implementing active constraints in our project
  - Analyzes the effect of haptic feedback on motor learning

- Future Steps
  - Test different paths or tasks
  - Larger sample size to further test hypothesis
    - Study had many sessions but small number of subjects

Conclusions

- Haptic feedback slightly decreased learning time for the assisted group, but it did not improve final performance when compared to the null group.
  - Promising results for future studies
- Providing breaks to limit fatigue helps gain a more accurate analysis
- Overall layout of user study is a good starting point to model for our experiments but need to make a few changes

References

- 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