Approximating hard physical transitions for haptic bilateral teleoperation

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1. Introduction

- What if you want to do a task while you are in another room?
- Haptic bilateral teleoperation is used to accomplish this goal, however network delays are a problem.
- Network delays could be problematic when a certain task contains transitioning of a physical state.
- Predictive force feedback can be used to mitigate this problem.

- **Research question:** Can we approximate hard physical transitions to get satisfactory force feedback for haptic bilateral teleoperation?
- This is done by:
  - Modelling the puncturing of paper with a needle.
  - Test the behaviour of this model.
  - Apply delays simulating the network delay of the robot and do an user study.

3. Methodology

- Physical testing
  - Apply force on real paper with a needle
  - Get indication of force threshold
- Model creation:
  - Implement force threshold mechanism that when breached transitions from not puncturing to puncturing.
  - Applied friction when needle moves in paper
  - Markings for punctured spots
  - Add delays to the model to simulate robot network delays
- Behaviour testing:
  - Test model if its behaviour aligns with logic
  - The Novint Falcon is used for this
- User study:
  - Add delays to the model:
    25, 50, 75, 100, 150 and 200
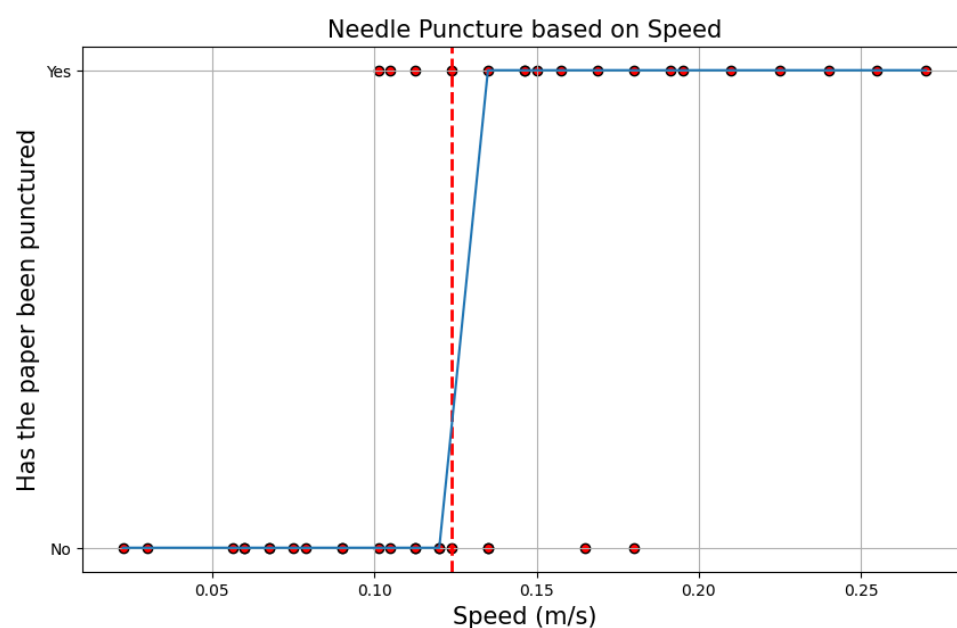 - Randomly generated seed creates a random order for each user
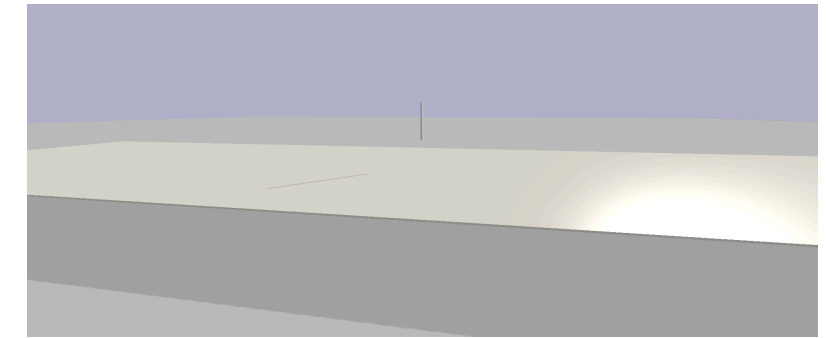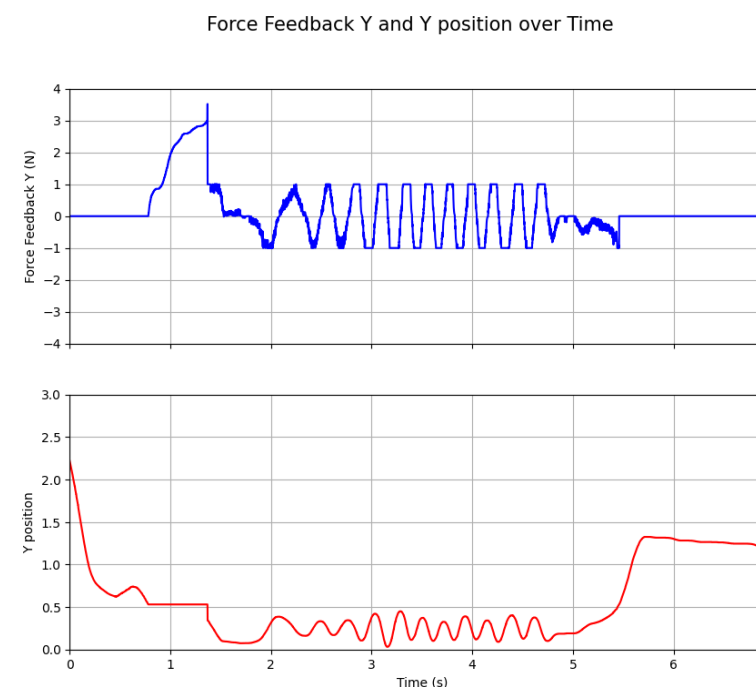
5. Conclusions

- The model behaves properly like predicted.
- Does not perfectly imitate the feeling of puncturing a piece of paper, but does capture the essence of hard physical transitioning
- User study shows with the increase in delay that:
  - that the difficulty goes up but it does not become unusable
  - It stays relatively comfortable for users to use.
- The results conclude that hard physical transitions can be approximated to get force feedback in haptic bilateral teleoperation

4. Results

Physical test

Needle Puncture based on Speed

Behaviour test

Force Feedback Y and Y position over Time

Evaluation test

Average User Rating for Varying Network Delays

- The visual feedback is different from the baseline performance.
- The difference in visual feedback makes the task harder.
- The difference in visual feedback detracts from my experience.
- The difference in visual feedback makes the system unusable.}
- I feel comfortable interacting with this application.
- The needle behaves the way I expect.

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