Predicting Force Feedback for Interactions with Objects in Motion

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1. Background

- Haptic bilateral teleoperation is used to enable human operators to perform tasks in hazardous or distant environments, for example offering efficiency, safety and effectiveness to disaster response operations
- Operators need a sense of presence at the remote site, known as telepresence [1], which are sound, vision and touch
- Latency presents a significant challenge, making it impractical for the human operator and the robotic system to communicate over a network due to substantial delays [2]
- A solution to this problem involves 'cheating the system' by simulating the real-life environment in virtual reality with minimal delay for the human operator
- Limited research has been conducted on using a virtual reality to replicate the real-life environments when using teleoperation, making this a promising area to explore

2. Research question

Can we approximate dynamic object movement to achieve satisfactory force feedback for haptic bilateral teleoperation?

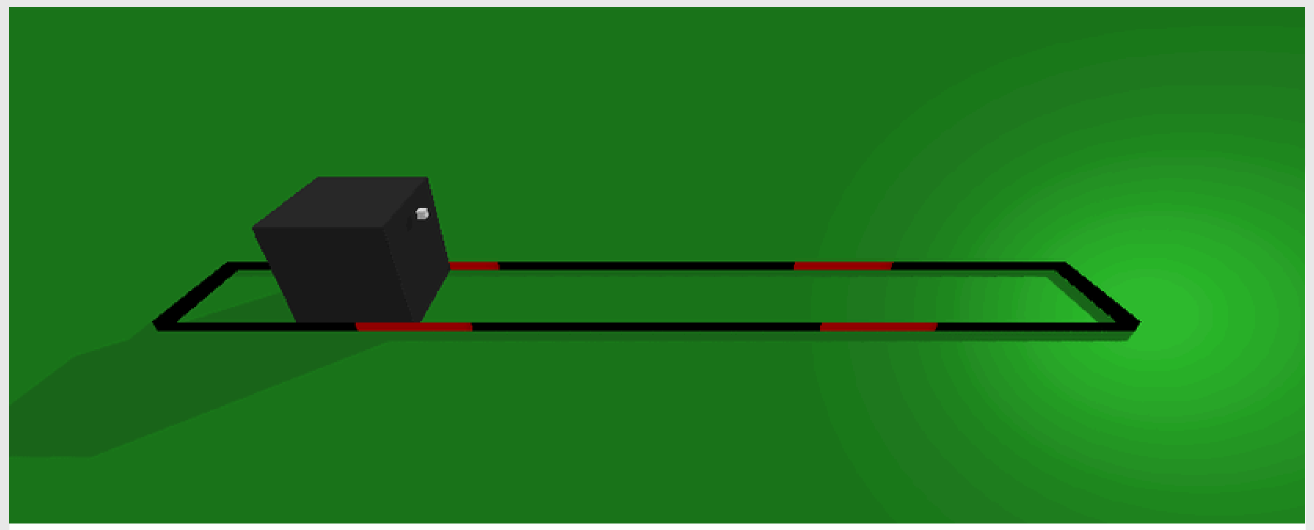

Figure 1: Simulation setup in OpenGL with the small with cube as proxy, large black cube as movable object, walls to prohibit the black cube from rotating and the red walls to highlight the position were the cube should be pushed to during the user study.

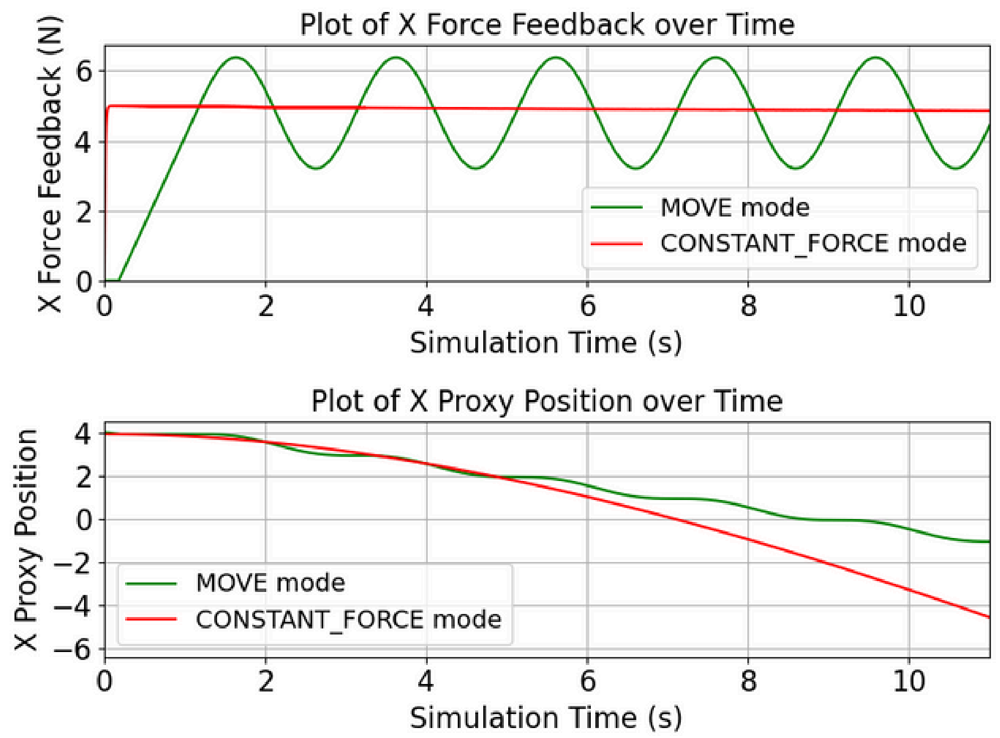

Figure 2: Two plots depicting different modes: MOVE and CONSTANT FORCE mode. The upper plot shows the force feedback of the proxy along the x-axis during the simulation, while the lower plot illustrates the x-axis position of the proxy during the simulation.

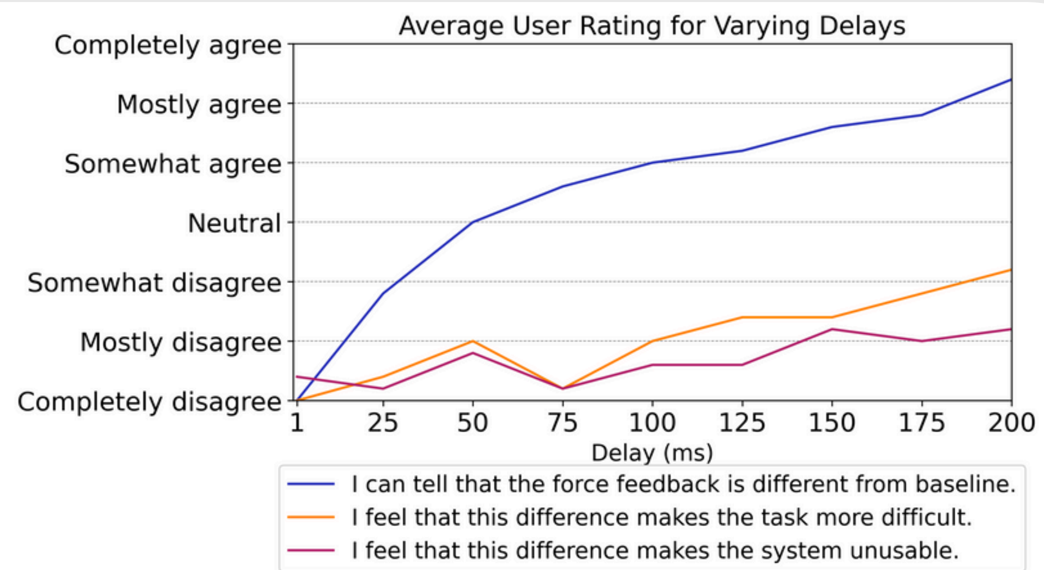

Figure 3: Average user ratings for varying network delays. Ratings indicate increasing sensitivity to delay, with noticeable impact on task difficulty starting around 75 ms and usability concerns rising beyond 125 ms, though the system remains mostly usable up to 200 ms delay.

5. Conclusion

We successfully approximated dynamic object movement to achieve realistic force feedback for haptic bilateral teleoperation. Users can handle tasks effectively with total delays up to 210 ms and find the system usable with delays up to 260 ms. Extra delays beyond 125 ms impact usability, with significant difficulty arising past 75 ms of network delay.

3. Methodology

1. Prepare the prerequisites that are required for the already existing project
2. Get familiar with the given framework and the Bullet Physics Engine
3. Create virtual reality scene of a cube that cannot rotate due to the walls and highlight two position in red on the walls (Figure 1). This can be used as task during the user study
4. Make the visual feedback in the simulation able to be delayed, so it can be used to test acceptable network delay
5. Test the latency of the laptop that will be used during the user study. This latency can then be used together with the set network delay to find the acceptable delay out
6. Do a user study to test the user experience with different network setting to find out if they feel the difference with no extra delay added, if the difference makes the given task harder and if the difference makes the system unusable

4. Results

- A force feedback can be predicted, as shown in the plot above in Figure 2
- The latency of the laptop, that will be used during the user study, was tested and the median of 20 trials was 135 ms delay
- Detection becomes more acute as the delay increases as shown in Figure 3. Task difficulty and system usability suggest that network delays do impact performance but not in a strictly linear fashion. Where with 75 ms network delay the task is still doable and with 125 ms delay the system is still usable

References

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2. D. Sinha, K. Haribabu, and S. Balasubramaniam, "Real-time monitoring of network latency in software defined networks," in 2015 IEEE International Conference on Advanced Networks and Telecommuncations Systems (ANTS), pp. 1–3, 2015.