Teleoperation in Mixed Reality

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Introduction

Background

As the paradigm of surgical robotics improves with the passage of time, it gets more imperative to make their assimilation into the operating room as seamless as possible. As such, the introduction of teleoperation seeks to directly address this matter, by giving surgeons increased flexibility, and increased intuitive control of complex robotic systems.

https://healthcaremarketexperts.com/en/news/joanna-szyman-for-pmr-robotics-the-future-of-surgery/

One great area of progress of surgery stems from Augmented and Mixed Reality, which is often the first step in improving the standard of visualization and pre- and intra-operative planner. Our project brings the realms of teleoperation and Mixed Reality together, by using Mixed Reality apparatuses to both augment the visual feedback during operation of the surgical system and allow surgeons to teleoperate the system via camera tracking and sensor fusion in a multisensory capacity.

This was implemented on the DaVinci Research Kit system (dVRK), which is based on the commercially available Da Vinci surgical robotic system, allowing surgeons to bypass the restrictive user console and teleoperate the Patient Side Manipulators from the ease of free space.

Motivation

Currently, teleoperative robots are controlled through the use of joysticks which are fixed in place. For surgical robots, such as Intuitive's Da Vinci, this could be less than ideal as it constrains the operating surgeon to the fixed master console. In addition, as the master control of the Da Vinci only displays the endoscopic view, the surgeons are required to move away from the control console to view the patient directly.
Thus, our project aims to mitigate these limitations by developing a non-grounded teleoperative control paradigm. We investigated the appropriateness of using hand position to control the dVRK end effector position.

Prior work

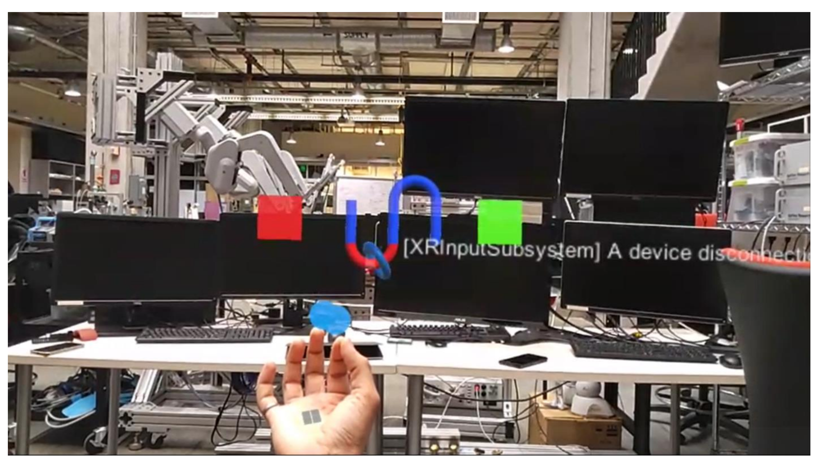
Previously, an investigation was performed to determine the effectiveness of using IMUs to determine wrist position and in turn controlling an end effector position of a robot. The study found that this form of teleoperative control could be a potentially effective means of control.

Fu, Guanhao, Ehsan Azimi, and Peter Kazanzides. "Mobile Teleoperation: Feasibility of Wireless Wearable Sensing of the Operator's Arm Motion." *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE.

Method

The primary consideration of our project was to implement effective hand tracking via the HoloLens 2 to control the translation of a single PSM arm, both in simulation and actuality. Given the novel, never-done-before nature of this project, our team had to design and propose a working communication and teleoperation architecture, while adhering to the visual constrains of the HoloLens 2 and the mechanical constraints of the actual system.

As an initial functionality test, we set up a wire demo similar to that developed in the prior work. In our demo, the ring is controlled by the wrist position (as opposed to the IMUs).



We used the HoloLens 2, and implemented hand tracking, where we used a pinching motion as a clutch to engage/disengage teleoperation. The PSM arm was moved based off the change in wrist's position.

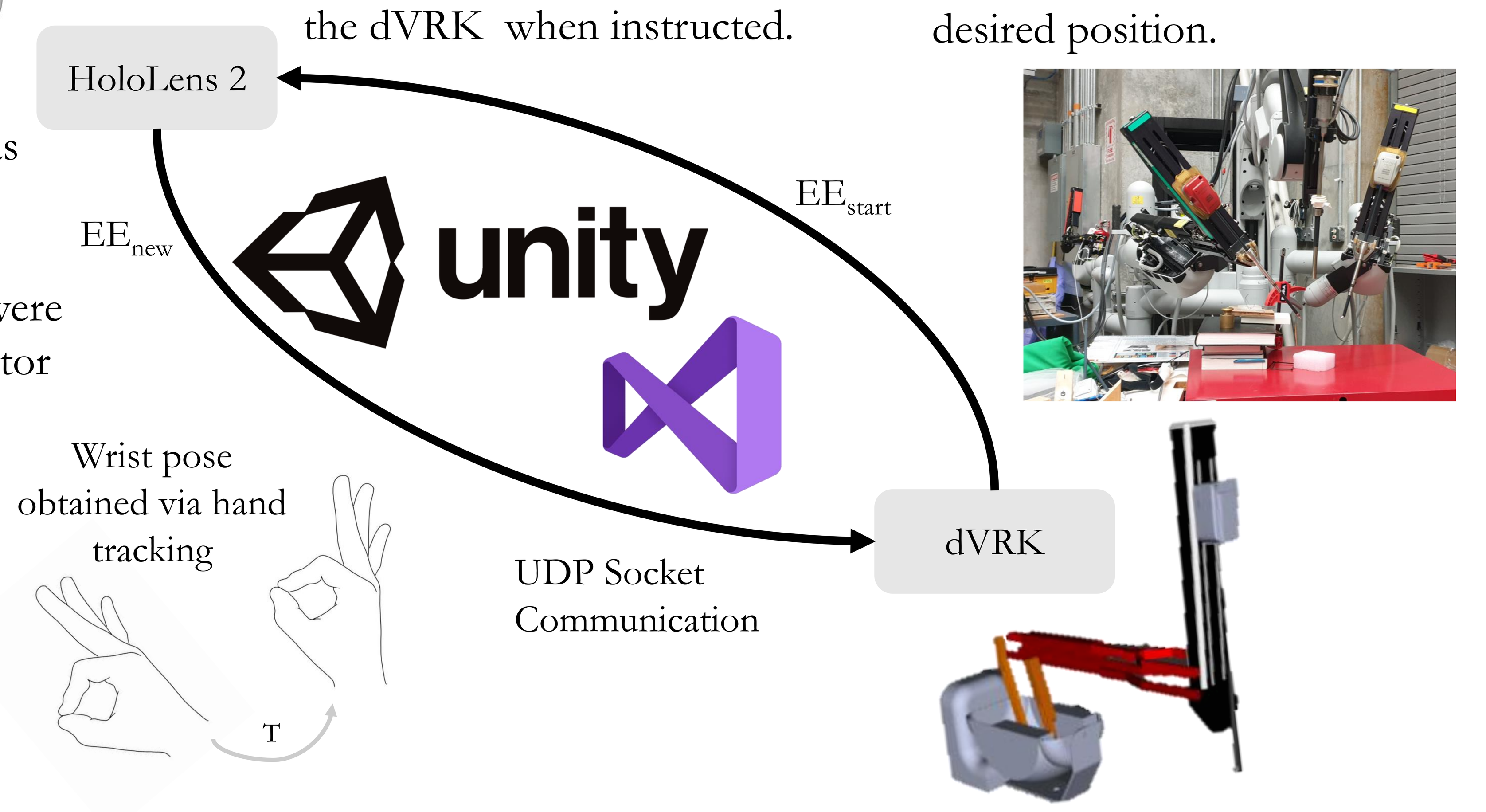
On a pinch gesture, the wrist and end effector positions were saved as starting positions. Subsequent translations between a new wrist position and the starting position were used to calculate the new end effector position.

$$EE_{new} = EE_{start} + sT$$

EE_{new} = New end effector position
EE_{start} = Starting end effect position
T = Change in wrist position
s = Scaling factor

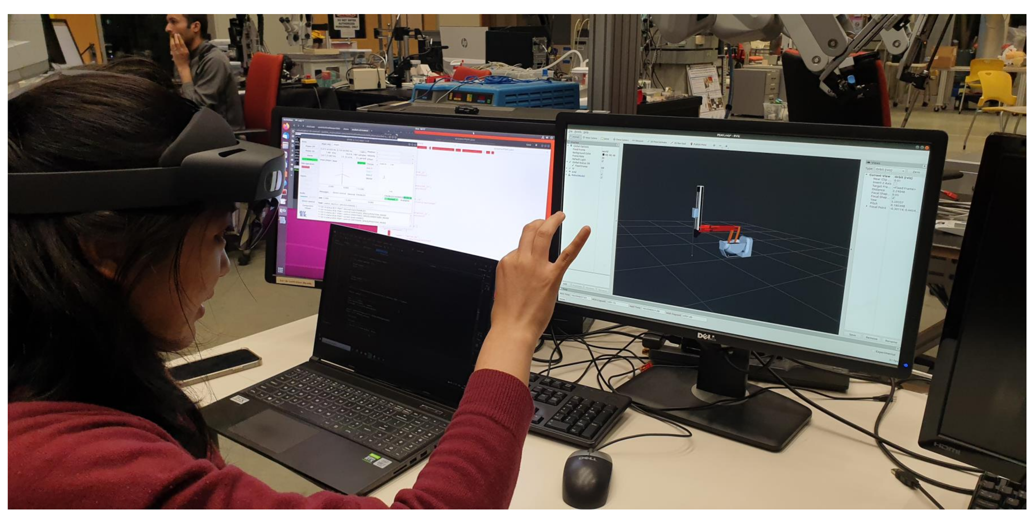
For the communication protocol between the HoloLens 2 and dVRK, we utilized UDP communication and .json strings. The dVRK continually sends it current setpoint position to the HoloLens 2 which in turn will send the updated end effector positions back to the dVRK when instructed.

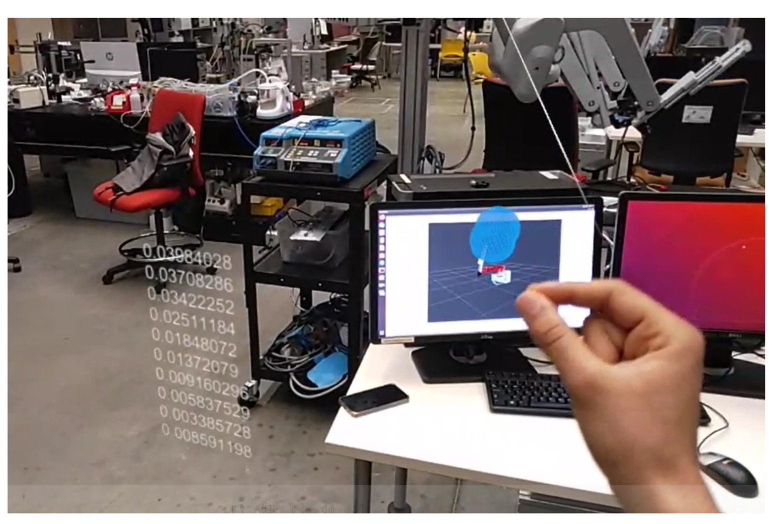
The dVRK simulator or actual system receives the new end effector position, performs the inverse kinematics, and calculates the corresponding joint positions. And as a result, moves the end effector to the desired position.



Results

There were no quantitative studies conducted to evaluate the effectiveness of the system. However, based on the user experience of the testers, the system offers a very promising start to a critical teleoperative system. The team was able to move the simulated and actual PSM effectively, without hyperextending the system too often. Effective scaling, and careful assumption helped reduce the complexity of the system.





Conclusions

While this is not a full teleoperation system for the dVRK, it serves as a critical building block for this novel approach to teleoperative control using Augmented/Mixed Reality.

Future Work

Our next steps will involve achieving sensor fusion, by using the aforementioned IMUs to teleoperatively control the dVRK when the hand is not in the field of view of the HoloLens, and in turn using the HoloLens to correct for sensor drift.

Acknowledgements

We would like to acknowledge Professor Azimi, Professor Kazanzides, Anton Deuguet, Yihaou Liu, Sign Chun, and JHU alum Dean Fu for their unwavering support during this entire project