A Virtual Reality Planning Environment for High-Risk, High-Latency Teleoperation

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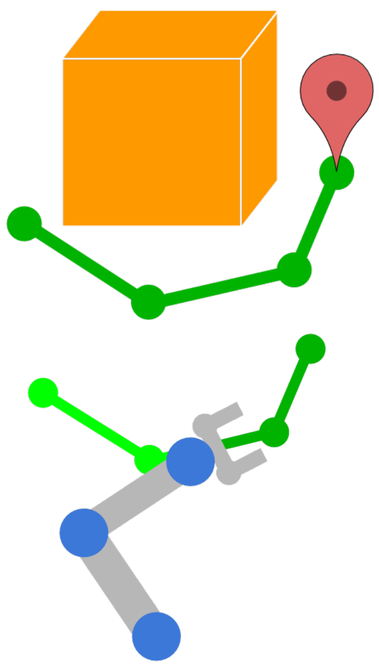
Problem

In-Space Servicing, Assembly, and Manufacturing has the potential to enable larger-scale and longer-lived infrastructure projects in space. Servicing in particular has the potential to vastly increase the usable lifetimes of satellites, both newly launched and existing. However, some of these servicing tasks require delicate manipulation and, to apply to existing satellites, need to be able to operate on structures that were not designed for servicing and, in some cases, where the exact shape of the structure is not known in advance. For this reason, human-in-the-loop ground-based teleoperation is the only option for some missions.

Ground-based teleoperation presents its own difficulties. In addition to the challenge of performing delicate operations in constrained spaces, communication with the servicing platform is subject to a variable time delay on the order of 2-7 seconds, and the only visual feedback comes from camera views with limited situational awareness and viewing angles.

Interactive Planning and Supervised Execution



Interactive Planning:

- Build a motion plan
- Preview in virtual environment
- Adjust as needed

Supervised Execution:

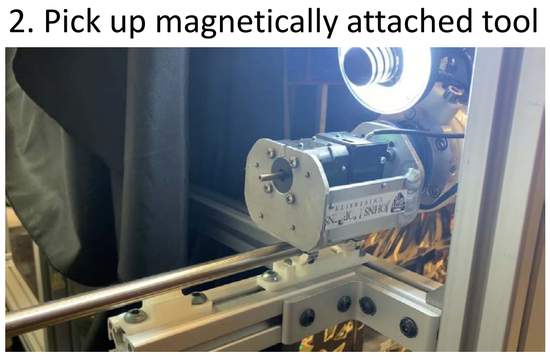
- Execute plan
- Watch in Augmented Virtuality
- Stop early if errors occur

Experiments

Experimental task designed to mimic satellite servicing operation.

1. Move to tool pickup location

2. Pick up magnetically attached tool



3. Move to refueling port

4. Insert tool 3cm into refueling port

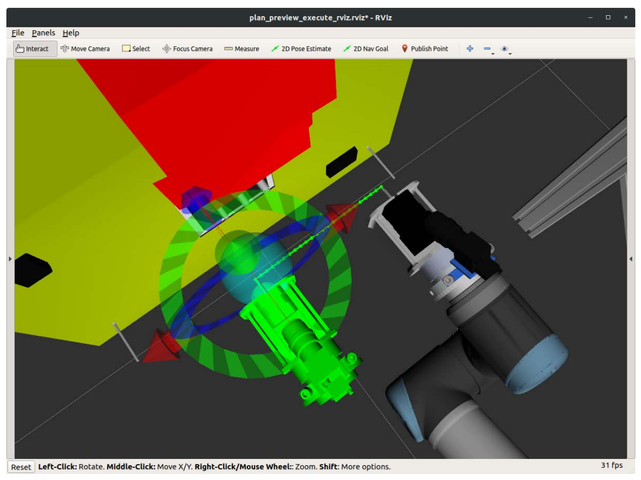
Previously: Compared 2D and da Vinci 3D interfaces (left) to a baseline interface designed to represent currently used interfaces. Baseline interface displays the tool and deck camera views and the robot is controlled by entering a desired pose.

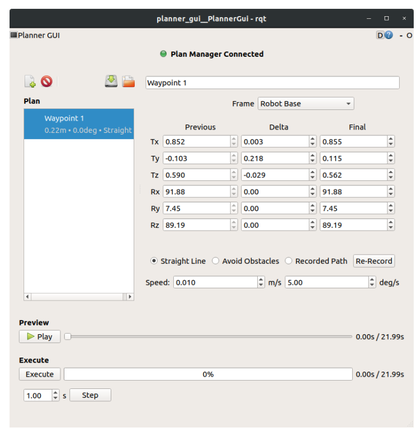
New: Compared 2D and VR HMD 3D interfaces (left).

Evaluation criteria: Task success rate, NASA Task Load Index (TLX) Score, and user difficulty rating.

Previously: 2D Interface

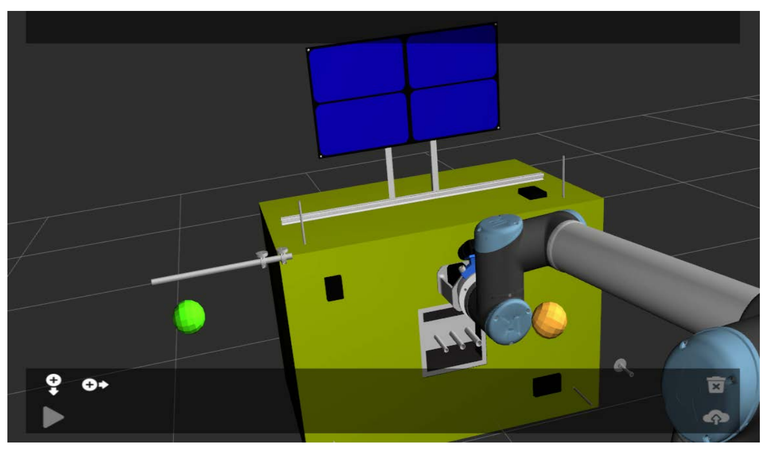
More successful than baseline





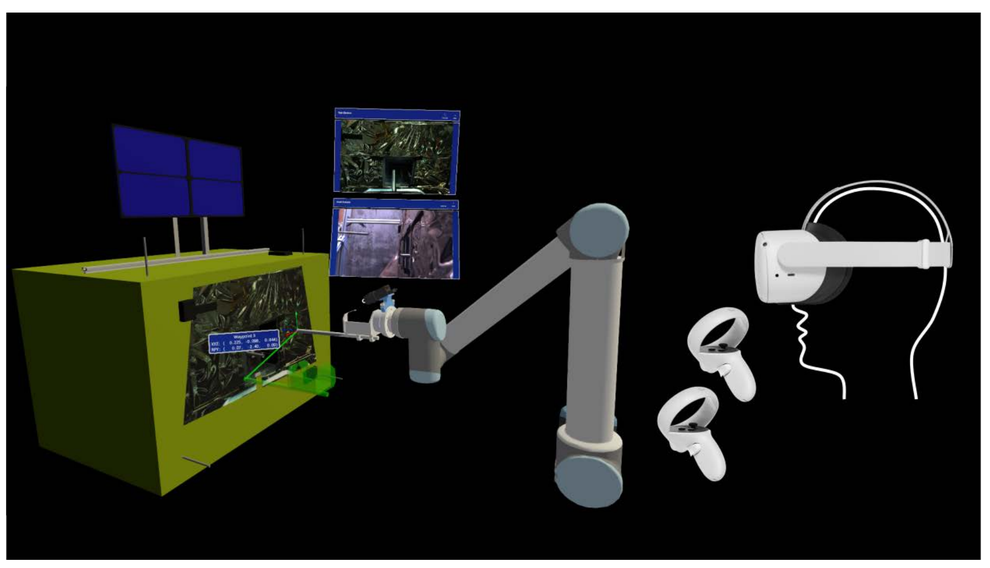
Previously: da Vinci 3D Interface

Less successful than baseline



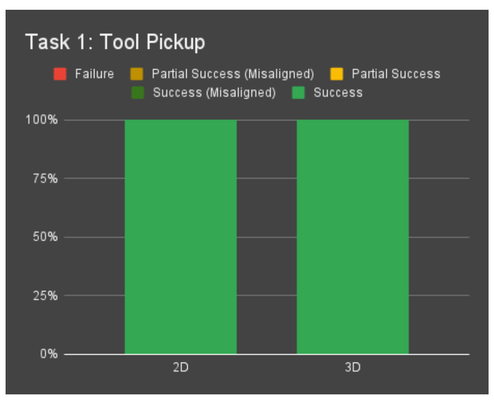
New: VR HMD 3D Interface

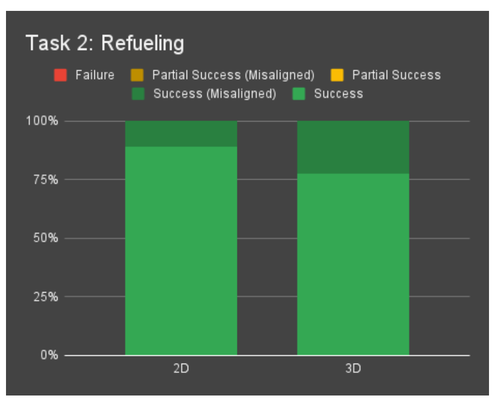
More successful than 2D (previous best)



Experiment Results

Success Rate: Equal performance





Operator load: VR HMD 3D interface is better