Shape-Based Remote Manipulation

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Advanced Testbed Setup Progress

Operator Side:

- **HaptX gloves** have been set up and we've written the necessary drivers for ROS2 communication
- **ABB Gofa** arms setup with force control
- Gofa arms will be connected to the operator's hands to simulate object weight and obstacles

Avatar Side:

- **Shadow Hands** have been set up and we are able to control them
- Shadow Hands support ROS1, working to make them ROS2 compatible
- **Next Step:** Develop scheme to map operator's hand motion to Shadow Hand
- Initial mapping will likely involve some form of **direct joint angle mapping** and **direct cartesian mapping**

How to Address Latency

Challenge: Latency in tele-operational setups can lead to jitter and causes a simple task to be lengthy.

Possible Solution: Operator interacts with a virtual environment while the Avatar predicts operator's intent. While the operator moves, the Avatar updates its predictions as delayed information is received.

Testing Latency and Models

The 2-DOF system is used to test the mathematical models that will close the latency gap.

- Hardware: End-effectors can move vertically and horizontally using two capstan-motor transmissions.
- Software: Both sides of the system send information packages containing positions and motor currents.
- Latency: Microcontroller between sides intercepts and holds the packages for a chosen amount of time to simulate system latency.

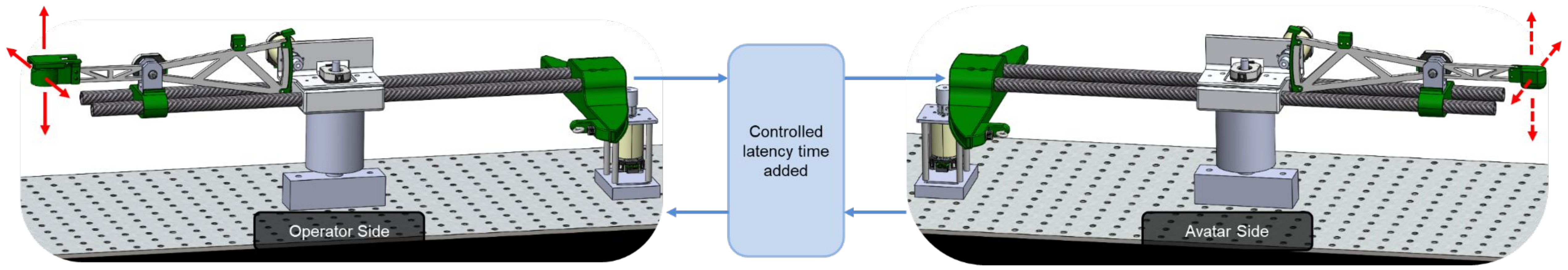

Figure 1: 2-DOF teleoperator setup for running latency experiments with and without inputted mathematical models.

Feeling Remote Shapes with Novel Haptic Interface

Our finger-based haptic interface: Fingertip thimble-gimbal, two-bar linkage, two translational carriages each containing a steered wheel, and a common cylinder.

- **Interface Alignment:** The common cylinder and translational carriages are aligned parallel to and under the palm (Figures 2a and 3).
- **CVT Joints:** The relative motion of each carriage depends upon its wheel orientation. As shown in Figure 2c, a free-rolling wheel pressed against a spinning cylinder is a CVT where its steering angle relates the wheels' translational speeds to the cylinder's angular velocity.
- **Shape Control:** Under computer control, the haptic interface wheels can be steered to allow any desired finger motion. To create a virtual shape, the wheels are steered so that the only permitted finger motion is parallel to the desired shape.

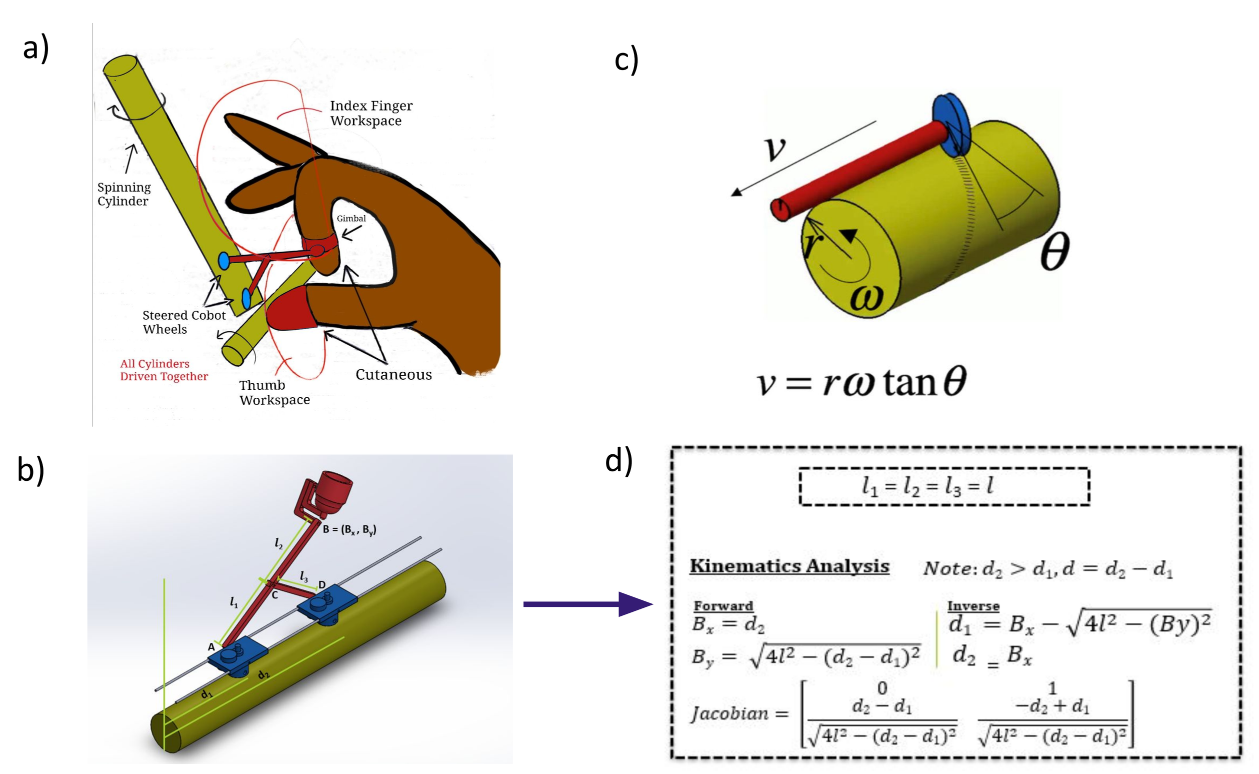

Figure 2: a) Conceptual drawing of the proposed haptic interface b) SolidWorks rendering c) Fundamental CVT principle d) Kinematic equations of the interface mechanism

Figure 3. The proposed SBRM testbed. The avatar will be placed at Northwestern, and the operator at Florida A&M.

Teleoperation Testbed Schematic

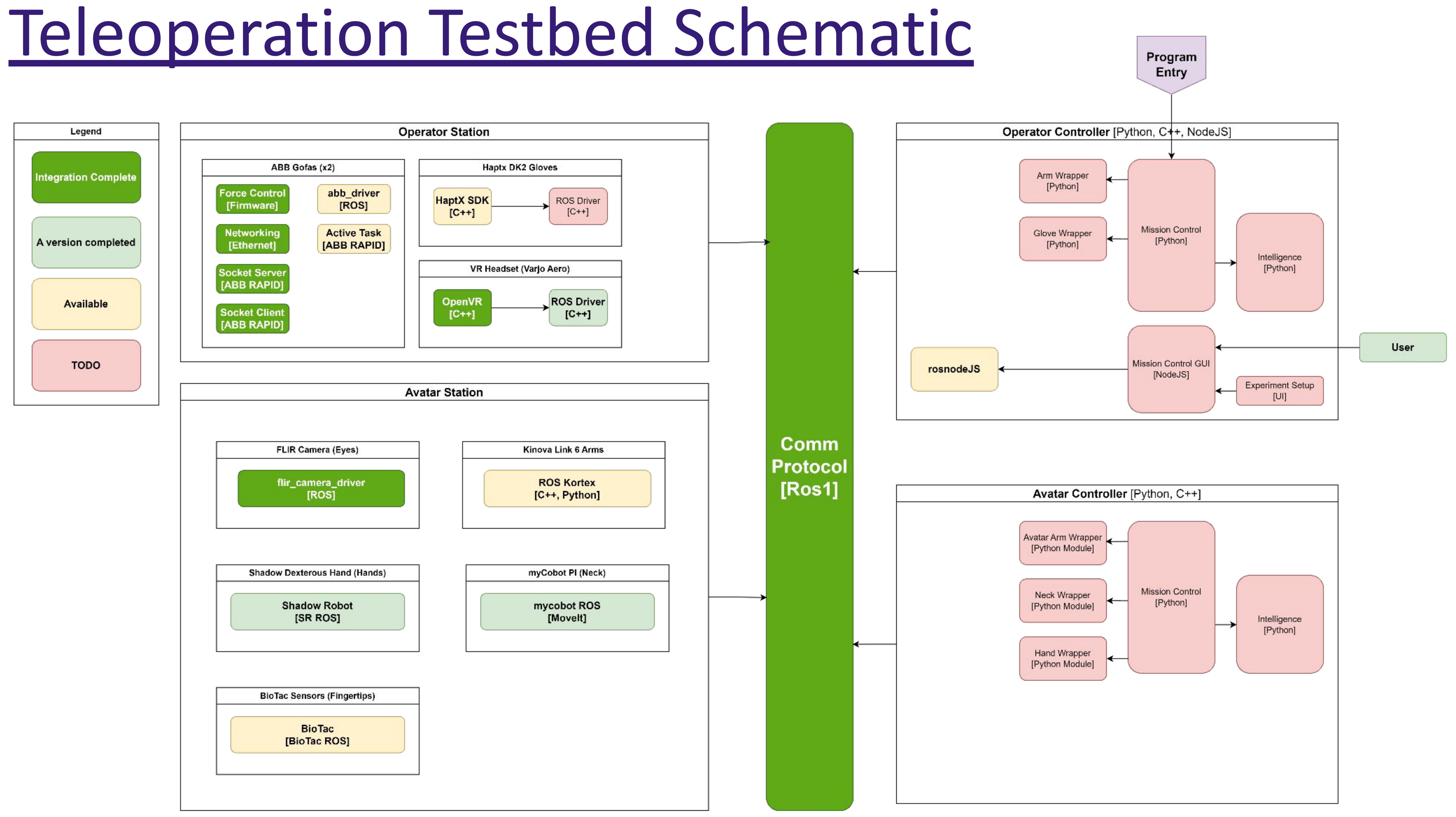

Figure 4: Schematic of the components and communication protocols of the teleoperation testbed.

Point Cloud to Semantically Labeling Geometry is a Fundamental Capability

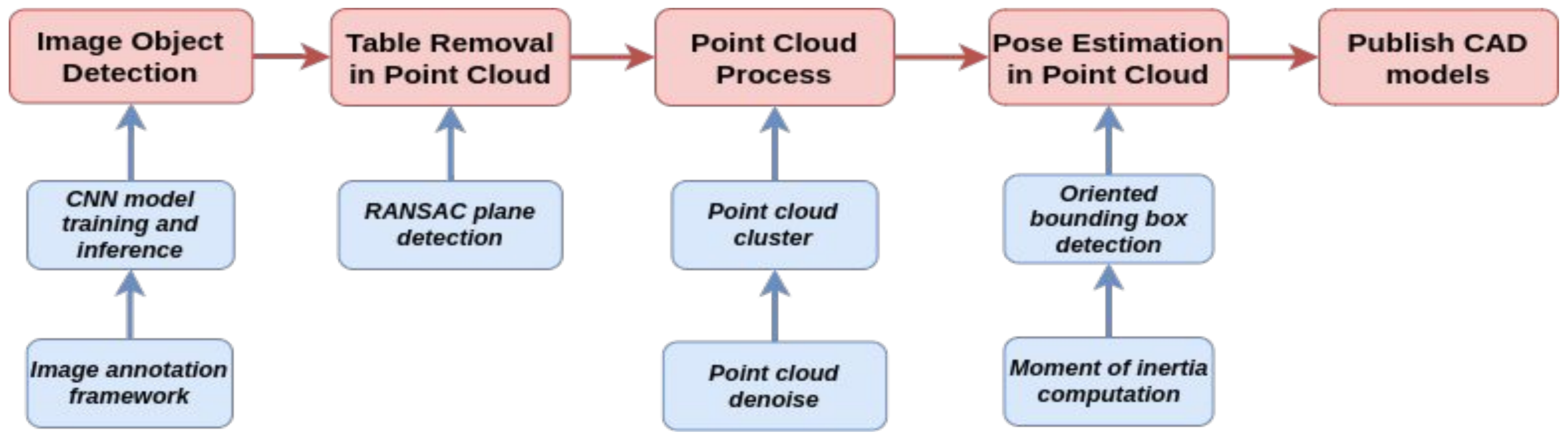

Figure 5: Communication flow of computer vision software used to detect and label objects in avatar environment.

Broader Impact

Our research suggests a paradigm shift to the telerobotics community by suggesting **teleoperation can be more robust** when the operator interacts with **virtually rendered shapes of remote objects**. A robust teleoperation system could have widespread impacts for consumers and industry. In industry, the system could facilitate **completing tasks that are too dangerous for humans**. For instance, a teleoperation system could be used to handle radioactive waste while decommissioning nuclear power plants. On the consumer side, a highly-dextrous teleoperation **system could enable people to handle remote objects designed for humans.** Imagine a caregiver remotely operating a kitchen robot to prepare a home-cooked meal.

Additional Benefits:

- Accessibility of low-level testbed is great for teaching students about remote touch and manipulation
- Expanding the reach of existing workers (e.g., help connect providers remotely to underserved communities)

Community Outreach:

- Sharing robots and hands with the public through FAMU-FSU Challenger Learning Center and Chicago Museum of Science & Industry.

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