

Haptic Teleoperation Solution

The content of this email refers to a prototype solution for haptic teleoperation.

The solution consists of a teleoperation setup with a leader and follower arm. The leader device (e.g. AgileX PiPER L or similar) is a lightweight robotic arm (low-cost) equipped with force torque sensing providing transparent operation and rendering haptic feedback.

The follower device is provided by the customer (can be provided by Bota as well¹) and equipped with a force torque sensor from Bota Systems measuring the interaction forces at the tool.

The leader and follower device are coupled through a controller that has the control authorities over the devices. The controller is implemented on a controller box, consisting of compute power for low-level control and connection for all devices.

The full robot state, as well as the force torque measurements are provided as live stream through an interface to the customer system. The teleoperation solution can be configured and enabled through a browser based user interface.

Additionally, the interaction forces during grasping can be recorded through tactile sensing at the gripper fingers. In a future step, the grasping forces will be provided as feedback to the operator.

Controller Box

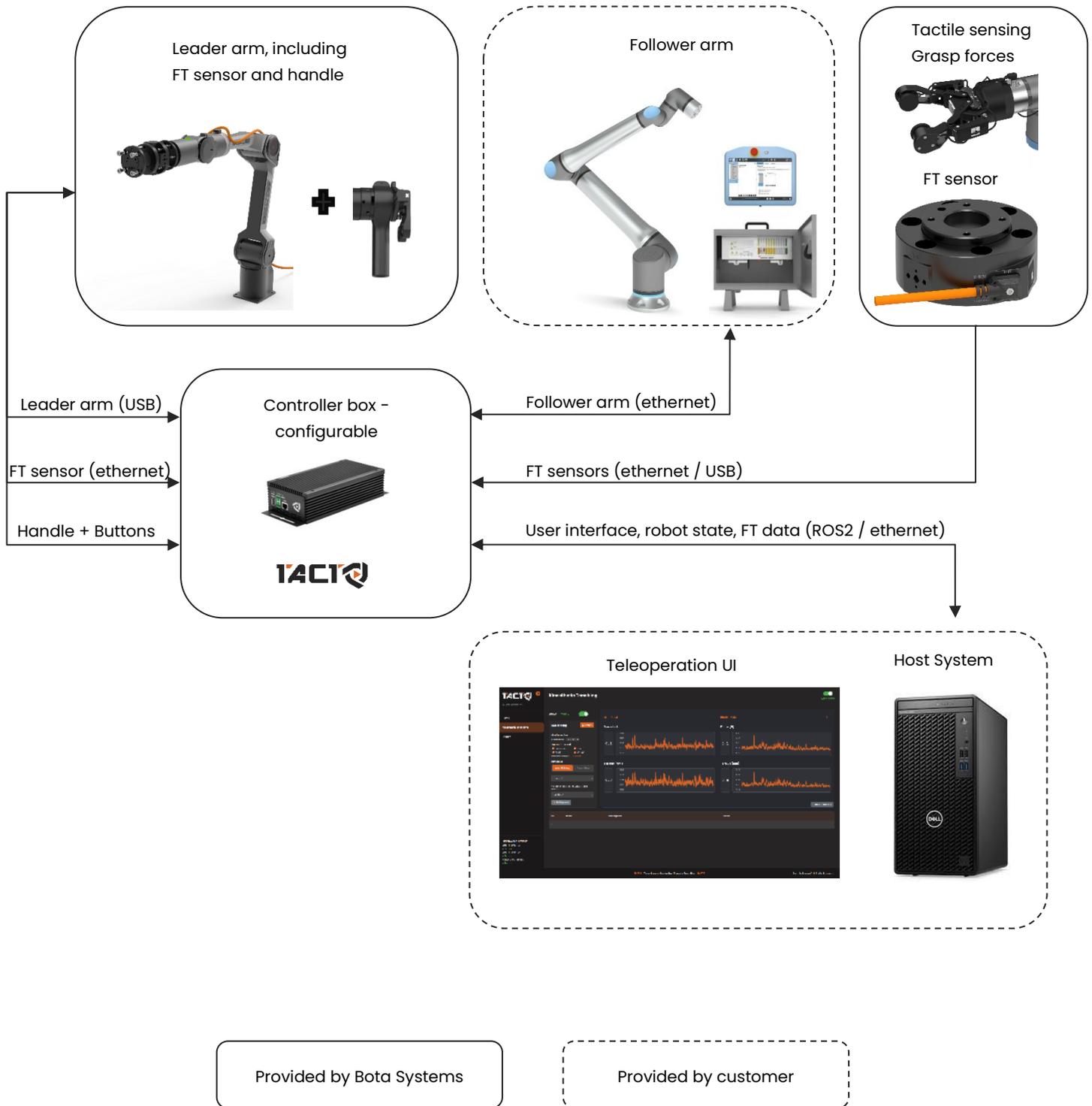
The controller box includes the (hardware) connections to all devices on the leader arm and follower arm side. On the controller box, the low-level control loop is running, coupling the follower device and the leader device with haptic feedback. The controller box is a pre-defined headless system, ensuring compatibility and performance with all devices.

The User Interface for configuration and enabling of the teleoperation controllers is accessible by a web interface on the same network.

The controller box is running the Bota teleoperation controller and provide the data stream for the states of the leader arm and follower arm, including force torque measurements. No data is recorded on the controller box itself.

¹ www.botasys.com/physical-ai

System Overview



List of components

Leader arm

| Component | Subcomponent | Comments |
|-------------------------|-----------------------|------------------------------|
| AgileX PiPER or similar | | Leader Arm |
| | 6 DoF robot arm | |
| | Mounting plate | |
| | Power Supply | |
| | USB to CAN converter | |
| | USB extension cable | |
| Leader 6-axis FT sensor | | |
| Handle | | |
| | Ergonomic handle | Mountable to PhysX FT sensor |
| | Trigger (for gripper) | |
| | USB extension cable | |
| Cable holder | | |

Follower arm

| Component | Subcomponent | Comments |
|--------------------------------|--------------------------------|--|
| Follower 6-axis FT sensor | | |
| Ethernet cable | | Follower arm control box to controller box |
| Follower gripper FT sensor kit | | |
| | 2x TactX FT sensor | |
| | 2x finger adapters (aluminum) | |
| | Connection hub | Mountable to Robotiq gripper |
| | Rubber pads, including adapter | Exchangeable |
| | USB extension cable | |
| Cable holder | | |

Controller box (headless setup)

| Component | Subcomponent | Comments |
|----------------|--------------|-----------------------------------|
| NUC PC | | Including power supply |
| Network switch | 1 Gbit/s | Min. 6 ports |
| USB hub | | Min. 4 ports |
| PoE (2x) | | For FT sensor leader and follower |
| Multiplugs | | Only one power plug required |
| Housing | | |

Host System requirements

- Expected: linux machine
- Access to network with controller box through ethernet
- Web browser for User Interface of teleoperation software