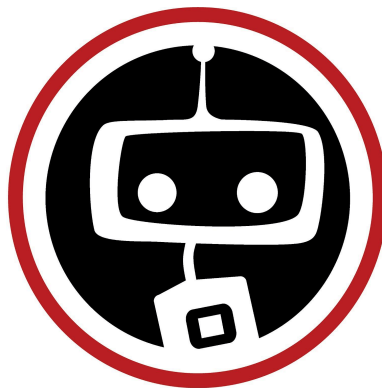




UBC OPEN ROBOTICS

(Public) Project Proposal: Haptic
Exoskeleton and Teleoperated Robot
Arm

Abstract

We are looking to design a master-slave control interface consisting of a wearable arm position tracker and a haptic rendering hand exoskeleton, linked to a remote 6-DOF robot arm manipulator. By translating the operator's arm position into robotic movement, and mapping the robot's contact forces back into the operator's fingers, the user can physically "feel" and manipulate objects in remote environments. This project will explore the areas of effective human-robot interaction (HRI), haptics, and wearable exoskeletons.



Background Information

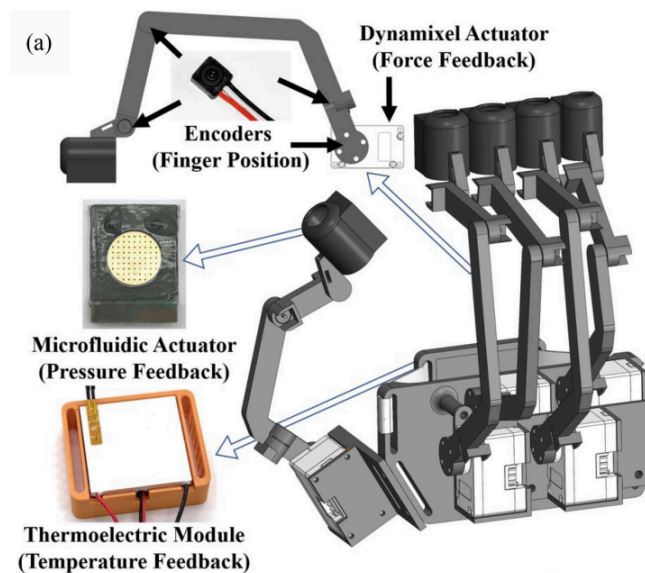
The following sections provide the foundational background knowledge for this project.

Haptics

Haptics is the study of touch and the technology that renders it artificially. There are two types of haptic force feedback:

- **Kinesthetic:** the macro motion forces you feel in your muscles and joints, and
- **Cutaneous:** the tactile forces you feel in your skin (pressure, texture, temperature).

Research shows haptic feedback measurably improves remote manipulation, leading to better force control, faster task completion, and fewer errors compared to vision alone. The ideal haptic device replicates the **high bandwidth** (>1000 Hz) that the human sensory system outputs. As humans, we are able to perceive the difference between free space and a hard surface instantly. Achieving this with a robotic system requires an extremely fast control system in every electrical, mechanical, and software stage.

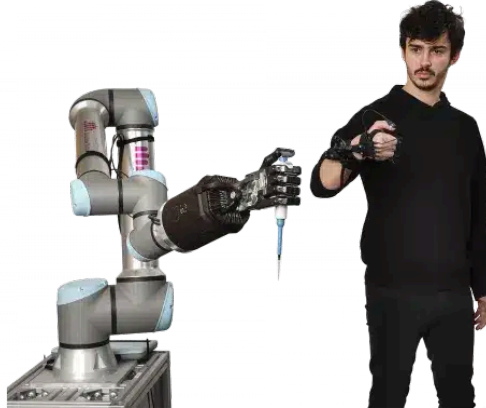


Exoskeletons

A wearable mechanical structure that interacts physically with the body. Some exoskeletons are strength-amplifying and some are rehabilitative. When used in teleoperation and haptics. The main goal is transparency. With no force being rendered, the device should feel like it isn't there, requiring a lightweight, low-friction mechanism.

Teleoperation

Teleoperation is the manual control of a robot from a distance, often used where direct human presence is dangerous or impossible, such as bomb disposal, space, and surgery. Systems are structured as master-slave: the master is what the operator directly controls (Ex: a joystick, a glove), the slave is the remote machine that mirrors it. Most teleoperation relies on vision alone, but can be enhanced with haptic feedback for increased operator perception.



Degree of Freedom (DOF)

A degree of freedom is one independent way an object can move. Position (X, Y, Z) gives three DOF. Rotation (pitch, roll, yaw) gives three more. Six DOF is enough to reach any position and point any direction in space, called 6-DOF. Robot arms are described by DOF count because it indicates capability: fewer than six limits reachable orientations, six covers all of them, and more than six (redundant) adds flexibility to avoid obstacles while still hitting the same target.



Bilateral Control

Control systems send information one way (unilateral, open loop) or both ways (bilateral, closed loop). Bilateral systems are harder to design because both directions must stay synchronized and stable.

Subteams

Operator Haptic Rendering Exoskeleton

A wearable device that allows the operator to physically feel the robot's gripping force in real-time. It uses resistive actuators and vibration to simulate contact and textures while remaining unnoticeable during free-space movement.

Key skills you will likely learn:

- **Mechanical:** Ergonomic wearable linkages, rapid 3D prototyping.
- **Electrical:** Custom PCB and circuit design, component selection, and encoder integration.
- **Firmware:** Motor control, current control loop architectures, communication protocols (I2C/SPI), PID tuning, and haptic rendering algorithms.

Operator Hand Motion Tracking System

A spatial tracking system that captures the operator's exact hand / arm position and orientation in real-time to drive the remote robot arm. It fuses camera and sensor data to ensure smooth, low-latency, and highly accurate motion mapping.

Key skills you will likely learn:

- **Software:** Computer vision, ML pose estimation, 3D coordinate transformations, applied linear algebra.
- **Firmware / Electrical:** IMU calibration and drift compensation, and sensor fusion algorithms.

Robot Force-Sensing End Effector

A custom robotic gripper designed to securely grasp a variety of objects while measuring the physical contact force applied. The measured force drives the haptic feedback loop back to the operator.

Key skills you will likely learn:

- **Mechanical:** Gripper kinematics, actuator and transmission selection, rapid 3D prototyping.
- **Electrical:** Custom PCB and circuit design, signal processing and amplification, and force sensor integration.

Robot 6DOF Arm

The core robotic arm system that physically mirrors the operator's tracked movements in real-time, allowing complete teleoperation. This subsystem will complete a full 6-DOF arm and integration with the gripper.

Key skills you will likely learn:

- **Mechanical:** Actuator selection, force / torque calculations, bearing / joint design.
- **Software:** Inverse kinematics, Robot Operating System (ROS).
- **Electrical:** Custom PCB and circuit design, encoder integration, power distribution, motor control.

Communications & Telemetry System

This system manages all real-time data transfer between the operator and the robot. It will also feature a telemetry system with a live dashboard to monitor system health, sensor data, and tracking status.

Key skills you will likely learn:

- **Software:** Low-latency networking protocols (UDP, ROS2/DDS), packet handling, GUI development, system logging, real-time data visualization.
- **Firmware:** Microcontroller data collection, sensor polling, and diagnostic state reporting.