Increasing Situational Awareness in Robotic Manipulation: A High-Force Haptic System

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Background

- Unpredictable settings like disaster zones require systems that combine dexterity, mobility, and precision.
- Autonomous systems often struggle with real-time adaptability, while human operators bring intuitive decision-making but face physical safety limits.
- This research explores the development of a teleoperated robotic system capable of simulating high-force haptic interactions with the environment.

Haptic Teleoperation

- The system includes two Barrett WAM arms: a 7-DoF follower and a 4-DoF leader, enabling high-force, bilateral haptic feedback.
- A custom 3-DoF cable-driven wrist exoskeleton provides precise, correctly-scaled force application to the operator, enhancing control and accuracy during teleoperation tasks.
- The Cable-driven design enables a linear mapping between motor output and joint torque, enhancing operator control and situational responsiveness
- High-force teleoperation offers advantages in tasks requiring forceful interactions with the environment.

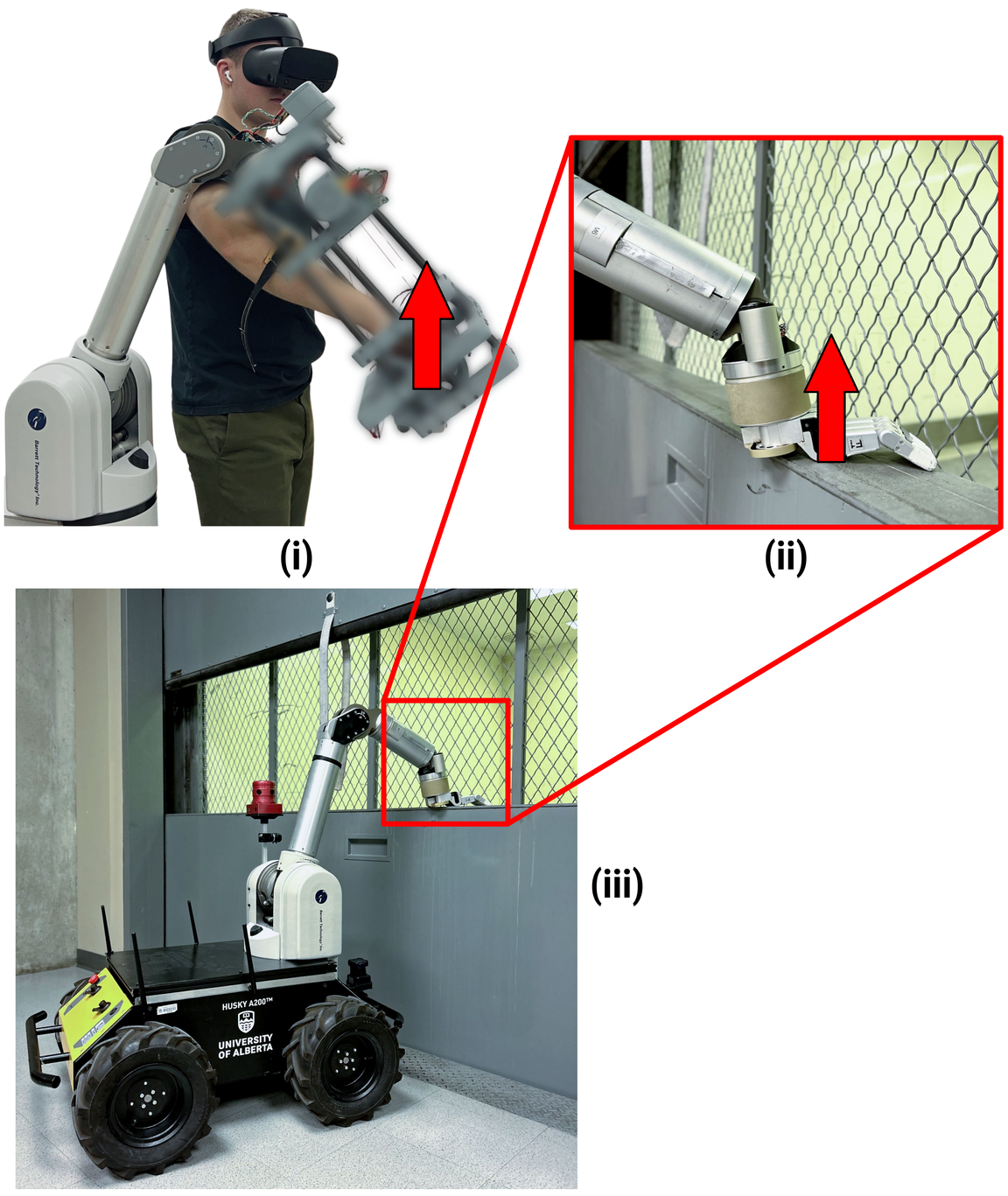


Fig. 1: (i)-(iii) Operator tele-operating the system to remotely open an elevator shaft; (ii) As the robot experiences a force F_N, the operator simultaneously feels the corresponding force through haptic feedback.

- The arms are coupled in joint space by running PD position control loops on each joint, using the real-time states of the corresponding joints on the opposite arm as setpoints.

Immersive Visual Feedback

- FLIR LadyBug2 spherical camera provides 360-degree imagery, projected onto an Oculus Rift HMD for an immersive environment view.
- Dual FLIR Blackfly cameras deliver high-resolution front and rear perspectives, aiding in detailed scene understanding.

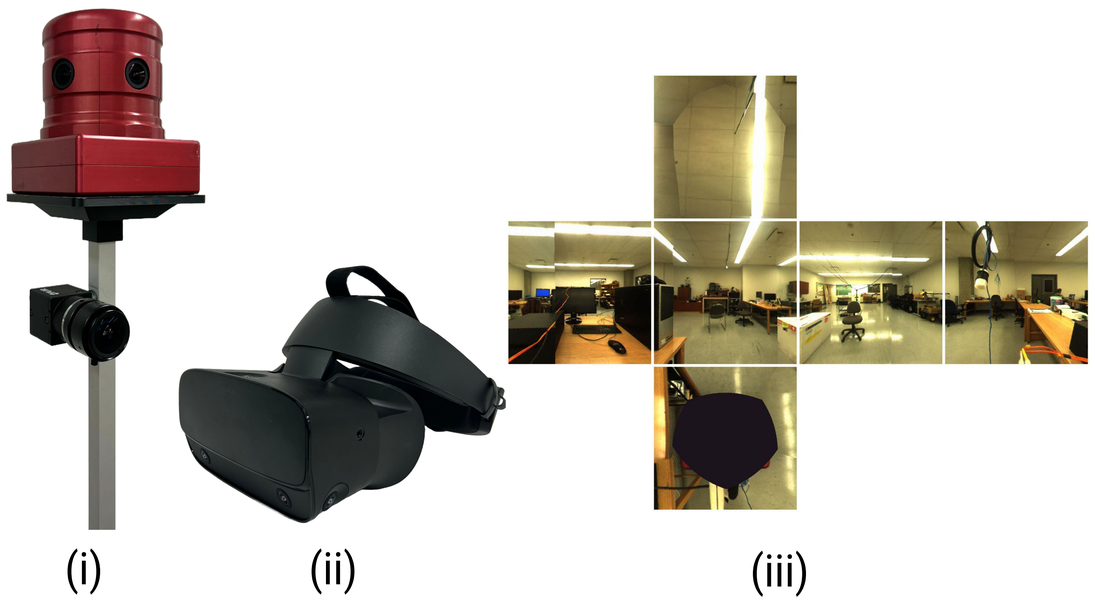


Fig. 2: (i) Camera mast equipped with the FLIR LadyBug2 and Blackfly cameras; (ii) Oculus Rift HMD; (iii) 360-degree environmental images projected onto a virtual cube.

Mobility Platform & Navigation

- The system uses a ClearPath Husky robot equipped with a low-mounted WAM arm for enhanced stability.
- SLAM-based navigation powered by Hokuyo LIDAR enables autonomous mapping and navigation

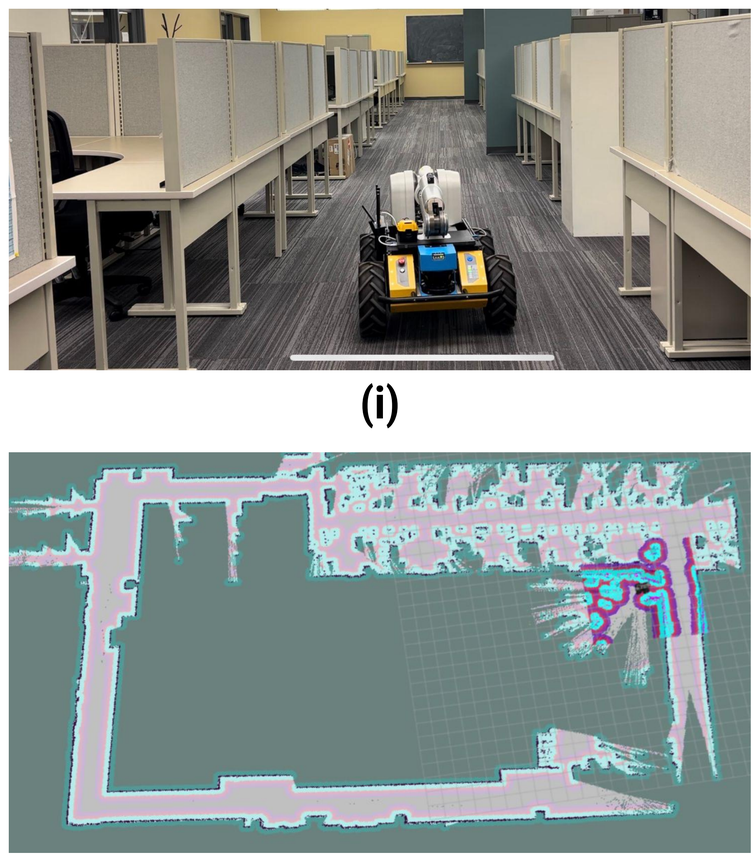


Fig. 3: (i) Robot autonomously navigating and mapping the fourth floor of ECERF; (ii) SLAM-generated map created by the robot during navigation.

Conclusion

- The integration of high-force haptic feedback, immersive visual input, and autonomous mobility in our system has shown substantial potential for enhancing control in real-world disaster response and hazardous environment tasks.

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