NRI: FND: Immersive Whole-Body Teleoperation of Wheeled Humanoid Robots for Dynamic Mobile Manipulation

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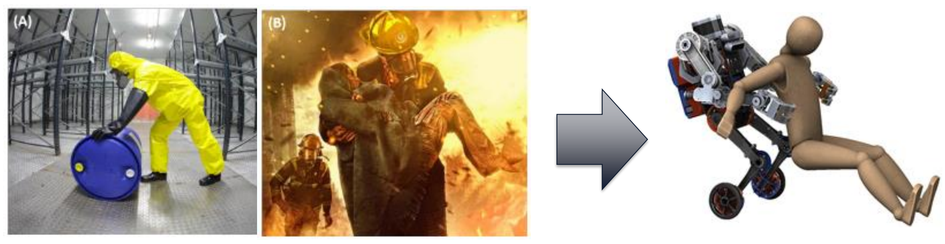
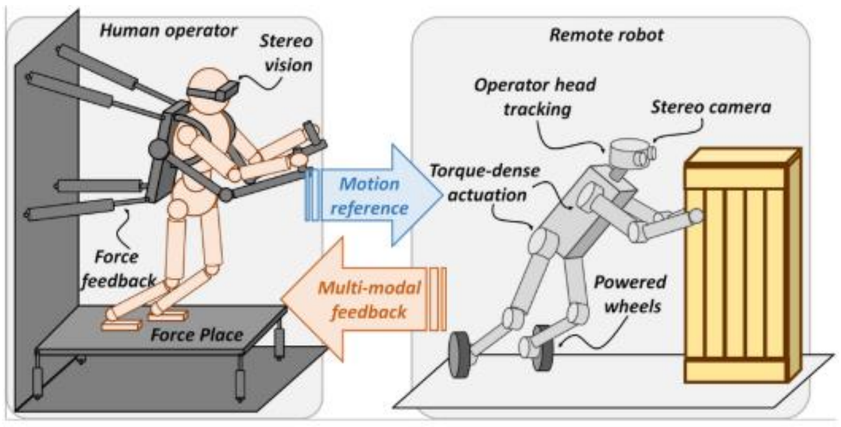
Motivation

- Workers in jobs involving physically demanding tasks and unsafe environments can be assisted by robots
- Such robots need to be capable of **Dynamic Mobile Manipulation (DMM)** in unstructured, chaotic environments

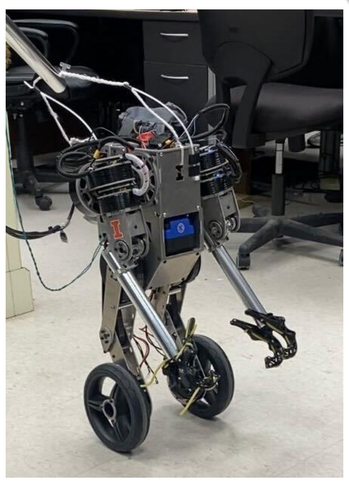


- **Hypothesis**: Bilateral teleoperation via whole-body haptics can achieve safe and intuitive DMM

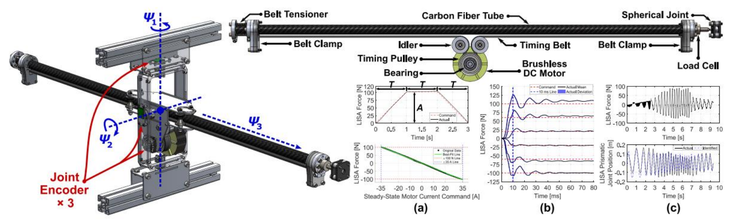


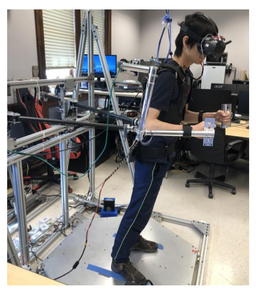
Novel Hardware Platform

- Development of a bi-wheeled humanoid: **Semi-Anthropomorphic Teleoperated Dynamic Rolling Robot (SATYRR)**



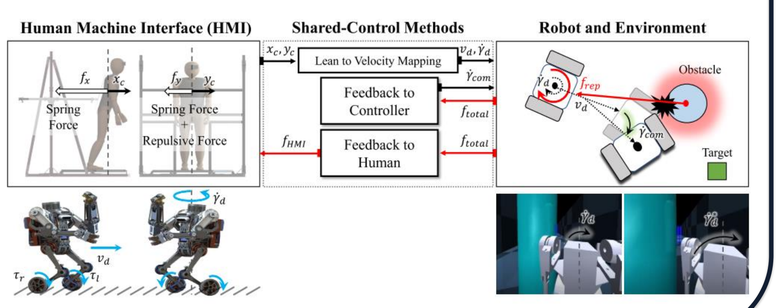
- Design of high bandwidth upper and lower-body motion capture & force feedback system
- Construction of force-plate that senses ground reaction wrench and human center of pressure
- Integration of SATYRR with human machine interface





Shared Control via MPC

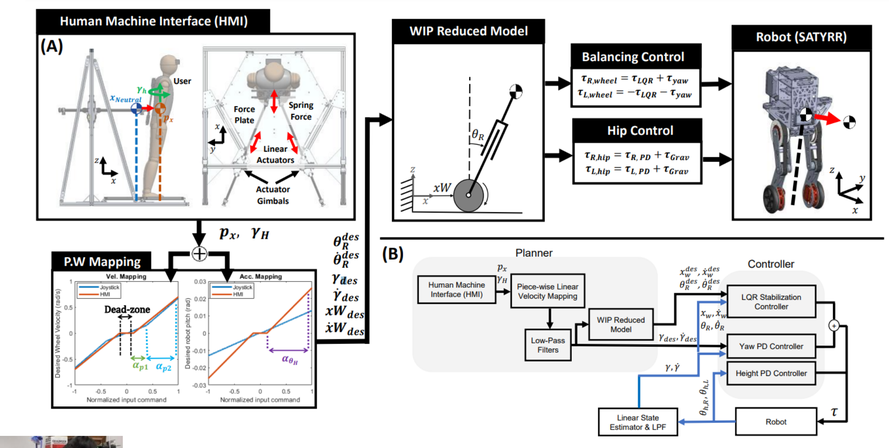
- Minimum intervention shared control (MISC) formulation handles obstacles & dynamical feasibility based on trajectory optimization approach [1,2]
- Real-time Model Predictive Control (MPC) enforces dynamics, state, and control constraints to follow command as closely as possible.

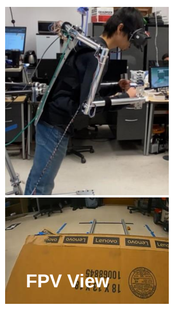


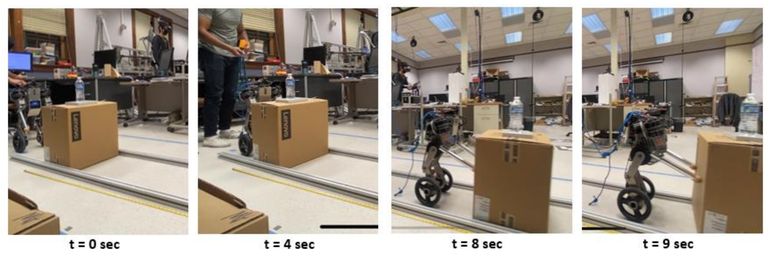
Control Results

Whole-Body Control & Motion Retargeting

- Using human lean, joint angles, and balancing strategy we can intuitively achieve dynamic whole body humanoid control
- Leveraging the robot's body inertia, we can push boxes 1.5x the robot's weight while regulating contact forces

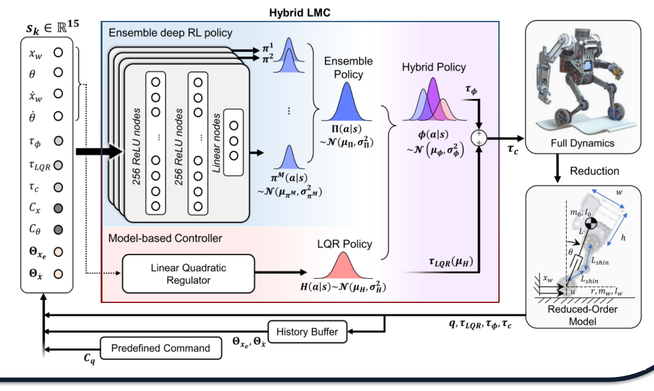




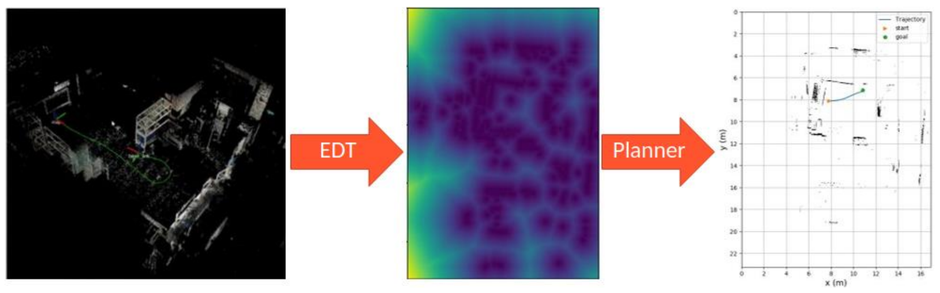


Improvements via Reinforcement Learning

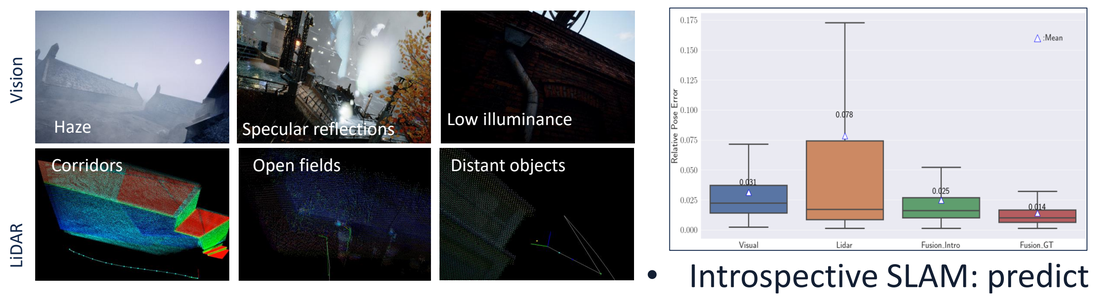
- Hybrid method combining LQR & ensemble RL policy outperforms residual RL, LQR, and model-free RL.
- Hybrid LMC has a better sample-efficiency than a model-free RL.



Perception for Shared Autonomy



- MISC constraints: LiDAR-Inertial SLAM (RTAB-Map) => encode map obstacles as soft constraints using Euclidean Distance Transform (EDT)



- Sensor quality degrades under certain environmental conditions
- Introspective SLAM: predict accuracy of modality to bias bundle adjustment weights

Future Work

- Force feedback strategies
- Integration of shared control & HMI
- Augmented situational awareness
- Testing in realistic obstacle course

1. Zhou, Yu and Hauser. Kris. *"CPI: Conservativeness, Permissiveness and Intervention Metrics for Shared Control Evaluation."* IEEE Robotics and Automation Letters, 7(3): 6367-6374 July 2022.
2. Zhou, Yu. *"Safe shared autonomy and evaluation metrics."* MS thesis, UIUC, 2022.

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