Automotive Research Center

A U.S. Army Center of Excellence for Modeling and Simulation of Ground Vehicles

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Evaluation and Performance Modeling of User Interfaces for UGVs

Thrust Area 2: Human Centered Modeling and Simulation

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Motivation

Despite advances in autonomous robotics, there are still many situations in which teleoperation is required or preferred.

- **Teleoperation remains a slow and difficult task** for remote operators, even when time is of the essence
- Novel user interfaces **(UIs) have the potential to alleviate some of the issues** faced by teleoperators
- It is not always clear which design decisions will **yield the greatest performance improvement at the lowest cost.**

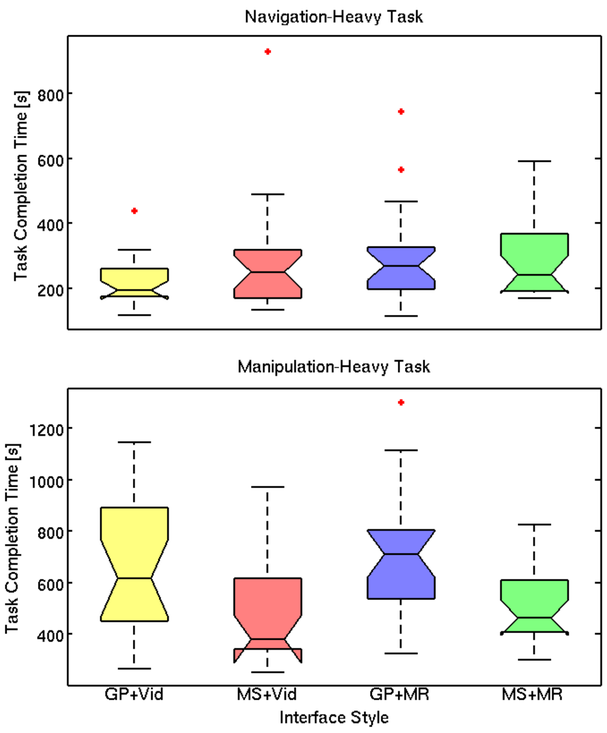
Objectives

- **Characterize the key factors limiting teleoperation speed** and performance for UGV tasks
- Develop **intuitive manual input and visual feedback interfaces** for UGV teleoperation
- Create performance models for teleoperated UGV tasks that can be used to **predict the impact of implementing a given UI**
- **Analyze the cost-effectiveness** of integrating novel UIs into new and existing teleoperated UGV systems

Methodology and Results

We consider teleoperation control as a closed-loop feedback system with a human operator in the loop [4].

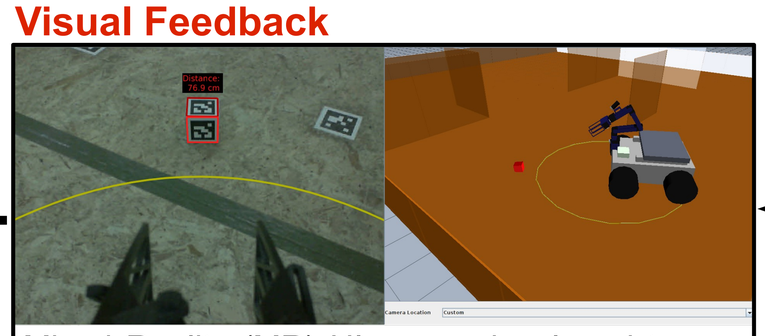
User



User tests were conducted to determine the effects of user interface on performance.

- Manipulation tasks benefited significantly from the Master-Slave (MS) controller
- No significant difference for navigation tasks
- Visualization did not significantly affect task completion time [Publication Forthcoming]

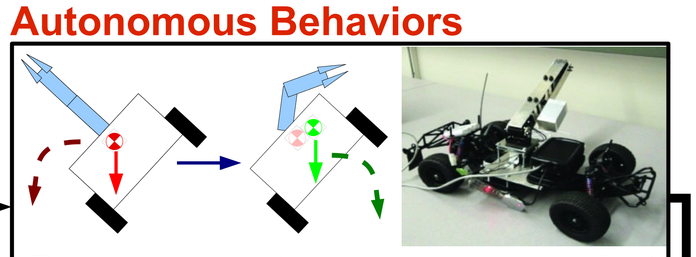
Visual Feedback



Mixed Reality (MR) UIs were developed to provide enhanced visual feedback with more spatial cues than video-only feedback (Vid) [1, 2].

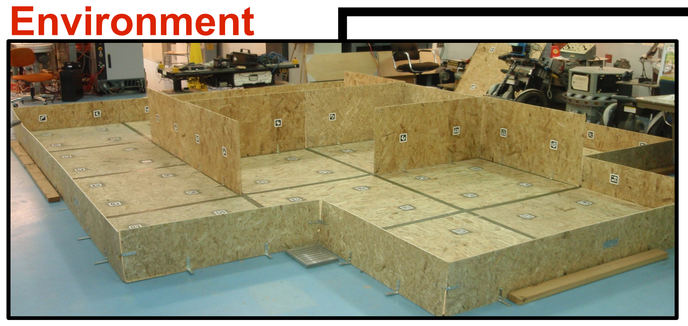
Sensors

Autonomous Behaviors

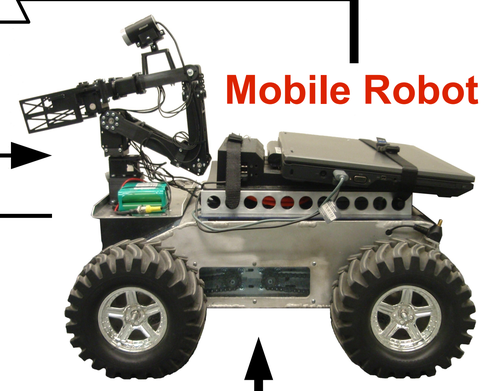


Rollover prevention via dynamic weight shifting of a manipulator arm was explored by a Capstone Design Team (F12).

Environment

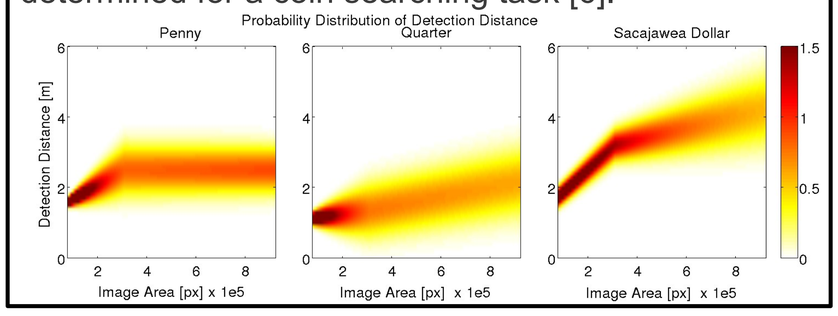


Mobile Robot

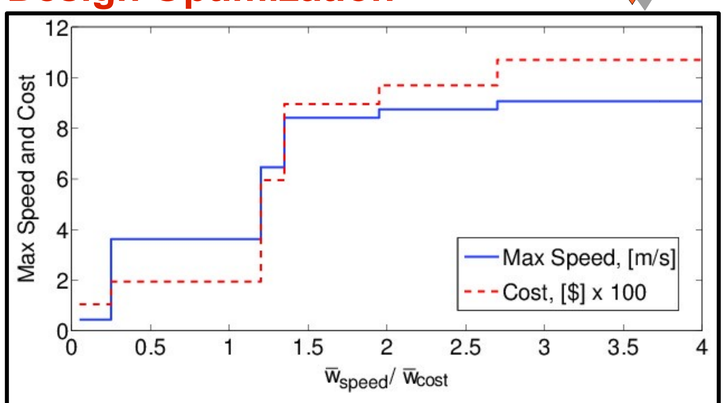


Key factors limiting teleoperation speed include various delays (δ) and detection distance (ℓ), and are related to the system components, such as sensors, networks, and UIs [6].

Empirical statistical models of detection distance were determined for a coin searching task [6].

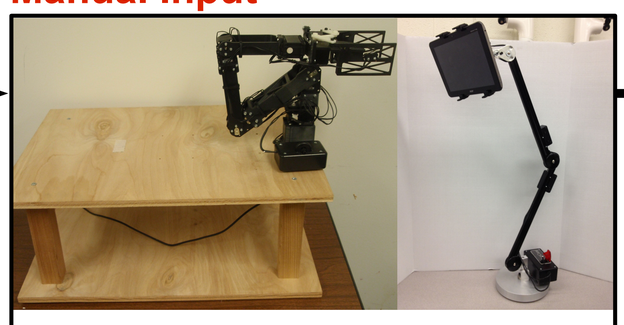


Design Optimization



We integrate performance models into the feedback loop and use a multi-objective optimization approach to determine if various components warrant implementation [4].

Manual Input



Master-slave (MS) position controllers were designed to make users' manual input to the robot more intuitive than gamepad (GP) interfaces [2,5].

Publications

[1] S. Vozar and D. M. Tilbury, "Augmented Reality User Interface for Mobile Ground Robots with Manipulator Arms," *Proceedings of the IS&T/SPIE Electronic Imaging Conference*, San Francisco, January 2011.

[2] S. Vozar and D. M. Tilbury, "Improving UGV teleoperation performanceusing novel visualization techniques and manual interfaces", *Proceedings of SPIE Volume 8387, Unmanned Systems Technology XIV,* Baltimore, May 2012.

[3] S. Vozar and D. M. Tilbury, "Augmented Reality User Interface for Mobile Robots with Manipulator Arms: Development, Testing, and Qualitative Analysis," *Proceedings of the ASME-IDETC/CIE*, Chicago, August 2012.

[4] S. Vozar and D. M. Tilbury, "Improving Teleoperated Robot Speed using Optimization Techniques," *Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction,* Tokyo, March 2013.

[5] P. Turpel, B. Xia, X. Ge, S. Mo, and S. Vozar, "Balance-Arm Tablet Computer Stand for Robotic Camera Control," *Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction,* Tokyo, March 2013.

[6] S. Vozar and D. M. Tilbury, "A System-Level Methodology for Optimizing the Speed of Teleoperated Mobile Robots," submitted to the *Robotics and Autonomous Systems,* April 2013.

Future Work

- Continue sub-system modeling efforts
- Determine if user performance on simple sub-tasks can be concatenated to predict performance on mission-level tasks
- Evaluate and model user acceptance of autonomous behaviors

Cooperative Agreement W56HZV-04-2-0001 U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC)