# Mixed Reality Interface for Managing Heterogeneous Robot Teams in Complex Environments

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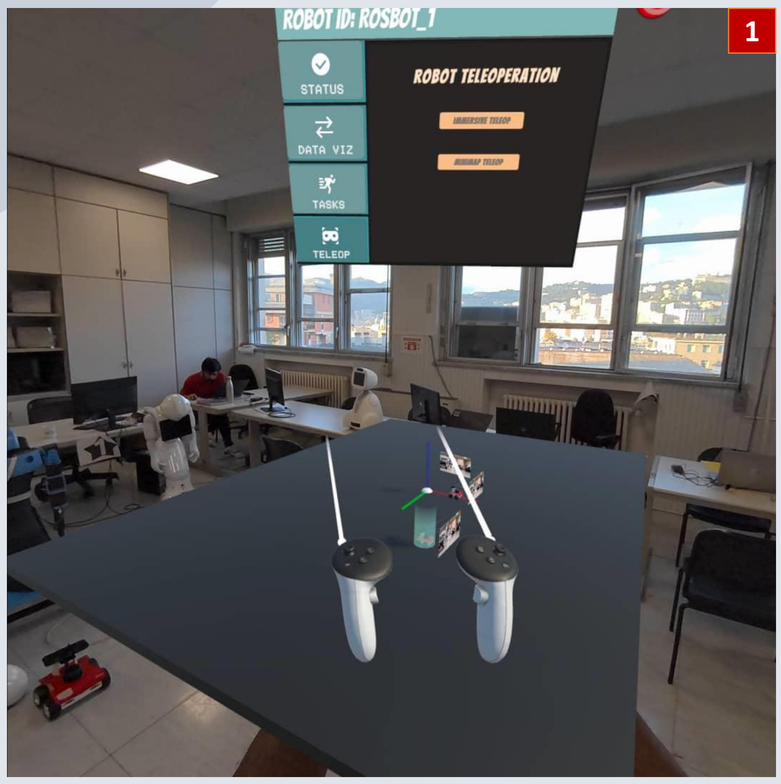
**Omotoye Shamsudeen Adekoya, Antonio Sgorbissa, Carmine Recchiuto**

*DIBRIS, University of Genoa.*

## Introduction

The field of robotics has seen remarkable advancements in recent years, particularly in the development of heterogeneous robot teams for complex tasks such as disaster response (search and rescue operations)[1] As these teams become more diverse and capable, there is a growing need for intuitive and efficient interfaces that allow human operators to manage multiple robots simultaneously. While Mixed Reality (MR) interfaces have been widely used for controlling single mobile robots, offering improved situational awareness and intuitive command inputs, their application for managing teams of mobile robots remains an under-explored area. Notable examples like Arviz[2] and iviz[3] have demonstrated the potential of MR interfaces for visualizing sensor data and controlling individual robots, and researchers have explored MR applications in aerial robotics to enhance operator awareness and control precision[4][5]. However, there is still a significant gap in integrating comprehensive functionalities for managing diverse robot types within a single MR interface. This paper presents preliminary work on **HORUS:** Holistic Operational Reality for Unified Systems, a novel Mixed Reality interface designed to address these challenges. HORUS aims to manage diverse robot teams, including wheeled, legged, and aerial robots, within a unified MR environment.




**MiniMap (GroundStation) with 3 connected ROSBot, ROSBot with ID 1, is selected which shows the Robot Manager Panel for checking the robot status, sending task, switching on/off specific data to visualize, sending a task, and acticating robot teleoperation**

## References

[1] M. Tranzatto et al “Cerberus in the darpa subterranean challenge,” 05 2022.
[2] K. C. Hoang et al, “Arviz: An augmented reality-enabled visualization platform for ros applications,” 03 2022.
[3] A. Zea, U. D. Hanebeck, “iviz: A ros visualization app for mobile devices,” Software impacts, vol. 8, pp. 100057–100057, 05 2021.
[4] M. E. Walker et al “Robot teleoperation with augmented reality virtual surrogates,” 03 2019.
[5] M. Allenspach et al “Mixed reality human-robot interface to generate and visualize 6dof trajectories: Application to omnidirectional aerial vehicles,” 06 2023.

## Methodology

**Hardware Selection**:

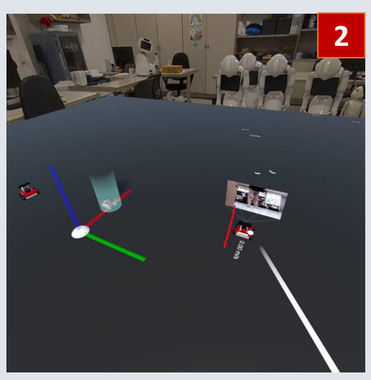
The **Meta Quest 3** was chosen as the primary MR device for HORUS due to its advanced color passthrough technology, which offers superior immersion compared to optical see-through displays. The Meta Quest 3's field of view, more than double that of alternatives like the Hololens 2, enables users to seamlessly blend virtual elements with the real environment, enhancing situational awareness during robot operations. The current robot team consists of **ROSbots** (wheeled robots), with plans to integrate **Spot** (legged robot) and various drone models (aerial robots) in future iterations.

**Software Development:**

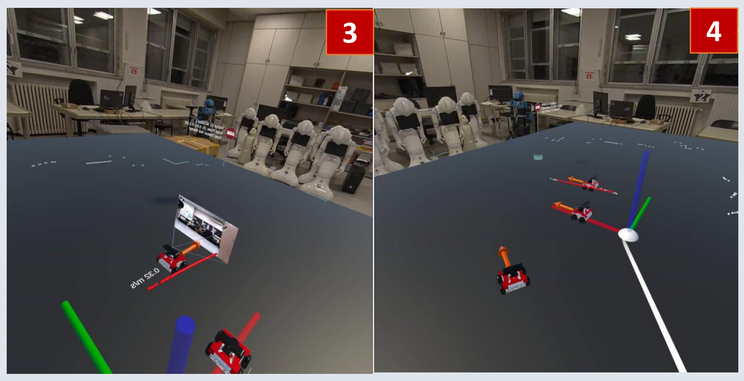
HORUS is developed using **Unity**, leveraging the **Meta Quest SDK** to fully utilize the headset's features. Robot Operating System (**ROS**) serves as the backbone for robot communication and control. The Unity TCP Connector Package was implemented to create subscribers and publishers, facilitating communication with the robot team through ROS Messages.

### Interface Features

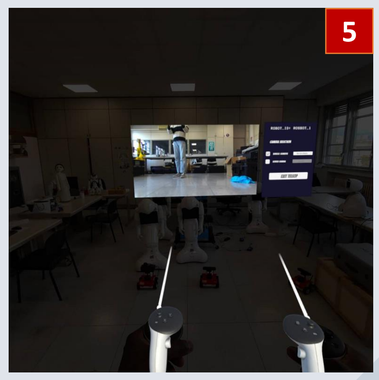
***Data Visualization***




***Single/Multi Robot Task Allocation***

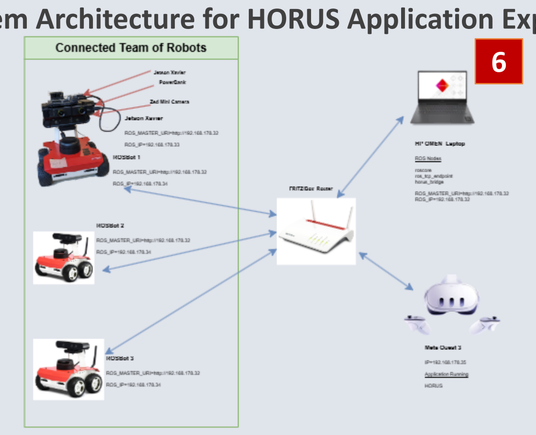



***Teleoperation***



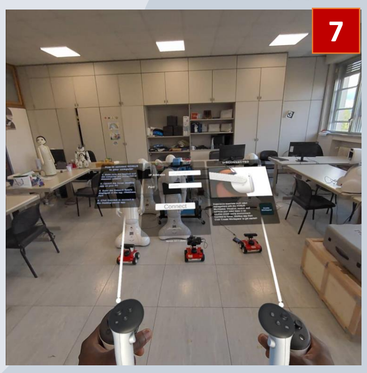

In HORUS, Operators can **monitor robot status**, checking individual properties, battery levels, and current task status. The interface allows **real-time visualization of sensor data**, including camera feeds projected from various perspectives, laser scans, and other sensor outputs. Task assignment is flexible, enabling operators to **allocate tasks** to single robots, subgroups, or the entire team directly from the Mini Map. Teleoperation in HORUS is available in three modes: **Mini Map Control;** High-level navigation commands sent via the overhead view, **Semi-immersive;** A large virtual screen displays the robot's camera feed, **Full immersion;** The operator's view is fully replaced by the robot's perspective, ideal for precise inspection tasks

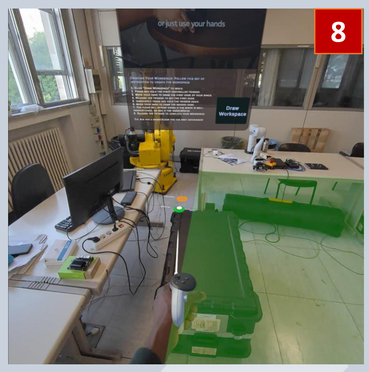
### System Architecture for HORUS Application Experiment




- **ROS Master**: Centralizes communication for all robots.
- **Network Configuration**: Connects all devices via a common local network.
- **ROS-Unity Bridge**: Enables real-time data exchange using the ros_tcp_endpoint package.
- **HORUS Application**: Compiled directly on Meta Quest 3 for untethered operation, reduced latency, and enhanced portability.
- **HORUS Bridge**: Custom ROS node managing multi-robot task allocation and interface-robot interactions.

### Application Usecase




**Initialization:** User opens the application and inputs the IP address and port of the TCP endpoint. System establishes connection to the ROS master.
**Workspace Setup:** Upon successful connection, user draws a workspace in the mixed reality environment. A minimap (workstation) is spawned within this designated area.
**Robot Interaction:** The minimap displays available robots in the team. Users can select individual robots to access various functions, View robot status, Visualize sensor data, Allocate tasks, Initiate teleoperation

## Discussion

Current implementation shows promise for wheeled robots. Future work includes:

- Integrating legged and aerial robots
- Developing multi-operator support
- Incorporating Multi-Modal Large Language Models for AI-assisted decision-making
- Enhancing data fusion capabilities
- Conducting user studies to assess usability, effectiveness, and cognitive load

## Conclusion

HORUS simplifies the management of diverse robot teams through intuitive visualization and control methods. While current implementation focuses on wheeled robots, future development will expand support for other robot types, improve multi-robot coordination, and validate the interface's effectiveness through user studies.

SCAN ME

Try HORUS yourself!
Scan the QR code below to access the HORUS GitHub repository. You can download the beta version of the application on your Meta Quest 3 and test it with your wheeled robot by following the instructions in the README file. We welcome your feedback and contributions!