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PURES

Mixed Reality based Multi-Agent Robotics Framework for Artificial Swarm Intelligence Experiments

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Abstract:
Swarm intelligence experiments necessitate a significant number of robot agents with specialized hardware, which is typically costly and requires a well-controlled environment. As an alternative, swarm robotics simulators that operate entirely in virtual environments are available today. However, such virtual environments may not always represent the complexities of real-world experimentation. The goal of this research is to introduce a mixed reality framework by merging the two realities and modeling swarm behaviors in such a way that both real and virtual robotic agents, as well as other environmental elements, can co-exist and interact with each other. In this approach, all real robotic agents and environmental elements in the system are simultaneously represented in virtual reality, while the simulated environment may contain various additional elements that are purely virtual. Thus, swarm behavioral experiments can be conducted with a few real robots and an unconstrained number of virtual robot instances by mimicking the characteristics of real robots.

Introduction

Challenges in Swarm Robotics
- Swarm intelligence related experiments require a considerable amount of robots as well as various environmental elements.
- Building a massive set of robots is both time-consuming and prohibitively expensive.

Existing Solution:
Computer-based simulations with virtual robots.

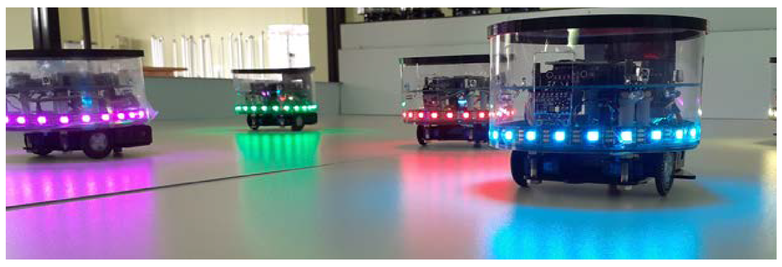
Advantages of the existing solution
- More convenient than physical swarms
- Less expensive
- High efficiency

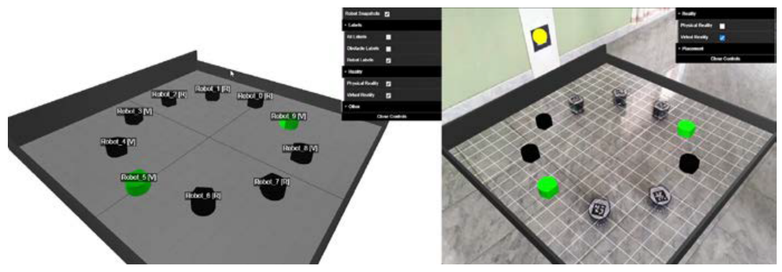
Issues of the existing solution
- Simulators do not ensure how robots act in an actual environment, how they react to complex physics, noisy sensor data, control loop delays, etc.

Mixed Reality in Swarm Robots
- Merge virtual and physical realities.
- Enabling a robot to sense both physical and virtual environments via augmented means allows the ability to interact with both environments.
- Collaborative design patterns and individual functionalities could be accessible and monitored remotely for debugging and development.

Advantages
- Reduce the experimental and development costs of robots while maintaining the scale and scope of swarm intelligence experiments.
- Enables the combination of accurate individual behaviors with highly scalable collective behaviors in experiments.
- Allows creating safer and lower-risk environments for extensive testing of swarm robotics behaviors as well as an unrestricted means of achieving additions to the robots that are physically impossible or expensive in reality.

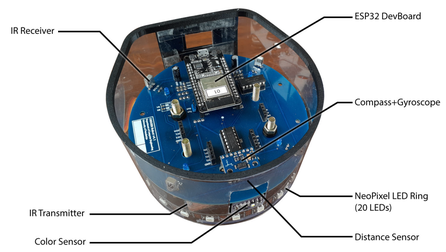
Focus of this study
To identify the requirements for implementing a mixed reality environment for swarm robotics simulation.

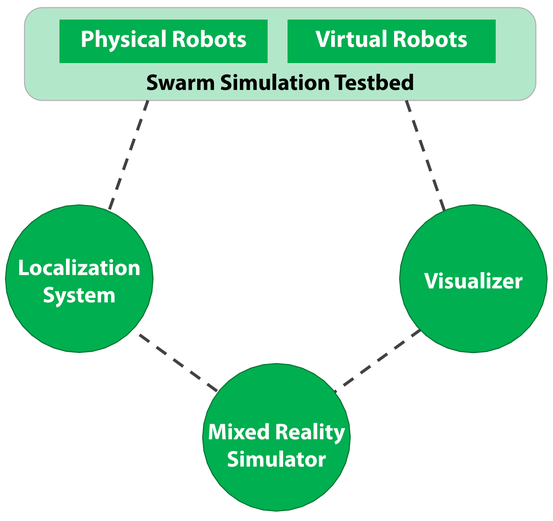




Physical Robots

Low-cost, general-purpose, differential drive robot (especially targeting the swarm behavioral experiments)





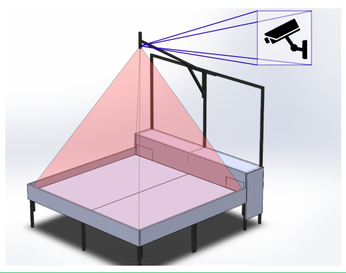
Virtual Robots

Virtual robot agents are the same as physical robots in functionality but only exist in the virtual domain.

Localization System

- An overhead camera with AR markers on top of the robots - to identify the coordinates of the physical robots.

- A mathematical model - to calculate and update the motion of the robots based on the control actions.



Reality Simulator

The simulator is a real-time inter-reality integration framework that facilitates the interactions between 2 realities, including the robots and the environmental elements. This framework consists of communication protocols, data structures, and workflows to support seamless integration.

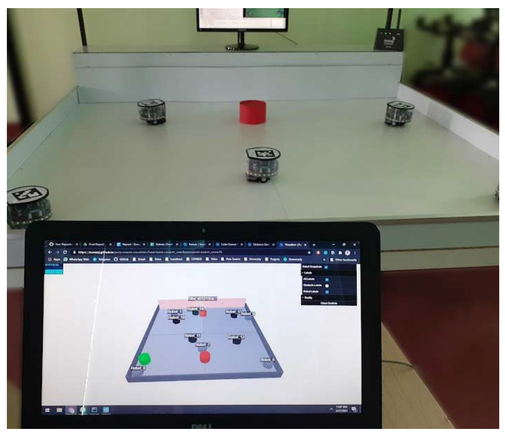
Visualizer

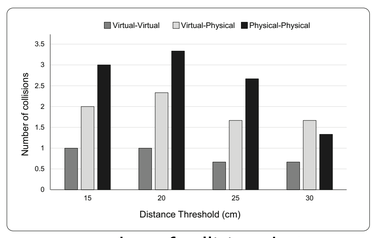
The visualizer visualizes the robot's movements in both realities in a single environment.

- The VR visualizer - defines at the software level and renders the robots of both realities in that virtual space.
- The AR visualizer- projects the virtual robots into the physical space on top of the video feed taken by a camera.

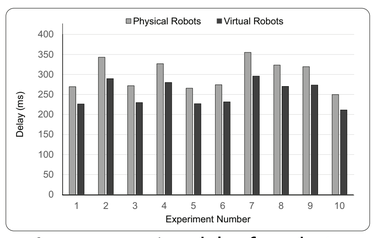
Conclusion

- The system can be used to test the functionalities of swarm robots with a large number of different environmental arrangements easily rather than physically creating them.
- Virtual sensors can be used for physical robots that have limited resources and space.
- The framework can be used by researchers to access the swarm robotics testbed, to connect the physically existing robot testbed from a remote computer and conduct the swarm and multi-agent robotics experiments





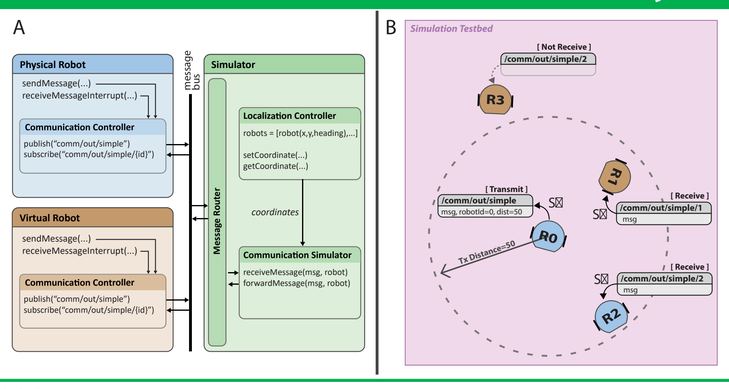
The average number of collisions between robots



Average sensing delay for robots

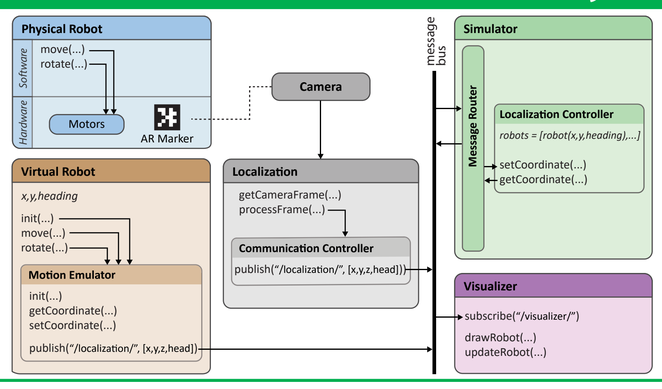
Visit *https://pera-swarm.ce.pdn.ac.lk* for more details

Communication in Mixed Reality



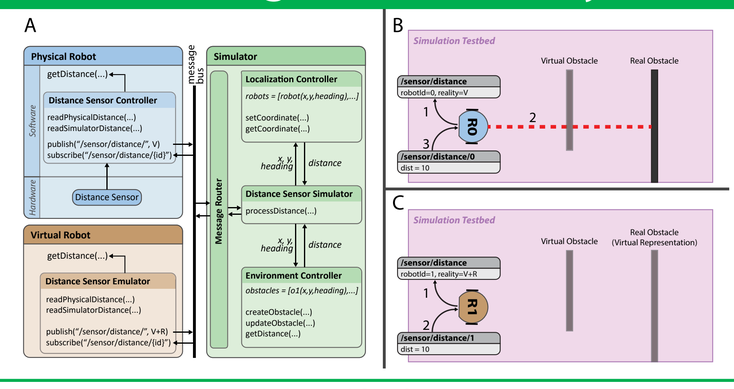
(A) Component diagram for communication in mixed reality.
(B) Demonstrate a scenario where the robot R0 broadcasts a message to robots within 50 units of distance.

Localization in Mixed Reality



The architecture of handling the localization in the mixed reality domain

Sensing in Mixed Reality



(A) Component diagram with the workflow for sensation in mixed reality.
(B) Demonstrates how a physical robot senses virtual and physical obstacles.
(C) Demonstrates how a virtual robot senses virtual and physical obstacles.

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