Simulation of a Multi-robot System for Outdoor Exploration

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1. Introduction

Swarm robotics is a subfield of robotics characterized by the deployment of multiple autonomous robots that perceive their environment and act independently [Srinivas Aditya et al. 2021], while maintaining communication and interaction with each other to accomplish a common overarching goal. Due to its modular architecture, this paradigm exhibits high operational efficiency [Habib and Chukwuemeka 2020]. Its applications span diverse domains, including environmental pollution monitoring [Salmon and Meissner 2015] and emergency response operations [Karishma and Binsu 2018].

This paper presents the simulation of a multi-agent robotic system, intended as a first step toward developing a robotic platform for outdoor exploration and navigation. The system was implemented using ROS 2 (Robot Operating System), an open-source set of software libraries and tools for robot application development, Gazebo as the simulation environment, and RViz 2 for real-time visualization of sensor data and robot states. For communication was used Eclipse mosquitto as a message broker for sharing the information collected by the agents, and display it in a User Interface, and its also integrated a vision recognition system using OpenCV library, for computer vision.

2. System Description

The platform is modeled as a simplified skid-steer rover configuration to enhance adaptability and mobility over uneven and irregular terrains, as illustrated in Figure 1.



Figure 1. Robotic Agent.

Each agent was equipped with a LiDAR sensor, an RGB camera, and a temperature sensor to emulate the environmental data acquisition process. The experimental scenario was simulated with three agents operating in an open-space environment generated in Gazebo. The simulation framework was integrated with core algorithms from the

ROS 2 libraries, employing the Nav2 stack to perform path planning for the developed agents. The systems were connected to the message broker based on Eclipse Mosquitto, which handled the transmission of sensor data to be visualized through a local network port.

The current system supports autonomous navigation within a Gazebo-simulated environment, enabling both environmental modeling and data acquisition. Collected environmental data, together with images captured by the onboard cameras, are transmitted to a broker for subsequent processing. In addition, an OpenCV-based recognition module has been integrated to perform automated labeling of basic geometric shapes detected in the camera images which are send through the broker and visualized in an User Interface.

3. Future Work

Furthermore, a Reinforcement Learning (RL) framework is under development to endow the system with full autonomy during environmental recognition missions, allowing it to optimize its navigation and perception strategies through interaction with the environment. The system described is intended to serve as an initial framework for the development of a multi-agent architecture dedicated to exploration tasks in outdoor environments.

References

Habib, M. K. and Chukwuemeka, C. I. (2020). Development of IoT/Cloud Integration Frameworks for Autonomous Networked Robots (ANR). In *2020 21st International Conference on Research and Education in Mechatronics (REM)*, pages 1–10.

Karishma, K. M. and Binsu, S. (2018). *A Review on Autonomous Rescue Navigation System Using Wireless Sensor Networks*. IEEE.

Salmon, P. C. and Meissner, P. L. (2015). Mobile bot swarms: They're closer than you might think! *IEEE Consumer Electronics Magazine*, 4:58–65.

Srinivas Aditya, U., Singh, R., Singh, P. K., and Kalla, A. (2021). A survey on blockchain in robotics: Issues, opportunities, challenges and future directions. *Journal of Network and Computer Applications*, 196:103245.