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ADVANCED COLLABORATIVE SLAM FOR MULTI-ROBOT SYSTEMS: ENHANCING DYNAMIC MAPPING AND COOPERATIVE SPACE EXPLORATION AND NAVIGATION

Abstract

This research aims to design and implement an advanced collaborative simultaneous localisation and mapping (CSLAM) system that significantly enhances the capabilities of multi-robot systems in dynamic space environments. By leveraging the Robot Operating System (ROS) and Python, this research incorporates advanced SLAM algorithms such as GMapping, Karto, and Cartographer, focusing on LiDAR-based techniques to enable multi-agent cooperation. The innovative CSLAM approach is designed to improve efficiency, ensure redundancy, and enhance robustness in mapping and navigation tasks, critical for addressing the unique challenges posed by space exploration missions.

This research has significant potential in several space-related applications. One promising use is in planetary exploration and mapping, where collaborative robots can autonomously navigate and map unfamiliar terrains, identify resource deposits, and locate safe landing points. Additionally, the CSLAM system can be vital in Lunar or Martian habitat construction, supporting tasks such as excavation, assembly, and transportation of materials, which require precise and cooperative robotic systems. The system's adaptability and coordination capabilities make it ideal for asteroid mining, where irregular shapes and microgravity environments present unique challenges that multi-robot cooperation can overcome efficiently. Another compelling application is in space station maintenance, where autonomous robots equipped with CSLAM can perform inspection, repair, and debris management tasks with minimal human intervention, enhancing the safety and sustainability of long-term space operations.

The research tackles the complex issues of maintaining consistent localization and integrating map data across multiple agents in uncertain and changing environments, crucial for space missions. Starting with comprehensive testing in simulated settings, the methodology paves the way for rigorous field trials, refining the algorithms for broader space applications and scalability. This ensures the robustness, reliability, and real-world applicability of the developed systems in challenging extraterrestrial conditions.

This work not only pushes the boundaries of CSLAM technology but also contributes to the space robotics domain by enabling advanced autonomy in multi-robot systems. These enhancements have the potential to revolutionize space exploration, making space missions more adaptable, reliable, and effective for tasks such as planetary exploration, habitat construction, asteroid mining, and space station maintenance.