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AI-DRIVEN COOPERATIVE PATH PLANNING FOR LUNAR ROVER SWARMS IN POLAR REGIONS

Abstract

Lunar polar regions are prime targets for future exploration due to their potential water ice deposits, essential for sustaining human presence and enabling deep-space missions. Efficiently exploring these regions requires autonomous, cooperative robotic systems capable of maximizing surface coverage in minimal time. This research presents a novel multi-agent reinforcement learning (MARL) approach for cooperative path planning of a swarm of lunar rovers within a defined polar region. The study simulates a two-rover exploration mission, focusing on optimizing coverage while avoiding collisions and minimizing energy consumption. A customized simulation environment, built using ROS2, replicates the lunar terrain and rover dynamics. The model was evaluated through multiple simulated missions, measuring coverage efficiency, exploration time, and collision rate. Results demonstrated that the AI-driven swarm outperformed conventional random-walk strategies, achieving efficient surface coverage within a short operational window. Additionally, the learned cooperative behaviors effectively reduced rover-to-rover collisions. This study highlights the potential of reinforcement learning for enhancing autonomous rover operations in future lunar missions. The proposed approach is scalable, making it suitable for larger rover teams and broader exploration zones.