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RISK-AWARE MULTI-ROBOT SYSTEMS WITH FOUNDATIONAL ARTIFICIAL INTELLIGENCE FOR LUNAR SURFACE EXPLORATION

Abstract

In lunar surface exploration, the environment presents numerous challenges, including extreme temperatures, radiation, rough terrain, and communication delays. To address these, we are developing risk-aware multi-robot systems equipped with foundational artificial intelligence (FAI) that offers a promising solution. Such systems use AI-driven risk assessment, multi-robot collaboration, and autonomous decision-making to navigate the lunar surface, conduct exploration tasks, and respond dynamically to unforeseen challenges.

FAI for Risk Assessment and Adaptation is built to equip robots with the ability to assess environmental risks in real-time and adapt behavior to minimize hazards. Risk assessment models built on deep learning algorithms analyze sensor data (e.g., terrain, temperature, radiation) and predict potential hazards. Foundational AI models trained on extensive datasets (simulated and real-world analogous/lunar data) enable robots to recognize patterns and make intelligent decisions autonomously. This allows robots to intelligently identify and respond to potential dangers, such as unstable ground, hazardous temperatures, or radiation spikes, ensuring mission continuity and safety.

Multi-Robot Collaboration and Task Allocation is used to coordinate multiple robots for efficient exploration, resource gathering, and hazard management. Our proprietery swarm intelligence algorithms ensures that robots share information and collaboratively adapt tasks based on real-time conditions. Decentralized control systems are incorporated to make independent yet synchronized decisions, creating redundancy so they can complete tasks even if they lose contact with one another. Such a collaborative approach in exploration missions can cover more ground, handle larger tasks, and recover quickly from setbacks if one or more robots encounter difficulties.

The system also includes Autonomous Navigation and Hazard Detection to navigate safely and efficiently across the unpredictable lunar surface without continuous human oversight. We use Simultaneous Localization and Mapping (SLAM) and visual odometry to help robots map and localize themselves in real-time using LiDAR, stereo cameras, and radar. ML-based terrain classification identifies features like craters, slopes, and rocks, allowing robots to select safe paths and avoid dangerous terrain. Robust navigation systems ensure that each robot can autonomously find the safest and most efficient path while adapting to environmental changes and avoiding obstacles on the lunar surface.

In terms of communication, mesh networks enable robots to communicate and relay data to each other over short distances, maintaining network resilience. Low-latency protocols ensure data is efficiently transmitted between robots, facilitating collaboration and coordination in challenging communication conditions.

We discuss how our solution with dynamic risk assessment, autonomous navigation, and multi-robot collaboration offers transformative capabilities for lunar exploration.