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Interactive Presentations - 22nd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (IP)

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VESPER: VIRTUAL-REALITY EXPLORATION WITH SIMULTANEOUS PROSPECTING EXTRAVEHICULAR ROBOTS

Abstract

Recent Moon missions have highlighted the feasibility and benefits of using smaller-form-factor robots for lunar exploration. As future exploration missions will likely involve more and more extravehicular activities (EVAs) for astronauts, relying on a swarm of versatile robot agents would enable them to uncover unknown terrain faster and determine the optimal regions of interest (ROI) for scientific objectives or resource collection. In-situ resource utilization (ISRU) being a critical component of human presence beyond Earth, maintaining situational awareness and driving the exploration efficiently are essential to achieve mission objectives. Human swarm interfaces (HSI) provide the necessary visualizations and tools to monitor swarm state and respond to faults or changes. While collaborative terrain-mapping software deployed on robots supports sparse connectivity and robust error handling (Lajoie et al., 2024), current HIS suites require additional attention from the operator in the event of environment changes (eg. ROI detection) or hardware failures. We implement VESPER, an HIS framework for robust virtual-reality (VR) exploration of extraterrestrial surfaces with autonomous swarms of heterogeneous robots.

Providing an immersive visualization integrated with autonomous robotic platforms, VESPER enables intuitive navigation, real-time data visualization, and seamless interaction with remote environments to enhance mission efficiency. Building on common VR gestures, users may choose an overarching mission view or switch between robot-subjective perspectives to understand each agent's surroundings through mapped terrain data or direct camera feeds. The heads-up display can show informative overlays to monitor robot status (eg. battery level). Direct pointing interaction or game-like controller input allow for precise control of swarm or individual robot goals. Corrective actions can also be applied on the map to alter exploration behavior based on encountered hazards or robot failures: to reduce operator workload, fault-prevention fences are suggested from risk analysis maps computed from fault-prone locations (Ricard, Vielfaure, Beltrame, 2022).

The continued efforts towards integration of VR experiences for the exploration of lunar environments and analogues represents a significant opportunity to advance astronaut training, mission preparation, and EVA execution. By immersing operators in realistic simulated or physical Moon-like landscapes, VESPER aims to more closely mimic the challenges and complexities of actual lunar missions. Further development directions for our framework include direct integration of information delay (eg. 2-second latency on the Moon) to address the unique challenges of remotely controlled environments. Additionally, interactive ahead-of-time path-planning with delayed execution may further enhance the autonomy, reliability and adaptability of robotic systems operating in extraterrestrial contexts.