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PHYSICALLY ACCURATE AND VISUALLY REALISTIC LUNAR SURFACE SIMULATOR FOR MOON EXPLORATION MISSIONS

Abstract

Upcoming lunar exploration rover missions are short-lived, dynamic and with the ambitious goal to prove the feasibility of mobile science platforms and the robotic technologies needed for In-Situ Resource Utilization. However, detailed pre-mission planning is hampered by the low resolution of orbital data and the harsh lunar environment that will require near real-time decision-making by operators on Earth to respond to anomalies and perform opportunistic science.

Developing the onboard systems, the ground tools, and the training for the operators requires a physically accurate and visually realistic lunar surface simulator. By providing simulated rover camera and sensor data while reacting to the commands sent by mission control, the simulator enables training operators to correctly analyze the telemetry, follow and adapt the mission plan, and overcome unexpected challenges.

This paper presents the main features and capabilities of the lunar surface simulator implemented by JAOPS for the next rover missions to the Moon.

Based on the NVIDIA IsaacSim framework, the simulator leverages ray tracing for real-time photo-realistic rendering. Shadows and surface illumination conditions are accurately modeled based on the physical properties of light propagation.

Camera extrinsics and intrinsics are customized to simulate flight hardware, including stereo cameras and LiDARs. Dedicated sensor models for the rover's motors, Inertial Measurement Unit, temperature sensors, solar panel, and radio communication are implemented to provide operators with the accurate and comprehensive telemetry they would receive during an actual mission.

The lunar surface itself is modeled from 3D Digital Elevation Models of reference landing sites provided by NASA's Lunar Reconnaissance Orbiter. Finer scale features such as smaller craters, hills and boulders are added based on size versus frequency distribution models. A qualitative comparison between simulated images of the lunar surface and images from the Apollo and Chang'e missions is provided.

The rover's 3D model includes all outside surfaces and a detailed physics simulation of mechanisms such as the in-wheel motors, suspension, and antenna deployment as well as mass and inertia properties. Special care is taken to accurately model lunar gravity and wheel/regolith interaction.

The results of a demonstration of the lunar surface simulator integrated within JAOPS command and control software are provided as a reference implementation. The rover travels several 100m across the simulated lunar surface, controlled by the telecommands sent by human operators. The rover sends back simulated telemetry and camera images which are displayed on the operators' console displays.