Paper ID: 85199
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IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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ENHANCED PATH TRACKING AND MANEUVERING STRATEGIES FOR LUNAR ROVERS

Abstract

In an era of intense excitement and enthusiasm for space exploration and the return of humans to the Moon, the application of robotics and autonomous systems as space rovers represents a fundamental technological challenge. Autonomous navigation lies at the heart of such exploration endeavors, enabling planetary rovers to collect scientific data, perform maintenance autonomously, and navigate in extremely hostile and dynamic environments with limited communication resources and minimal human support. For these reasons, the research, development and implementation of robust control and navigation stacks are of fundamental importance for the reliability and safety of planetary rover missions, both for secure and remote teleoperations, as well as for autonomous traverses.

This paper delves into the critical role of autonomous navigation systems in advancing the capabilities of space rovers. We focus on the navigation stack, specifically emphasizing the control system for maneuver selection planning and secure trajectory following. With this intent, we aim to describe and analyze the scheduling procedure for control and maneuvering strategies for a prototype lunar rover in a natural and unstructured terrain. The selected rover model is equipped with four steering wheels, each with independent active suspension, an architectural trend in recent space rovers adopted by RP15, VIPER (NASA), and EMRS (ESA, TAS-I and GMV designs). Permissible movements for this configuration include pure translation or 'crabbing', pure rotation, and Ackermann steering. Given this plurality of maneuvers, the control system should be able to integrate and leverage this additional degree of freedom, indicating the best strategy according to the particular scenario, such as encountering a dead-end situation, the need for pointing panels, or stability.

After identifying the main challenges and criticalities, we provide a potential solution for the control system to autonomously drive the rover and follow a predetermined trajectory, taking advantage of the model's motion flexibility. This involves selecting the nature and sequence of maneuvers based on safety and energy consumption criteria. The development environment utilized is provided by ROS 2, using Nav 2 to build upon a robust navigation stack, and Gazebo, a powerful and robust simulation toolkit that enabled us to simulate our rover in Moon-like environments. We provide results in terms of tracking precision of the path, considering the set of maneuvers and kinematic limits inherent in the specific locomotion solution chosen.