Paper ID: 84000
oral
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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TOWARDS SAFER PLANETARY EXPLORATION: A HYBRID ARCHITECTURE FOR TERRAIN TRAVERSABILITY ANALYSIS IN MARS ROVERS

Abstract

The field of autonomous navigation for unmanned ground vehicles (UGVs) is in continuous growth and increasing levels of autonomy have been reached in the last few years. The task becomes, however, more challenging when the focus is the exploration of planet surfaces such as Mars. In those situations, UGVs are forced to navigate through unstable and rugged terrains which, inevitably, open the vehicle to more hazards, accidents, and, in extreme cases, complete failure of the mission. This paper tackles the problem of terrain traversability analysis in the context of planetary exploration rovers, delving particularly into Mars exploration. The aim of the research is the development of a hybrid architecture, which enables the assessment of terrain traversability based on the results of both an appearance-based approach and a geometry-based approach. The coexistence of the two methodologies has the objective of balancing each other's flaws, reaching a more robust and complete understanding of the operating environment. The appearance-based method employs semantic segmentation, operated by a deep neural network, to understand the different classes of terrain present in the scene. Predictions are refined by an additional module that performs pixel-level terrain roughness regression from the same RGB image. The rationale behind this choice resides in the will to be able to assign different costs, even to areas belonging to the same terrain class, while including an analysis of the physical properties of the soil. This first cost map is then combined with a second one yielded by the geometry-based approach. This module evaluates the geometrical characteristics of the surrounding environment, highlighting categories of hazards that are not easily detectable by semantic segmentation. The proposed architecture has been trained using synthetic datasets and developed as a ROS2 application to be easily integrated into a higher-level framework for autonomous navigation in harsh environments. Simulations have been performed in Gazebo, showing the ability of the method to assess online traversability analysis. The proposed approach has also been tested with real-world samples from available datasets, confirming its ability to adapt to real-world applications, while employing only artificial data in the training phase.