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ROBUST, LIGHT-WEIGHT, AND LOW-POWER NAVIGATION ARCHITECTURE OF A SEMI-STOCHASTIC WIND-DRIVEN MOBILE ROVER ON MARS

Abstract

Recently, rising interest in semi-controlled, wind-driven Tumbleweed Rovers for Martian surface exploration led to increased relevance for finding a suitable navigation method on Mars. In this paper, we discuss the position determination of a semi-controlled, fast-moving agent in a GNSS-denied, uniform, and unknown environment.

The lack of constantly available sources for radio ranging leads to a lack of absolute positioning (anchoring), while the uniform appearance of the environment hampers the performance of prevalent vision-based navigation which is typically optimized for feature-rich environments. SWaP constraints of the application make the use of precise inertial sensors as a sole source for location unsuitable. This problem can not only be found in planetary exploration rovers, but applies to many fast-moving sensor stations deployed on air, land, sea, and space, and is thus relevant to the wider positioning community.

In this paper, we close the gap between state-of-the-art multi-sensor positioning systems in applications like autonomous cars and the need for position determination for semi-controlled, fast-moving agents in uniform and unknown environments. Knowing the position of the Tumbleweed Rover is crucial context information for any other sensor measurement, and is required for the operations of the rover. The objective of this paper is to identify a system to position the rover on Mars with an accuracy of 100m or better. Next to that, we generate labeled visual training data for the Martian environment to test the performance of the proposed multi-sensor system. A review of prevalent methods is conducted, followed by assessing qualitatively the suitability to position determination of a semi-controlled, fast-moving planetary exploration rover. These positioning methods are simulated and their performance is tested - standalone and in combination - in a simulation environment. A visual game engine is used to simulate the visual environment on Mars.

Results show the qualitative assessment of star trackers, radio navigation, visual navigation, inertial sensors, and magnetometers. Labeled visual test data is created using the simulated Martian environment which is finally used for a quantitative assessment of the different positioning methods and to establish a preliminary architecture for position determination.

Overall, we present the superior performance of a custom positioning architecture based on sensor fusion over existing solutions for position determination for semi-controlled, fast-moving agents in challenging environments, which are shown using the example of a wind-driven Tumbleweed Rover.