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SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Part 1 (3A)

Author: Mr. Robert Hewitt
Faculty of Engineering, Queen's University, Canada, r.hewitt@queensu.ca

Prof. Alex Ellery
Carleton University, Canada, aellery@mae.carleton.ca
Dr. Anton de Ruiter
Canada, aderuiter@ryerson.ca

NAVIGATION AND MAPPING WITHIN THE CONSTRAINTS OF A MARS MICRO-ROVER

Abstract

Planetary rover missions have thus far performed in relatively benign environments to prevent loss of expensive hardware in risky, but potentially more scientifically valuable environments. Mission risk can be reduced by using micro-rover scouts that map the terrain prior to the main mission. However, micro-rovers will have more limited power and computation ability than their larger counterparts. Kapvik, a Canadian micro-rover, shares these power and computation constraints. This paper explores methods of implementing simultaneous localization and mapping (SLAM) using a laser range finder and stereo cameras on Kapvik along with inertial sensors including gyroscopes, accelerometers, a sun sensor and wheel encoders. To perform SLAM in outdoor and unstructured environments 6 degree-of-freedom SLAM is usually required, where the complete pose of the rover is estimated along with the 3D position of its environment. This is a computationally expensive problem to run in an online fashion. The FastSLAM algorithm has been selected for Kapvik's navigation due to its efficiency, scalability, and robustness. The performance of a novel modification of the FastSLAM algorithm using the nonlinear Cubature Kalman Filter is compared with other implementations of the FastSLAM algorithm. The modification also makes use of the inertial sensors aboard Kapvik to improve its localization between scans of its environment with either the laser or camera. By increasing the pose estimation accuracy between scans the number of times laser or camera data must be processed is reduced. For initial testing of the SLAM algorithms a simulation environment is developed. This includes a 3D motion model for the Kapvik micro-rover which incorporates an articulated rocker-bogie chassis driving over uneven terrain including wheel slip as an external input. Mapping sensors such as a laser range finder and the inertial sensors that sense the rover's motion are also simulated in addition to terrain being randomly generated that represents a planetary surface for the rover to traverse. Finally, the implementation of the algorithm on actual Kapvik hardware is outlined and the process to validate the results is discussed. The standard operation of the rover's navigation system including the autonomous decision process to take a scan as it drives along a specified path is also presented. Testing using the Kapvik micro-rover demonstrates the importance of Earth analogue missions as precursors to missions to Mars.