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PLANETARY MICRO-ROVER OPERATIONS ON MARS USING A BAYESIAN FRAMEWORK FOR INFERENCE AND CONTROL

Abstract

With the recent progress towards the application of commercially-available hardware to small-scale space missions, it is now becoming feasible for groups of small, efficient robots based on low-power embedded hardware to perform simple tasks on other planets in the place of large-scale, heavy and expensive robots, reducing the potential losses if problems occur with individual units. In this paper, we describe the design and programming of the Beaver micro-rover, a 6kg prototype mobile robot that has been developed for the Northern Light mission. Northern Light is a Canadian initiative to send a small lander and rover to Mars to study the Martian surface and subsurface and validate the ability of small-scale missions and robots to operate on other planets while returning useable scientific results. The main challenges in the operation of small planetary robots are having to handle an uncertain and mostly unknown environment with significant limitations on the stored energy, processing power, and sensors available. To free planetary micro-rovers from the need for constant management by human operators, a method for probabilistic methods for autonomous decision making provide a relatively tractable solution. The basis for our approach to autonomy is inference using a Bayesian network as an abstraction of expert knowledge regarding the rover itself and assumptions about its environment, such as obstacles and hazards. Most Bayesian networks used in research are very large and complex. For use on resource-constrained micro-rovers, a framework for efficient construction and use of a Bayesian network using only the C language and fixed-point mathematics on embedded hardware has been developed. We make use of this framework to allow a micro-rover to make intelligent decisions with minimal sensor data and respond appropriately to uncertain situations given a set of probabilistic relationships between known variables. To validate the performance of this Bayesian network on the Beaver micro-rover hardware, we study the performance of this system while the Beaver is traversing difficult terrain that requires intelligent responses to problems, including obstacles and traction concerns. The results of this study show that the Beaver and other small and simple robotic platforms can use probabilistic reasoning and our Bayesian framework to effectively perform simple tasks in uncertain planetary environments.