SPACE EXPLORATION SYMPOSIUM (A3)
Small Bodies Missions and Technologies (5)

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GUIDANCE AND CONTROL OF HOPPERS FOR SMALL BODY SURFACE EXPLORATION

Abstract

The importance of small-body exploration missions to the understanding of solar system origins and evolution has been established from several decades off research. A few missions have now touched the surface of asteroids, for instance, NEAR, Deep Impact, and Hayabusa, and more missions are proposed in the near future. As these missions increase in complexity, rovers, hoppers and other mobile craft will begin to deploy on the asteroid for greater science measurement capability and for the collection of varied sample material (Verdant, 1998; Yoshikawa, 2008).

To collect material from desired locations, mission objectives will require vehicles to move to a certain area or in an optimal (in the sense of time or energy) manner but the vehicles will be subject to local dynamics and relative estimated state. Thus the problem of vehicle movement can be broken into several parts: Navigation, Guidance and Control or, Where am I?, Where do I want to be? and How do I get there?. In this paper, we focus on the guidance and control problem for hoppers exploring small-bodies while assuming global position is known.

Previous work has examined basic surface dynamics and even the control of hoppers under the influence of small body gravity and motion (Guibout, 2003; Bellerose, 2008). Here we extend this work to consider energy / velocity constraints upon the hopper to avoid escape speeds. Based on these constraints and local dynamics, we provide a feedback law to correctly control the vehicles from a desired input.

Given this control law, we also examine how local stability regions can be exploited to improve upon hopper movement without the need for massive onboard actuators. We present accessibility plots to indicate regions on a ellipsoidal asteroid model that can be reached without the need for any onboard steering thus reducing hopper complexity.

With the derived control laws, we then examine how to travel from the current location of the hopper to a desired final position. A comparison is given between minimum time and minimum energy paths, and simulations of each path type are presented for an ellipsoidal asteroid model. Considerations are also given to actual implementation where non-idealized gravity models and surfaces apply. We show that while asteroid dynamics can be challenging, it is possible to account for the environment and still collect the required scientific data.