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AUTONOMOUS NAVIGATION OF MICRO AIR VEHICLES IN GPS-DENIED ENVIRONMENTS FOR EXTREME TERRAIN PLANETARY EXPLORATION

Abstract

The ability to accurately reach a desired location, without human intervention, in extreme terrain makes aerial vehicles an excellent choice in applications such as planetary exploration, civil engineering inspection, search and rescue, or military surveillance. Consequently, Micro Air Vehicles (MAVs), i.e., drones and quadcopters, are gathering increased interest among researchers due to their speed, agility, low-cost, and ability to traverse unknown or challenging environments. Currently, almost all robotic systems depend on GPS to operate effectively. However, environments on extraterrestrial surfaces such as the Moon, Mars, or Titan remain without access to external positioning systems such as GPS. Autonomous MAVs today are thus limited in their ability to fly through these areas.

Present ground-based rovers that are operational on Mars are faced with the unique problem of limited mobility, upon encountering extreme terrains such as caves, lava tubes, cliffs etc. On the contrary, MAVs are not capable of continuous flight over long periods of time due to the energy consumption necessary to keep them airborne.

This research addresses the above-mentioned limitations by introducing a robotic platform, H-TAV, a Hybrid Terrestrial and Aerial Vehicle. This robot is designed for both aerial and terrestrial locomotion. The energy consumption system of H-TAV is also more efficient due to its ability to switch between air and ground mediums for travel.

In spite of considerable progress in the area of MAVs, a significant issue in fast autonomous flight is planning real-time safe and high-speed trajectories in unknown and unstructured environments. In order to overcome this problem, we intend to enable fast flight with the idea of active perception in mind. Essentially, we address the problem of planning high-speed motions in confidence-rich maps, while considering the future map uncertainty. A confidence-rich map is a planning-oriented representation of the environment and an extension to the traditional occupancy grid map.

The key contributions of our approach are:

1) A detailed analysis of a probabilistic safety measure for a trajectory (including the proposed improvements) 2) Incorporating the confidence-rich map representation into a planning framework that includes future map predictions. 3) A novel cost function that utilizes the estimate of the covariance of the map and enables faster and safer plans

We evaluate the proposed planning approach in a series of simulation experiments and in a 3D environment that will later be used to perform tests on robotic systems.