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Author: Mr. Arjun Chhabra
University of Toronto, Canada, arjunengsci.chhabra@mail.utoronto.ca

Mr. Gabriele D'Eleuterio
University of Toronto Institute for Aerospace Studies, Canada, gabriele.deleuterio@utoronto.ca

A ROBUST GRAPH SLAM APPROACH FOR NEAR EARTH ASTEROID NAVIGATION

Abstract

Over the past few decades, there has been increased interest in the exploration and sampling of near earth asteroids (NEAs) for purposes ranging from scientific research to in-situ resouce utilization. Since such missions must navigate based solely on information from their sensors, with limited prior knowledge about terrain and surface conditions, they must localize the spacecraft in order to determine its position relative to the NEA as well as generate a map for navigation. These tasks are well suited to be formulated as a Simultaneous Localization and Mapping (SLAM) problem, which is a well studied paradigm in the field of robotics for the localization and mapping of a robot in an unfamiliar environment.

Multiple approaches to formulate the SLAM problem for NEA exploration have been studied, and successful techniques have been incorporated into missions by the Japanese Aerospace Exploration Agency (JAXA) to enable orbit-based mapping and landing sites determination on their Hayabusa I and II missions. However, these approaches only perform robustly under specific conditions and must be manually adapted for individual missions. A broader, more robust approach to SLAM for NEA exploration is required for autonomous navigation of spacecraft across missions.

The state-of-the-art method in this field, Active Asteroid-SLAM by Nakath et al., presents a graph-based method to localize and map NEAs, as well as identify candidate landing sites and plan trajectories for landing. It uses LiDAR sensors to generate point cloud models of an asteroid's terrain, and uses a scan-matching algorithm to match iterative point clouds, infer alignment, and formulate a pose constraint for the spacecraft. Incorrect scan-matching can lead to inaccurate pose constraints which in turn increase errors in the spacecraft's belief about its pose.

We propose an extension to this work that incorporates salient terrain features and landmarks extracted from camera images aligned with the spacecraft's LiDAR sensors. This approach provides a mechanism to improve the accuracy of scan-matches by corroborating them against the features detected by the cameras, and provides additional well-formed pose constraints that lead to a tighter bound on the estimate of the spacecraft's motion. We employ LiDAR-aided camera feature tracking, a technique previously used in the lunar context, to detect terrain features which the spacecraft can use for relative navigation. By exploring multiple feature trackers and their impact on the robustness of the scan-matching process, we aim to offer increased robustness and autonomy for navigation systems aboard future missions.