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SURF Proposal: Visual Radar

Introduction/Background

Unmanned Aerial Systems (UAS) have become increasingly pervasive in both scientific and industrial settings, adopting a wide range of roles, from agriculture to search and rescue. Their application in the realm of space exploration is especially interesting, as these systems offer a versatile tool for remote observation and data acquisition. As part of the mars 2020 mission, the NASA Jet Propulsion Laboratory is designing a robotic helicopter to test UAS technology. Although its immediate objective is to scout targets for study on Mars, this “Mars Rotorcraft” fulfills a much more significant role as a proof of concept, establishing the foundation on which more capable and sophisticated systems can be developed for the aerial exploration of Mars and other planetary targets with atmosphere.

Automated collision avoidance for aircraft and Unmanned Aerial Systems (UAS) is a key capability for autonomous operations during low-altitude flights. While pre-calculated terrain maps can guide an UAS to prevent terrain collisions, onboard 3D perception is required for exploratory endeavors, in which the environment is unmapped or dynamic, and for environments in which obstacles exist that are smaller than the resolution of a pre-existing terrain map. This can be the case for thin obstacles (e.g. trees, telephone poles, etc. on Earth) or because the resolution of any pre-existing map is too coarse.

Traditionally, unmanned aerial vehicles use range sensors for navigation and obstacle avoidance. However, these active sensors are resource expensive, especially for smaller vehicles and aerial systems, as they drain large amounts of battery power and weigh down the aircraft. However, with the development of efficient and robust computer vision algorithms, it is possible to replace these costly active range sensors with a single, downward facing camera. This alternative is lightweight and allows accurate localization and stabilization. A single moving camera is effectively a stereo system that has the ability to dynamically adjust its baseline according to the demands of observational parameters. A system of moving cameras allows for 3D terrain reconstruction from aerial images, generating a real-time map of the nearby environment for navigation and visualization purposes.

Objectives

The goal of this project is to develop and implement a method to produce highly accurate online terrain-elevation maps to enable collision free flight in Earth and Mars like environments. This will involve developing efficient computer vision algorithms to performing real time dense reconstruction. Different sensor configurations will be explored for 3D reconstruction, including a calibrated stereo camera system, and a monocular moving camera.

Approach

The construction of terrain elevation maps will be based on 3D point cloud measurements acquired through one or more cameras onboard a UAS or aircraft. Each point cloud incorporates the pose of the vehicle at acquisition time and constraints on measurement accuracies that have to be incorporated into a common map. Evaluation of the approach will involve data acquisition campaigns using JPL Micro Air Vehicles (MAVs) in various flight scenarios.

Work Plan:

1. Literature review and familiarization with the theory of 3D reconstruction with one or two cameras and terrain mapping (week 1)
2. Implement stereo processing algorithm to produce disparity maps from fixed stereo camera setup (OpenCV or JPL software) (week 2)
3. Develop algorithmic approach (based on open source algorithms from literature or existing JPL algorithm) to fuse stereo disparity maps into a common elevation map (week 3-5)
4. Implement Structure from Motion approach (based on open source algorithms from literature or existing JPL algorithm) to produce 3D point clouds from a moving monocular camera or two non-rigidly coupled stereo cameras, and produce elevation maps from the output (week 6-8)
5. Evaluate elevation mapping approaches with data from MAV (week 9-10)

References:

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