The Feasibility of Structure from Motion over Planetary Bodies using Small Satellites

Caleb Adams

The Mapping and Ocean Color Imager (MOCI) is a 3U cube satellite mission that seeks to preform Structure from Motion (SfM) at a landscape scale while in Low Earth Orbit (LEO). MOCI will have the ability to passively map terrains by slewing over targeted regions and taking a rapid succession of images. MOCI is being developed by the University of Georgia's (UGA) Small Satellite Research Laboratory (SSRL) through the Air Force Research Laboratory's ninth iteration of the University NanoSatellite Program (UNP-9). The project is led by undergraduates from a wide range of backgrounds and supervised by a multidisciplinary team of Principal Investigators at UGA. The students are developing the software capable of on orbit calculations to derive 3-D point clouds and compression techniques allowing the transmission of 3-D data sets.

The majority of works using point clouds employ 3D representations derived from terrestrial and aerial LiDAR (Light Detection and Ranging) and have benefitted from the increased availability of LiDAR data in recent years. But progresses in computer vision have made available a series of algorithms that allow for the generation of point clouds and surfaces that do not need a point-based collection characteristic of LiDAR systems. Among those algorithms, Structure from Motion (SfM) has received increased attention due to its ability of extracting 3D features and reconstruction of objects/structures based on multiple photographs or video frames.

MOCI will uses these techniques on a space based platform that acquires sets of 2D images, which will then perform a series of machine vision algorithms to produce a topographical mesh. A Scale-Invariant Feature Transform (SIFT) is first performed on the set to find various gradients and determine image rotations. A sparse point cloud, consisting of points identified as similar between a series of images, can be computed from a combination of SIFT and the parallax of satellite with its target area. This sparse point cloud can then be used to compute a dense point cloud. This dense point cloud, typically consisting of 100,000 or more vertices, is used to compute a surface mesh with Poisson Surface Reconstruction.

Initial tests have been performed to determine the feasibility of this type of passive mapping in LEO. Tests consisted of generating an earth sized model in blender and placing various features on the surface of the modeled earth. Using python scripts, the imaging process of the MOCI satellite can be simulated with the resulting images being similar to what would be expected from LEO. Structure from Motion is then performed on the image set and a sparse point cloud, dense point cloud, and mesh are computed. Initial test have shown SfM to be feasible at a landscape scale. Planetary SfM was also performed with data from the International Space Station. It was demonstrated that cloud lines, with height differentials of 1000 - 3000 feet, could be distinguished. Large scale surface maps of pluto were also generated using the techniques described above with available imaging data from the New Horizons pluto fly by.