Structure from Motion from a Constrained Orbiting Platform

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Overview

Structure from Motion (SfM) is a photogrammetry technique which reconstructs 3D objects from a series of images. The International Space Station (ISS) is an optimal platform to test these processing techniques due to the imagery acquired by ISS imagers. Using these existing features of the ISS, we have successfully reconstructed cloudlines as shown in figures 4, 5, and 6 with pre existing SfM implementations. Using these models, we can measure the height of clouds as well as the possible altitude of the cloud. Specifically this will be focused on cloud tops and cloud structure to supplement short term weather models for increased understanding of the complex formation of super cell storms and other mesoscale phenomena.

International Space Station Data Examples

Figure 1

We gathered a total of nine image sets[1] from the International Space Station. The two sets that we chose to present were selected based on the success we had reconstructing features. We had a number of criteria when choosing our image sets.

Image set Criteria:

- Clouds must be present in all images
- The clouds have visible texture
- Any land shown should have features that can be geo-referenced

The first image set used were acquired from the International Space Station on March 25, 2016 over the ocean. There were a total of 30 images used taken between 11:45:02 to 11:57:17 GMT.

The second image set (Fig. 1) used in our experiment were made from the International Space Station on November 9th, 2015 capturing three images of a portion of the coast of Argentina. The latitude was approximately -35.30, and the longitude was -51.60.

Point Cloud and Reconstruction Workflow

A typical implementation of the Structure from Motion algorithm can be seen in figure 2. Starting with an image set, a Scale Invariant Feature Transform[2] (SIFT) is performed. A package, known as Bundler, produces a sparse point cloud. Clustered Multi-view Stereo (CMVS) and Patch-based Multi-view Stereo (PMVS) processes are used to produce a dense point cloud. Of these typical processing steps SIFT was identified as a primary target for optimizing the workflow as it is the most time intensive step in the SfM process.

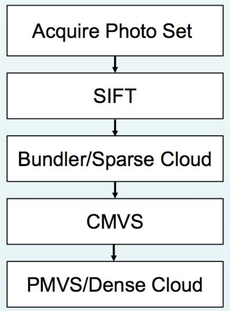

Figure 2

Visual Structure from Motion (VSfM) was used to generate the point clouds in this work, as this package contains siftGPU, Bundler, CMVS, PMVS, and PMVS2. After the dense cloud is generated using VSFM, the data is loaded into MeshLab, a modeling and mesh generation program. Although a variety of surface reconstruction methods exist, including Poisson Surface[3] reconstruction and Screened Poisson Surface reconstruction[4] which were used due to their integration and ease of use with MeshLab.

Cloudline Results

Figure 3 shows the dense point cloud generated from the 3 images shown in Figure 1. These images, put through the standard VSfM, generated a sparse point cloud with 4,928 vertices and a dense point cloud with 30,246 vertices. After a Screened Poisson Surface Reconstruction with a reconstruction depth of 8 was performed, a mesh with 39,976 vertices and 79,753 faces was generated. A higher vertex count is typically due to the surface generation building vertices pairs past the area of the dense cloud. The sparse cloud, dense cloud and mesh were: 664 KB, 31.2 MB, and 916 KB respectively.

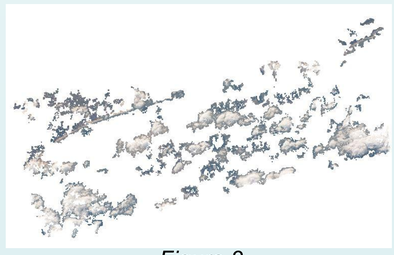

Figure 3

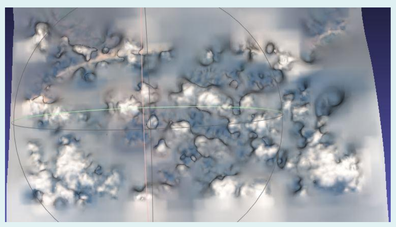

Figure 4

Cloud Height

We found that the cloud heights from figures 1,3,4 were 5.926-7.012 km in altitude. We calculated these heights by georeferencing two key points to existing maps to find a scaling value for the point cloud. From there we fit a plane to surface points and projected cloud key points to that plane. Finally we simply subtracted vectors and found their norm.

Other Cloudline Results

Some tests were performed with existing space based data to determine what the current capabilities of SfM may be. Figure 5, for example, is a dense point cloud of the earth's upper atmosphere generated from a crew operated high definition camera on the ISS. This data sample consisted of 30 images and a total data size of 50.1MB. Figure 6 is the resulting mesh from this data set and dense cloud.

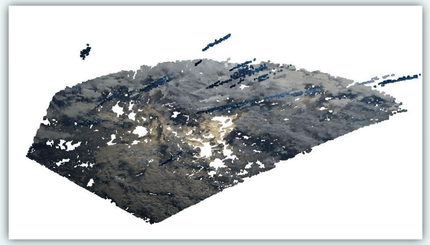

Figure 5

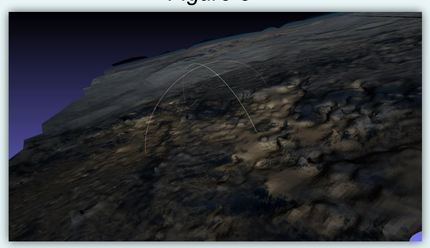

Figure 6

Future Studies

The University of Georgia Small Satellite Research Laboratory (UGA SSRL) and Center for Geospatial Research (CGR) have partnered with the Air Force Research Laboratory (AFRL) to build the Mapping and Ocean Color (MOCI) satellite, which will perform SfM from LEO after an ISS deployment. This mission seeks to improve space based SfM by streamlining the algorithms used in this study. Continued studies with ISS data are expected to help confirm the accuracy of the MOCI satellite.

Citations

1. issphotolibrary.com/
2. Lowe, David G. "Distinctive image features from scale-invariant keypoints." International journal of computer vision 60.2 (2004): 91-110.
3. Kazhdan, Michael , Matthew Bolitho, and Hugues Hoppe. "Poisson Surface Reconstruction." Eurographics Symposium on Geometry Processing (2006)
4. Kazhdan, Michael, and Hugues Hoppe. "Screened poisson surface reconstruction." ACM Transactions on Graphics (TOG) 32.3 (2013): 29.