Validation of Structure from Motion Algorithms Through Testing Apparatuses

Center for Undergraduate Research Opportunities
UNIVERSITY OF GEORGIA

Clay Busbey#1 , David L. Cotten^1,2
#cwb58331@uga.edu, ^dcotte1@uga.edu

[1]Small Satellite Research Laboratory, University of Georgia,
[2]Center for Geospatial Research, University of Georgia

Overview

The Small Satellite Research Laboratory (SSRL) Multiview Onboard Computational Imager (MOCI) satellite has been developed to test the feasibility of Structure from Motion (SfM) from orbit. The SSRL has run several simulations to have a baseline of what to expect from orbit. Using in house and commercially available software the SSRL is capable of simulating the image gathering, Structure from Motion, and post processing data flows. SfM will be performed on board the satellite, as a proof-of-concept, with the processed data being transmitted back to earth. These algorithms developed for processing within the space environment can be used in future missions to create 3D models using higher resolution sensors. Thus, when combined with efficient data compression algorithms, transmission and creation of 3D models by the small satellite will allow for faster, more efficient creation of 3D models. This can be used to help with humanitarian, emergency, or defense support. MOCI is also capable of passively determining cloud heights for weather prediction models. Such a capability is essential for the weather modeling that the United States Air Force uses for a tactical situational awareness. As part of the proof-of-concept demonstration, MOCI will be able to produce real-time Point Clouds, Digital Surface Models (DSMs) and Digital Elevation Models (DEMs) in a matter of minutes. A demonstration of MOCI's capabilities will lay the groundwork for a future constellation of MOCI satellites, potentially using synthetic aperture and/or plenoptic cameras to extract 3D light fields/light vectors, that can produce Point Clouds, DSMs, and DEMs in a matter of minutes on demand anywhere in the world.

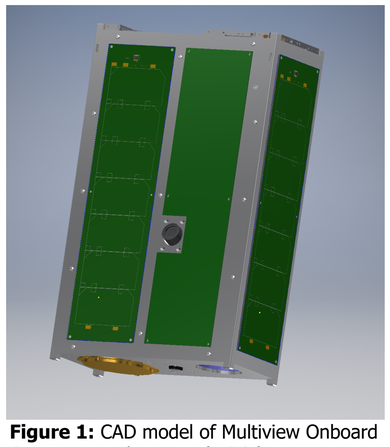
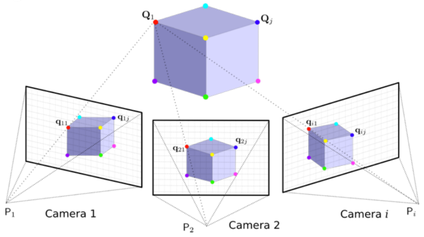


Figure 1: CAD model of Multiview Onboard Computational Imager (MOCI)

What is Structure from Motion

Structure from Motion (SfM) is a software range imaging technique for estimating three-dimensional structures from two-dimensional image sequences. SfM is considered computer vision and can recover 3D structure from the projected 2D motion fields of a moving objects. This is accomplished by taking multiple images from different perspectives relative to a subject, see figure 2. These images are passed through algorithms to identify common points and assign them locations in 3D space relative to each other. This set of points if know as a point cloud, see figure 3.

Figure 2: Multiview Reconstruction



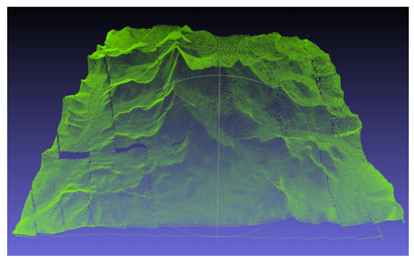


Figure 3: A point cloud of Mount Everest generated from a simulation of a 2-view

Structure from Motion Rig

"The purpose of the SFM rig that has been designed in UGA's Small Satellite Research Lab is to test the Multiview Onboard Computational Imager's (MOCI's) computer vision software library, dubbed SSRLCV. With the rig's ability to take images of a single object at specified viewpoint angle intervals, we can qualitatively and quantitatively test the functionality of SSRLCV's feature detection/description, matching, point cloud generation and surface reconstruction algorithms. As this library is meant to facilitate MOCI's primary mission objective of performing Structure from Motion (SfM) computation onboard, the efficiency of the implemented algorithms based on viewpoint angle differences and resolution need to be understood. This rig provides a method of doing so." - Jackson Parker

Designing a Test Apparatus

In order to test the SfM algorithms and determine the effectiveness of SSRL's computer vision software library, I was tasked to create a testing apparatus. This apparatus had specific requirements that needed to be taken into consideration to create an effective tool to create realistic testing data for SfM. These requirements are below:

1) Must be a stable platform with repeatable positional accuracy
2) Must be able to rotate and object to multiple views with <1 degree increments
3) Must be user friendly and time efficient
4) Must be user adjustable in order to setup multiple camera angles and distances

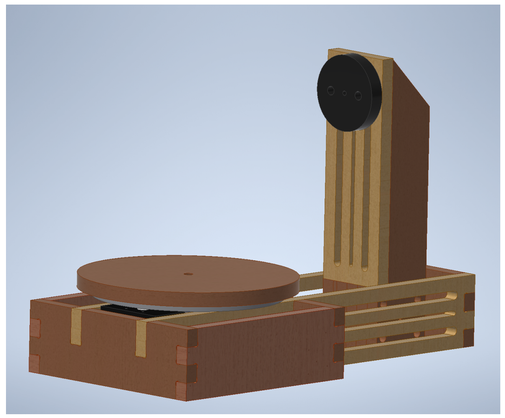


Figure 4: CAD design of SfM Rig apparatus

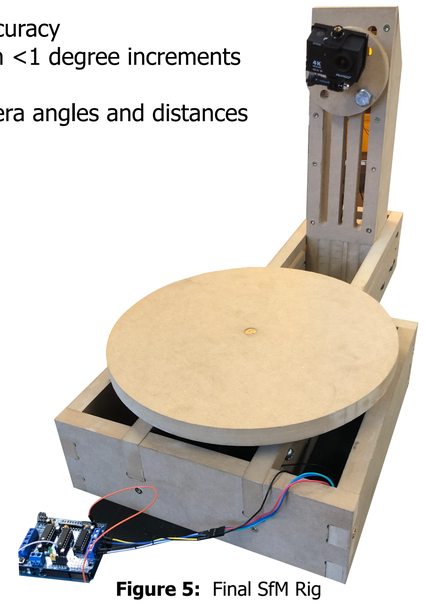


Figure 5: Final SfM Rig

Figure 4 shows the final design concept in that has a digitally controlled stepper motor that drives a rotating platform to place models on. Under this there is a horizontal rail that houses another vertical rail for the camera to be mounted on. This design was then recreated out of 0.75" MDF sheets by using a CNC router to cut out each individual part. This was then assembled with glue, screws, metal rods, bearing and a motor to create the final functional version in figure 5. This final version is equipped with a Raspberry Pi, stepper motor controller, and camera to control and automate the SfM Rig.

Conclusions and Future Improvements

The SfM Rig design and manufacturing is complete and we have begun to put it into our software testing workflow for MOCI's mission. Figure 6 shows some of the test data that the rig has produced. On the left is the original model being photographed and on the right is the SfM generated data (3D point cloud) with an overlay of the corresponding features. Over all this testing apparatus has been a success allow SSRL's software team to produce real world SfM data to test their algorithms.

In the future, we would like to improve the automation and usability of the system through a better user interface on the Raspberry Pi. This would include completely automated data collection and a GUI with configurable user parameters to vary the data collection process.

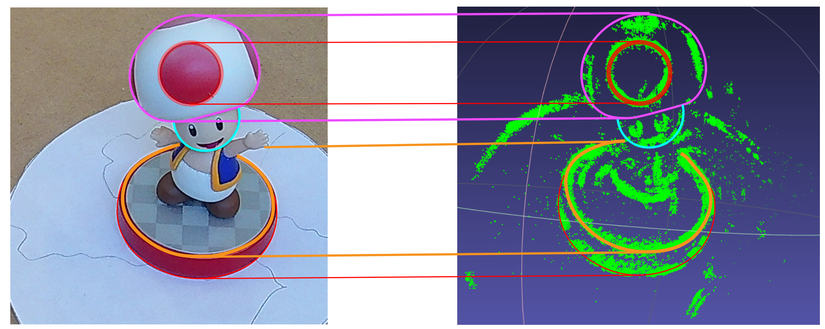


Figure 6: Test model and 3D point cloud created with SfM Rig

For more information about our research/missions, visit
www.smallsat.uga.edu

Small Satellite Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA

CGR Center for Geospatial Research, The University of Georgia
UNP UNIVERSITY NANOSATELLITE PROGRAM