Preliminary Experiment of Point Cloud Acquisition and Integration for Groundbreaking Surveying of Lunar Base Construction

Abstract

In recent years, approaches for construction works of lunar bases are discussed. In construction work, groundbreaking surveying is necessary. However, the lunar environment is hard for conventional surveying methods. Therefore, we focus on an unmanned surveying approach using point clouds. First, we conduct feasibility studies on point cloud acquisition and self-localization toward groundbreaking surveying at the lunar surface. Next, we conducted two experiments. The first experiment was a comparison of point cloud acquisition and location estimation methodologies, such as structure from motion and multi-view stereo (SfM/MVS), light detection and ranging (LiDAR)-based simultaneous localization and mapping (LiDAR-SLAM), and visual odometry (VO), without GNSS positioning in environments consisting of few geometrical features. The second experiment was a simultaneous data acquisition of surface point clouds and underground at simulated lunar surfaces. First, we confirmed SfM/MVS can achieve more stable point cloud acquisition. Second, we confirmed that the SLAM process failed in environments consisting of few geometrical features. Finally, we confirmed that scale reduction and non-closed events occurred through VO. In this study, we confirmed that Visual SLAM has an advantage of stability and accuracy in point cloud acquisition and trajectory estimation at the simulated lunar surfaces.

Introduction

In recent years, approaches for construction work of lunar bases are considered. However, there are numerous challenges in construction work in the lunar environment. These include positioning outside the global navigation satellite system (non-GNSS) environment, few geometrical features of ground surfaces covered with sand (lunar regolith), extreme temperature differences, strong cosmic rays, no air, and gravity at one-sixth the magnitude of gravity on Earth. Thus, in 3-D measurement and groundbreaking surveying on the lunar surface, there are many technical issues, such as positioning problems, point cloud matching problems, and image matching problems due to the few feature points. Previous research in lunar-like environments includes research related to NASA's Mars Exploration Rover (MER) mission, such as the verification of a spacecraft's self-position estimation on Mars (Cheng et al., 2005)[1]. Cheng et al. used several methods, including VO, to acquire trajectories to move to a set target. Their experiments showed that VO presented high accuracy under constraints. In this study, we propose an unmanned surveying method in the lunar environment with two experiments.

Methods

We apply SfM/MVS and LiDAR-SLAM to acquire the point cloud, and VO to acquire the observation position of the point cloud. For multidirectional images, the conversion process shown in Fig. 1 is performed. We set up several spherical markers in the experimental environment and conducted experiments.

Table 1. Sensor used in the experiment

Sensor name	Output data	Usage
LiDAR scanner	Point cloud	LiDAR-SLAM
IMU stereo camera	Trajectory (Image)	Visual Odometry
Multidirectional camera	Image	SfM/MVS
High resolution camera	Image	SfM/MVS

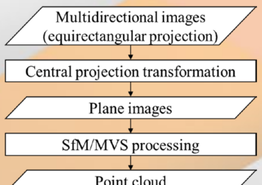

Figure 1. SfM/MVS processing flow using multidirectional images

Results

VO: Although distorted errors existed, the result was relatively closed to the actual path.
LiDAR-SLAM: SLAM processing was failed because the point clouds of vertical features were not included in the input
SfM/MVS: Shorter intervals improved the point clouds generation
SfM/MVS: Using a high-resolution still camera increased the point cloud density

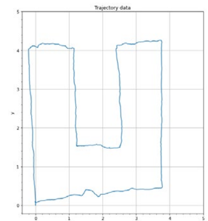

Figure 2. VO result (close to real path)

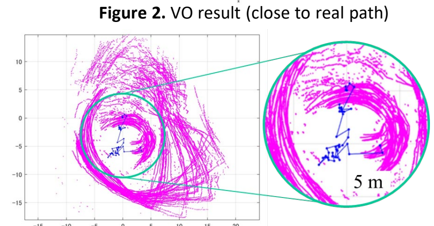

Figure 3. LiDAR-SLAM result (input: point cloud without geometric features)

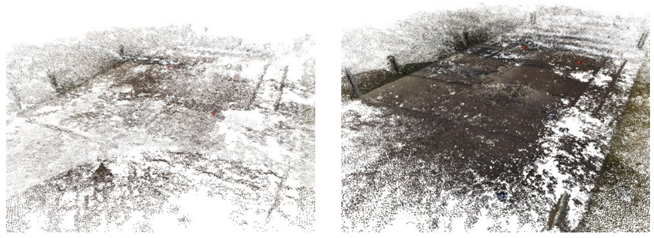

Figure 4. SfM/MVS results by acquisition interval (left: 2m, right 0.5m)

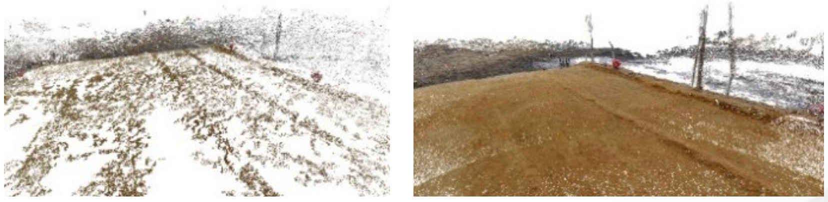

Figure 5. SfM/MVS results by camera type (left: multidirectional camera, right: High resolution camera)

Discussion

- The SLAM processing failed as expected only in the case of microtopography and fewer feature ground surfaces available.
- The SLAM processing succeeded when trees and buildings or features other than the ground surface were obtained.
- Applying LiDAR-SLAM to lunar surveying is difficult.
  (the lunar environment is consisting of microtopography and fewer feature ground surface)
- However, LiDAR has excellent ranging accuracy.
  e.g.) ranging between target markers
- Although the accuracy was not immediately applicable to surveying, trajectories can be estimated by VO in the environment with fewer features.
- The longer the path, the more errors accumulate (VO)

Conclusions

Overall: Non-GNSS and less geometrical features made 3-D measurement unstable.
SfM/MVS: higher resolution images and shorter intervals were effective for point cloud generation.
LiDAR-SLAM and VO: data acquisition challenges existed.
LiDAR-SLAM: less geometrical features made 3-D measurement unstable.
VO: trajectories were estimated.
SfM/MVS and VO: advantages of SfM/MVS and VO.

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References

1. Yang Cheng, Mark Maimone and Larry Matthies, 2005. Visual odometry on the Mars Exploration Rovers. IEEE International Conference on Systems, Man and Cybernetics.