# Point Cloud Generation by Gimbal-mounted LiDAR and Multi-directional Camera for Lunar Surveying

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## ABSTRACT

In recent years, research activities related to lunar surface development, such as the Artemis Project, have progressed. However, it is not easy to survey the lunar surface using conventional survey instruments such as a total station, because of no reference points, non-GNSS environments, extreme temperature differences, cosmic radiation, and less gravity. In addition, conventional image-based measurement and SLAM (Simultaneous Localization and Mapping) are also difficult due to a sandy surface covering the lunar surface, called as the regolith. On the other hand, the construction on the lunar requires more efficient work with digital twining to improve construction and transportation costs. Therefore, we have developed a point cloud acquisition method (LiDAR-SfM/MVS) that combines marker-based LiDAR-SLAM for reference point surveying and SfM/MVS processing for dense point cloud acquisition. In this research, we examined two types of measurement approaches. The first approach was a LiDAR-SfM/MVS methodology that combines SfM/MVS with multi-directional cameras and a LiDAR with an attitude heading reference system (AHRS). The second approach was SfM/MVS with multi-directional cameras and a LiDAR mounted on a 3-axis gimbal. Both approaches acquire asynchronous images with a multi-directional camera to achieve 3D measurement even in environments with poor geometrical and color features such as lunar surfaces. The asynchronous images are combined and processed to generate SfM point clouds, and the generated point clouds are registered with the marker positions obtained from the LiDAR point clouds to obtain with scale information. Our experiments were conducted in two types of simulated lunar surface environments. We have confirmed that even in a poor environment such as the lunar surface, it is possible to acquire point clouds of the ground surface with approximately 4[cm] accuracy by using LiDAR combined with AHRS, or measurement from a gimbal LiDAR mounted on a 3-axis gimbal and images from a multi-directional camera, even in black or white colored ground surfaces.

**Keywords:** Lunar Survey, Point Clouds, LiDAR-SLAM, SfM/MVS