Texas Department of Transportation

TEXAS A&M UNIVERSITY CORPUS CHRISTI | CONRAD BLUCHER INSTITUTE FOR SURVEYING AND SCIENCE

PROJECT SUMMARY REPORT

0-7157: Develop Guidelines for Integration of UAS LiDAR and Photogrammetry to Enhance Land Surveying Capabilities

Background

The Texas Department of Transportation (TxDOT) is focused on assessing and documenting the benefits and limitations of umanned aircraft system (UAS) survey technology. UASs equipped with digital cameras, light detection and ranging (LiDAR) sensors, or both enable the collection of high spatial resolution three-dimensional (3D) quantitative geospatial data. When using a camera, the technique is called structure-from-motion (SfM) photogrammetry or UAS-SfM.

In practice, there are important differences between UAS-SfM and UAS-LiDAR including measurement fidelity, operational considerations, post-processing workflows, and task suitablity. This research examined the performance and limitations of UAS-SfM and UAS-LiDAR for acquiring repeatable 3D and topographic geospatial data. The research included a review of UAS-SfM and UAS-LiDAR technologies, documentation of operational factors and current practices, completion of data collection field tests, comparative assessment of survey accuracy and repeatability, evaluation of data processing workflows, and development of recommendations for implementation.

What the Researchers Did

The researchers completed twelve UAS data collection field tests, ten at TxDOT district project sites and two at development test sites, using SfM and LiDAR. Two grades of LiDAR scanners were evaluated based on their ranging capabilities and quality of their position and orientation systems. Data collections were conducted across all four seasons including in summer during extreme heat conditions.

The TxDOT district project sites covered varying geographic locations and site conditions in metro and rural districts including greenfield sites and active roadways with different terrain relief, land cover, and traffic volume. The development field tests evaluated data collection workflows and quality control (QC) methods for improving survey repeatability, including use of ground control points (GCPs).

The researchers evaluated UAS-SfM and UAS-LiDAR data processing workflows, testing various SfM photogrammetry software and LiDAR trajectory and calibration solutions for point cloud creation. The researchers processed all datasets with and without GCPs to evaluate direct georeferencing of data using post-processed kinematic (PPK) global navigation satellite system (GNSS) trajectory corrections.

Field tests and evaluations achieved the following objectives:

- Compared data quality and survey repeatability between UAS-SfM and UAS-LiDAR.

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- Evaluated data collection workflows, processing workflows, and QC methods.
- Assessed operational factors and task suitability.
- Documented advantages, limitations, and lessons learned.

Additionally, the researchers evaluated digital survey workflows to extract mapping products from UAS-SfM and UAS-LiDAR data including ground point filtering, digital terrain model (DTM) generation, stockpile volume estimation, and artificial intelligence (AI) for automated feature extraction. The researchers further investigated how variations in GNSS control and ground truth data affect UAS survey workflows.

What They Found

The researchers grouped findings and major lessons learned into the following main categories: qualitative and quantitative assessment of UAS-SfM and UAS-LiDAR survey results, comparative assessment of UAS-SfM and UAS-LiDAR point cloud products and derived DTMs, assessment of task suitability and workflows, and QC methods.

UAS surveys enhance data collection efficiency and safety by quickly cataloging large amounts of geospatial data, reducing “boots on the ground”. The research demonstrated that UAS-SfM and UAS-LiDAR are both effective 3D mapping technologies, each with its own advantages and limitations. UAS-SfM excels in high-detail photorealistic reconstructions but may be affected by environmental factors. In contrast, UAS-LiDAR provides robust point cloud generation in diverse land cover including vegetation and terrain with high relief (Figure 1).

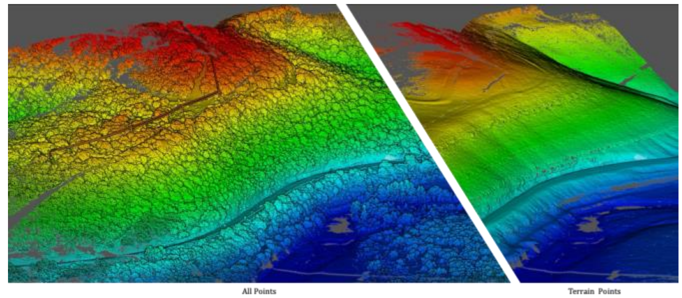

Figure 1. UAS-LiDAR Survey of a Cliff Face on FM 2341.

What This Means

The researchers summarized key findings and made several recommendations, including the following:

- Choose between UAS-SfM and UAS-LiDAR based on project requirements, data needs, and site conditions; UAS-SfM suits uncleared or built land, while UAS-LiDAR excels in topographic mapping, vertical feature scanning, and is unaffected by objects (e.g., vehicles) moving in the scene.
- Consider how flight operations and mapping efficiency differ based on UAS platform and sensor capabilities, as these factors can affect task suitability (e.g., LiDAR pulse rate and range).
- Implement accurate GNSS trajectory correction methods and use GCPs as needed to enhance UAS survey accuracy and repeatability.
- Implement QC methods with independently surveyed checkpoints on vegetated and non-vegetated surfaces and ensure QC procedures are in place for assessing derivative products.
- Continue integration of UAS technology into surveying activities at TxDOT, with exploration of new operational solutions and data processing workflows to further enhance survey efficiency.

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