VOLUME 11 ISSUE 3

LIDAR MAGAZINE

FALL 2021

SPECIAL ISSUE

SENSOR SPOTLIGHT

Accuracy Assessment of the Microdrones mdLiDAR3000DL

Testing sUAS-lidar system for large-scale mapping

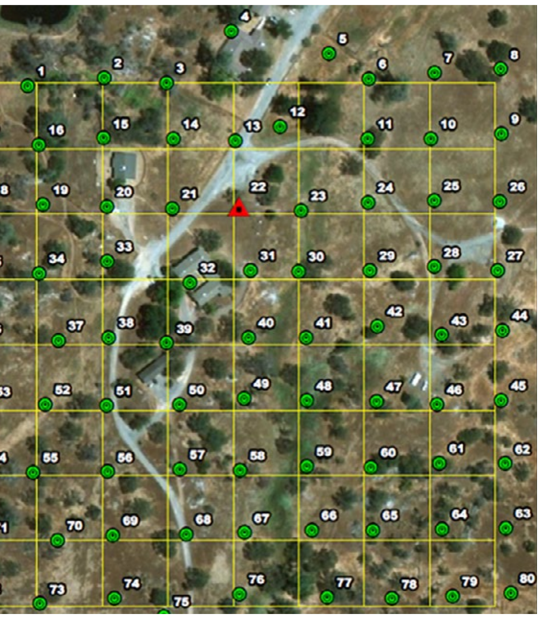

Figure 1: SJER test site.

Lidar systems based on small unmanned aerial systems (sUAS) are rapidly advancing. This research investigates a Microdrones mdLiDAR3000DL sUAS-based lidar system. Accuracy analysis of data is acquired for two different sites. These sites have dense ground control fields established using high-accuracy ground surveying methods. A lidar point cloud acquired from a manned helicopter was utilized to evaluate the mdLiDAR3000DL performance on paved roads, unpaved roads, and roof tops.

Standards and test fields

The *American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data*[1] were used to validate the mdLiDAR3000DL accuracy (**Table 1**). Two test sites with high-precision control points were established to test the technology. The first, San Joaquin Experimental Range (SJER), has 81 control points in a grid-like pattern with estimated accuracies of 1 cm $RMSE_{XY}$ horizontally using static GNSS and 0.5 cm $RMSE_Z$ vertically using digital leveling (**Figure 1**). The second

1 American Society for Photogrammetry and Remote Sensing (ASPRS), 2015. Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. November, 2014), *Photogrammetric Engineering & Remote Sensing*, 81(3): A1-A26, March 2015. https://www.asprs.org/wp-content/uploads/2015/01/ASPRS_Positional_Accuracy_Standar-ds_Edition1_Version100_November2014.pdf.

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Figure 2: Cal Fire test site.

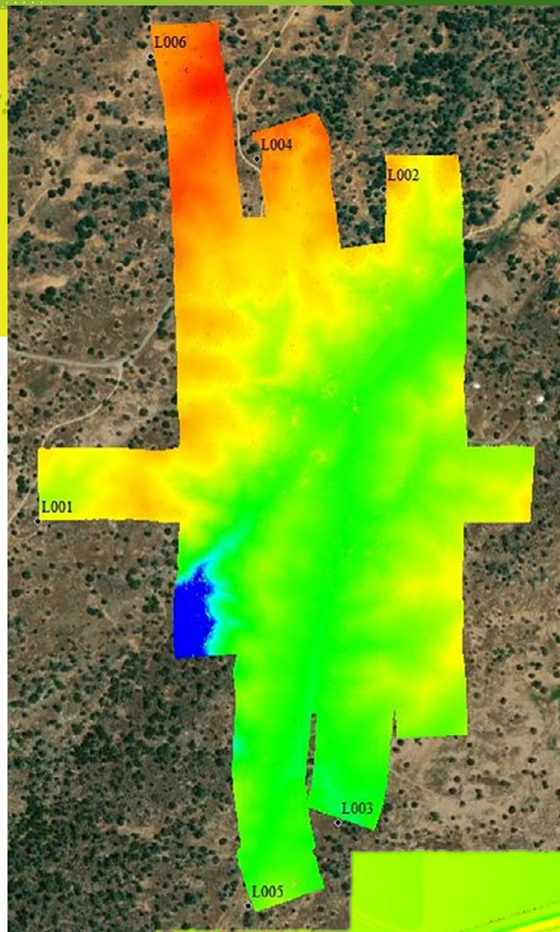

Figure 3: Flights of manned helicopter over SJER test site.

Table 1: ASPRS 2014 Vertical Accuracy			
Absolute Accuracy			
Vertical Accuracy Class (cm)	$RMSE_Z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95% (cm)
9.3	9.3	18.2	27.8

site (Cal Fire) has 30 control points with 0.5 cm $RMSE_{XY}$ horizontally and 0.5 cm $RMSE_Z$ vertically (**Figure 2**). Both test sites are remarkable, given the large number of control points with such a high degree of precision and accuracy. To validate the point clouds generated with this technology, both control sites were scanned using a high-precision lidar system flown on a manned helicopter, with 1 cm $RMSE_Z$ vertically and 120 points/m^2 density (**Figures 3 and 4**).

Microdrones sUAS-lidar

The Microdrones mdLiDAR3000DL is based on a md4-3000 quadcopter with a takeoff weight 14.8 kg (**Figure 5**). The payload consists of a Sony RX1R II RGB camera (not used in this research), Riegl miniVUX-1DL lidar system and Applanix APX-20 UAV PPK GNSS/IMU system.

The GNSS/IMU system has dual-frequency GNSS (L1 and L2) and IMU at 200 Hz with 0.025° heading accuracy and 0.015° roll and pitch accuracy. The expected accuracy specified by the manufacturer is 1-3 cm $RMSE_{XY}$ horizontally and 2-4 cm $RMSE_Z$ vertically.

The Riegl miniVUX-1DL builds upon the miniature UAV laser scanner Riegl miniVUX-1UAV. “DL” refers to “downward-looking”, indicating special design parameters for corridor mapping (downward-looking, optimized field of view of 46°, small size, 2.4 kg). The sensor is capable of five returns per laser shot. With a scan rate of 150 Hz, it can produce 100K laser pulses per second[2].

2 http://www.riegl.com/products/unmanned-scanning/riegl-minivux-1dl/.

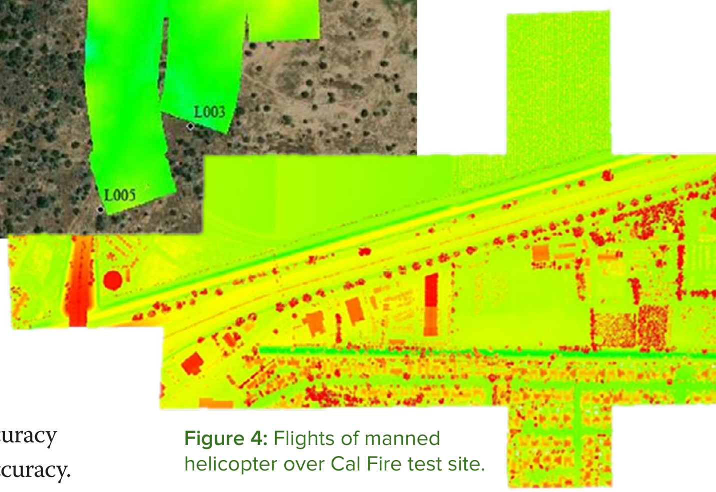

Figure 4: Flights of manned helicopter over Cal Fire test site.

Figure 5: Microdrone sUAS.

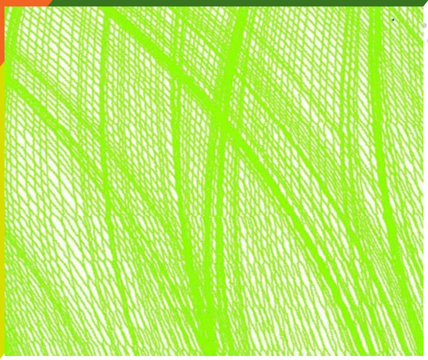

Figure 6: Scan pattern generated by Microdrones mdLiDAR3000DL with Riegl miniVUX-1DL.

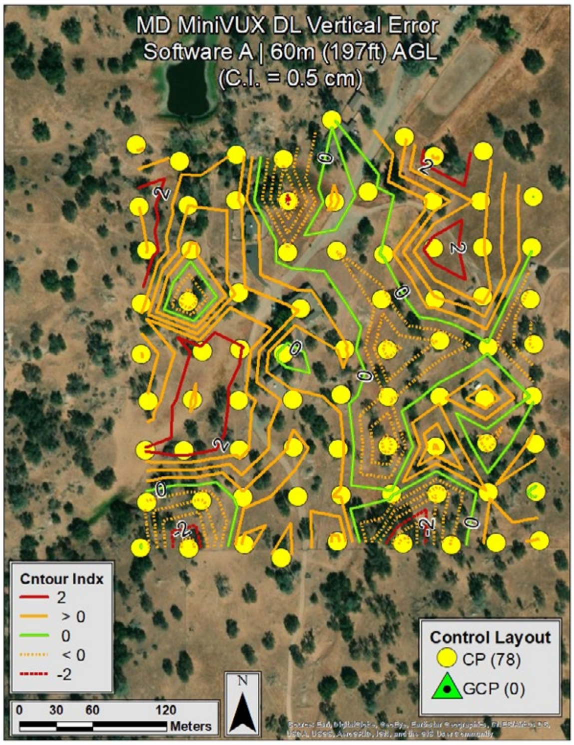

Figure 7: Error contour map for SJER test site.

Figure 8: Error contour map for Cal Fire test site.

The following mapping parameters were used at each test site: SJER - flying height 75 m AGL, flight speed 5 m/s, 50% sidelap; Cal Fire—80 m AGL, 5 m/s, 50%. The downward-looking, forward/backward-looking, rotating cone wedge pattern generates a well-distributed, circular scan with a point density of 270 points/m^2 (**Figure 6**).

Vertical accuracy

Check points

Using the lidar point cloud, a 5 cm grid digital elevation model (DEM) was generated for both test sites. The check-point elevations were interpolated from the DEM and compared to the ground elevations obtained from digital leveling. The statistical results of this comparison are shown in **Table 2**. The vertical RMSE$_Z$ for SJER and Cal Fire test sites are 1.8 cm and 1.4 cm respectively, with less than 1 cm bias. The noise ranged between 6 and 9 cm. The vertical error contour maps for both test sites are shown in **Figures 7 and 8**. These maps show no doming effect or large noise in the check point results.

Table 2: Results at Check Points

Site	Date	RMSE$_z$ (cm)	St. Err. Z	Avg Z(cm)	Range Z(cm)	No. of Strips
Cal Fire	9-24-2019	1.4	1.4	-0.3	6.4	6
SJER	10-27-2020	1.8	1.8	0.5	9.3	13

Table 3: Differences Between Profiles Derived From sUAS and Helicopter Point Clouds (cm)

SJER B1-1		SJER B1-2		SJER Driveway		SJER Road1	
Avg Z	RMSE$_z$	Avg Z	RMSE$_z$	Avg Z	RMSE$_z$	Avg Z	RMSE$_z$
0.6	0.9	0.3	0.9	0.4	0.7	-0.0	1.0
CAL FIRE-B1-1		**CAL FIRE B1-2**		**CAL FIRE PAD 1**		**CAL FIRE Road2**	
Avg Z	RMSE$_z$	Avg Z	RMSE$_z$	Avg Z	RMSE$_z$	Avg Z	RMSE$_z$
-1.5	1.7	1.3	1.6	-0.8	1.3	-1.8	2.1

Figure 9: Profiles at SJER test site.

Figure 10: Profiles at Cal Fire test site.

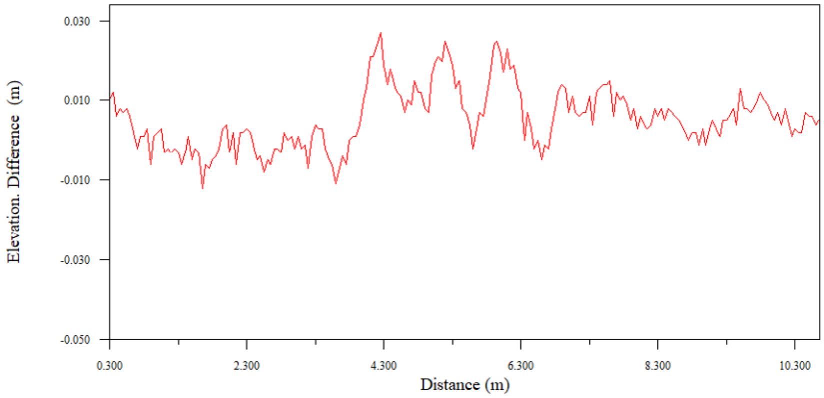

Figure 11: BLDG 1-2 profile difference at SJER test site.

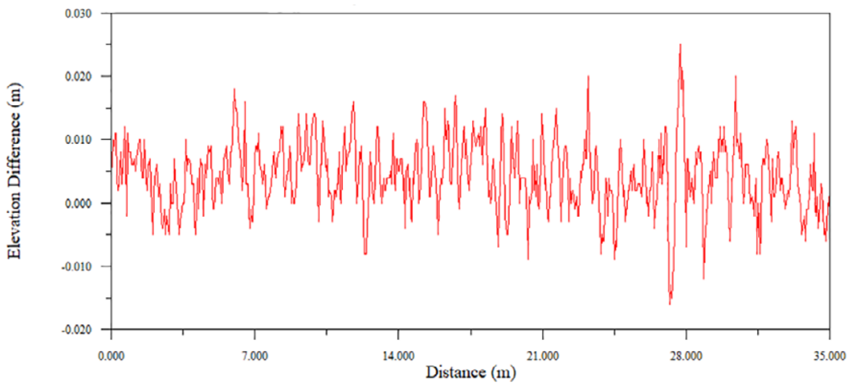

Figure 12: Asphalt Driveway profile difference at SJER test site.

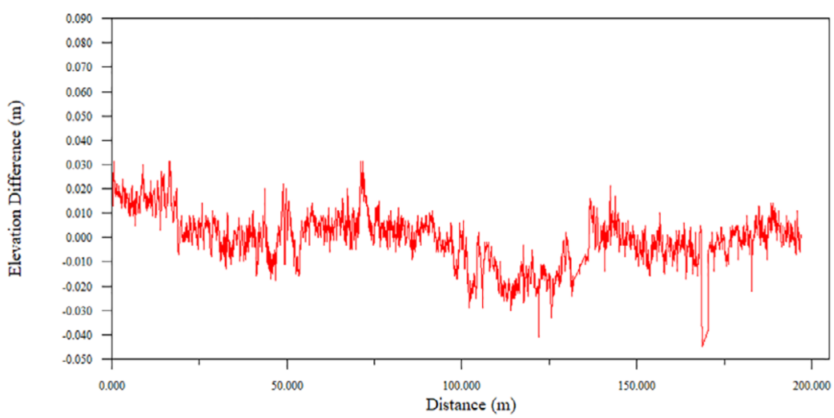

Figure 13: Unpaved Road 2 profile difference at SJER test site.

Profiles

Using the airborne helicopter laser point cloud from both sites, a profile analysis was conducted with Microdrones software for point-cloud comparison. Several profiles on different surfaces were generated as shown in **Figures 9 and 10**. Selected profile differences for the SJER and Cal Fire test sites are shown in **Figures 11–13** and **Figures 14–16** respectively. These are within the accuracy of the point cloud acquired from the manned helicopter. The noise is larger on dirt road surfaces, which is possibly due to a small planimetric shift between the sUAS and helicopter point clouds. **Table 3** shows the profile difference results with vertical $RMSE_Z$ ranges of 0.7-2.1 cm.

Conclusions

This study demonstrates the potential capability of an sUAS equipped with lidar (Microdrones mdLiDAR3000DL) to meet large-scale mapping specifications with a factor of safety. Site-specific

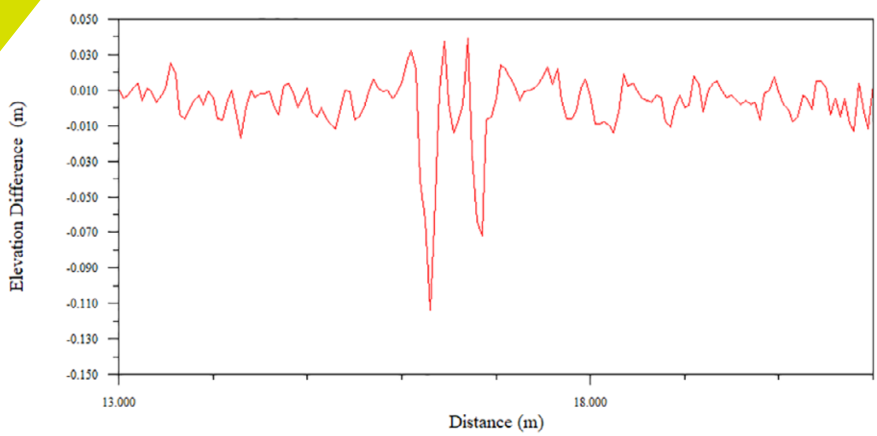

Figure 14: Overhang profile difference at Cal Fire test site.

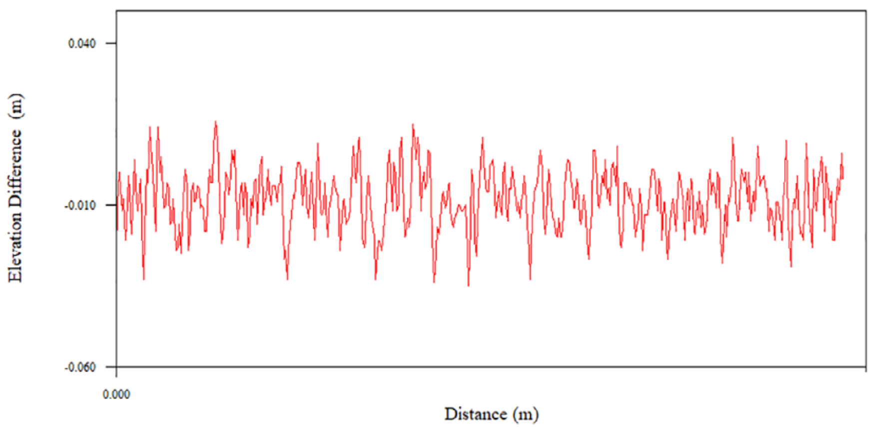

Figure 15: Concrete Pad 1 profile difference at Cal Fire test site.

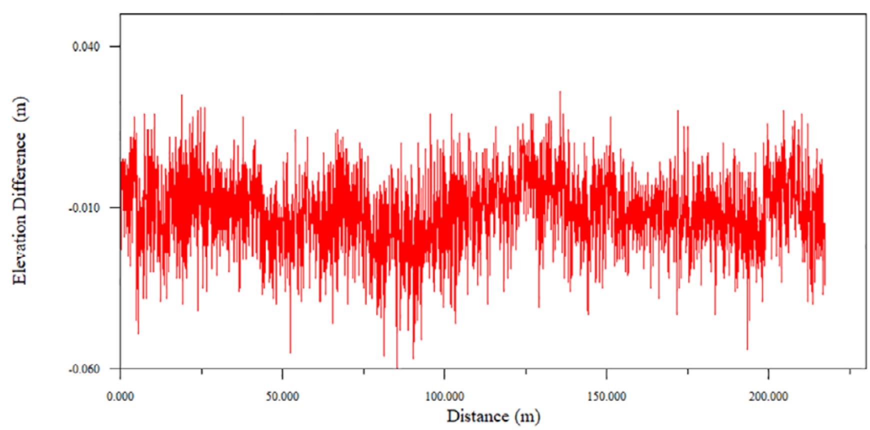

Figure 16: Unpaved Road 1 profile difference at Cal Fire test site.

considerations include extent of area of interest, terrain relief, vegetation coverage, surface variability, GNSS requirements, system specifications, flight-planning parameters, and site control requirements. These factors must be considered on an individual basis when evaluating system and site suitability and resulting accuracies.

Based on the test site conditions and system parameters, the test shows the system repeatability at two different test sites with varying height differences and land cover. It also validates the manufacturer's vertical accuracy specification of 2-4 cm $RMSE_Z$ for these test sites.

Acknowledgement

The research reported herein was performed by the Department of Civil and Geomatics Engineering at California State University, Fresno (CSUF) for the Division of Research, Innovation and System Information (DRISI) at California Department of Transportation.

The contents of this study reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein.

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