Presented at the FIG Congress 2018,
May 6-11, 2018 in Istanbul, Turkey

IMPROVED MAPPING SOLUTION USING TERRESTRIAL LASER SCANNERS AND LOW-COST UAV IMAGES

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Introduction

- Typically, low-cost small unmanned aerial vehicles (UAV) carry low resolution imaging system, which may not be suitable for topographic surveying.

- To enhance the mapping accuracy of such a system, it is essential that a well-distributed ground control points (GCP) are established.

- Usually, Terrestrial laser scanner (TLS) is used as the main scanning system to capture point cloud data from different locations in the area of interest.

Introduction

- Unfortunately, the area covered by TLS is limited and the quality of the 3D data depends on the scanning angles.
- Two data sets are collected by FARO Focus S TLS and a low-cost camera installed on board the DJI Phantom 4 Pro UAV, respectively.
- A number of ground control points, whose precise coordinates are determined using SOKKIA GCX2 receiver in the VRS mode, are used to enhance the image acquisition and registration, which are used to improve the accuracy of the point cloud registration.

Introduction

- A number of targets are created and placed at specific locations throughout the scanned structure.
- The precise coordinates of these targets are precisely determined using GPS and traditional surveying techniques.
- Both of the laser scanner’s point cloud and the UAV images are used to create a 3D model of the scanned structure and surroundings.

Experiment

Unmanned Aerial Vehicle

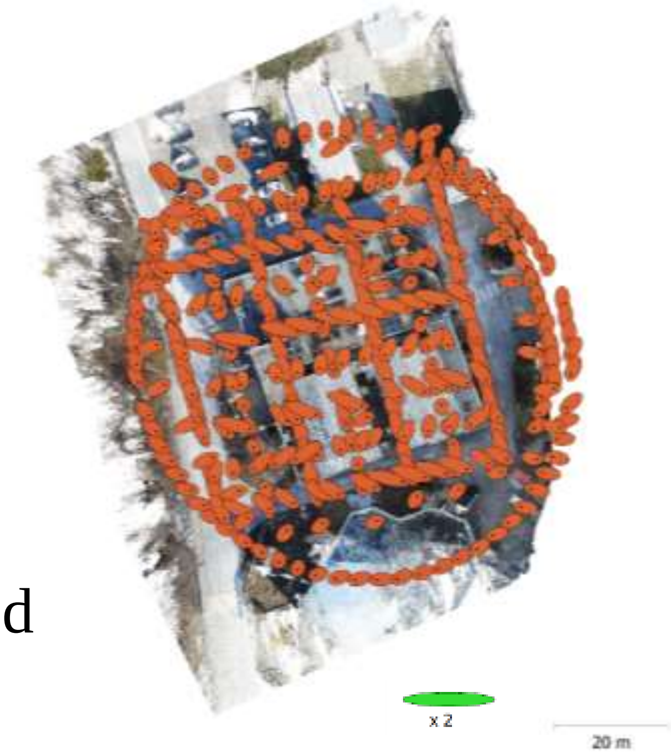
- Low-cost DJI Phantom 4 Pro UAV is used in this study, which is equipped with a 20-megapixel camera and a single-frequency GPS receiver.

- Unfortunately, the UAV positioning solution is based on a consumer-grade low-cost GPS receiver, which limits the positioning precision to meter level.

- The estimated UAV camera position for a total of 342 images and their corresponding error ellipses.

Experiment

- UAV camera position and the corresponding error ellipse.
- Uncertainties in the East and North components are represented by error ellipses.
- Estimated camera locations are marked with a black dot.



East Error (m)	North Error (m)	Total Error (m)
0.913	1.122	1.408

Experiment

- GCPs were used to calibrate the UAV camera using an adaptive camera model fitting.

- The adaptive camera model enables automatic selection of the camera parameters to be included in the adjustment process based on their reliability estimates.

- Data sets with strong camera geometries, such as images taken for all sides of a building, help fix more parameters during initial camera alignment.

Experiment

- The sequential photos captured by the UAV camera are used for 3D construction of the objects through the Photoscan software.

- The 3D objects created by the UAV camera images are georeferenced through the onboard GPS in the World Geodetic System 1984 (WGS84) reference frame.

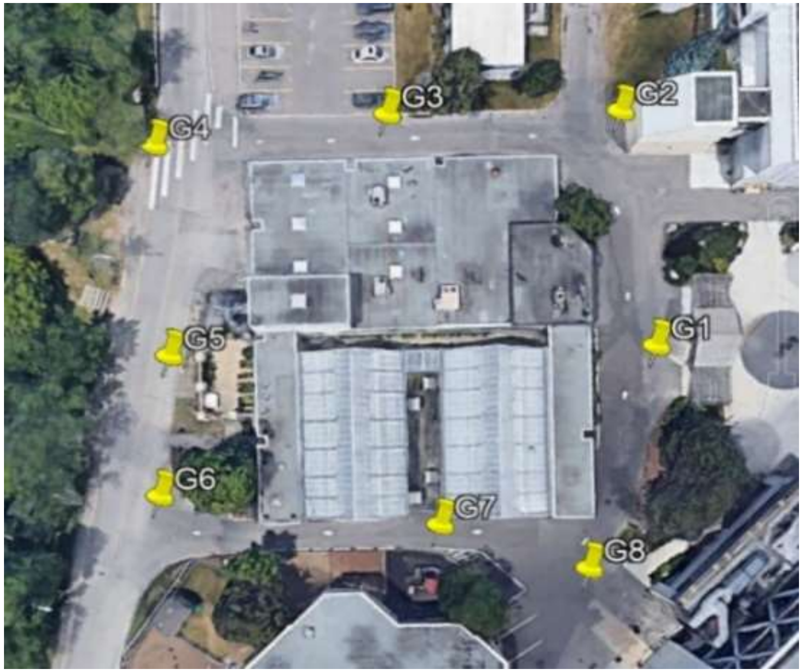
Ground Control points and Object targets

- To improve the 3D mapping accuracy, the XYZ coordinates of the 3D data created by the UAV-SfM and TLS are georeferenced using a number of GCPs and on-structure targets.

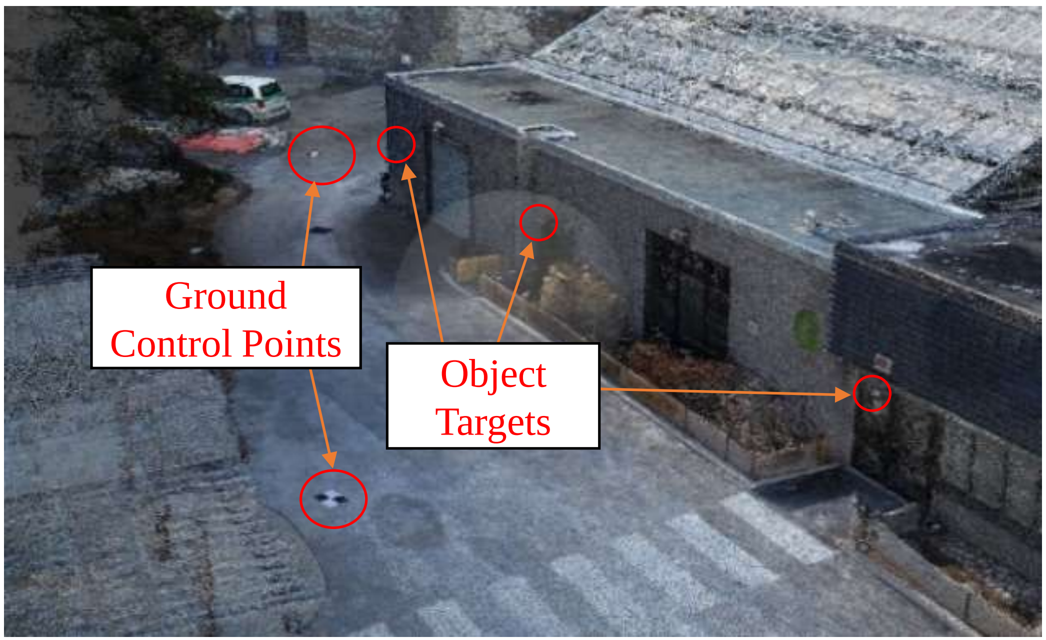
- A total of eight GCPs are established within the UAV mission location.

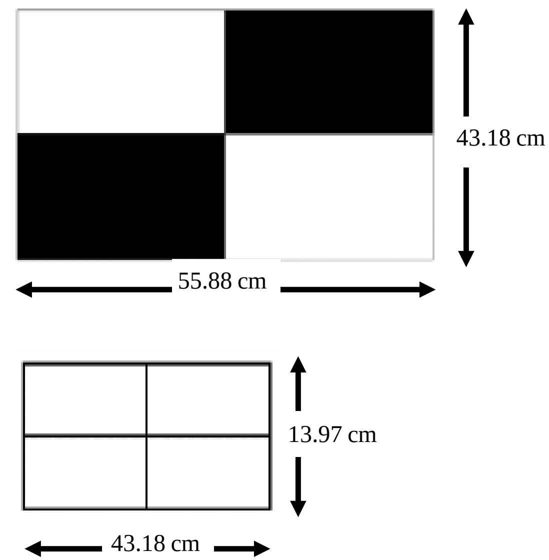
- A total of 16 object targets are designed and fixed to the building walls at different height.

Ground Control points and Object targets



Ground Control points and Object targets





Ground Control points and Object targets

- The GCP coordinates were obtained using a dual-frequency GPS receiver in the VRS mode.

- The object targets are captured using a total station with a GCP back-sighted.

Ground control points positioning error

Label	Positioning Error (cm)			Total (cm)
	East	North	Altitude	
G1	-0.8	-0.8	3.3	3.5
G2	3.1	2.1	-6.0	7.0
G3	-1.7	-2.0	3.2	4.1
G4	-0.4	-1.8	3.6	4.0
G5	2.9	-2.1	1.6	3.9
G6	1.9	-0.1	-2.6	3.2
G7	2.8	1.7	1.4	3.6
G8	0.4	1.7	-2.9	3.4
Total	2.0	1.7	3.3	4.3

Ground Control points and Object targets

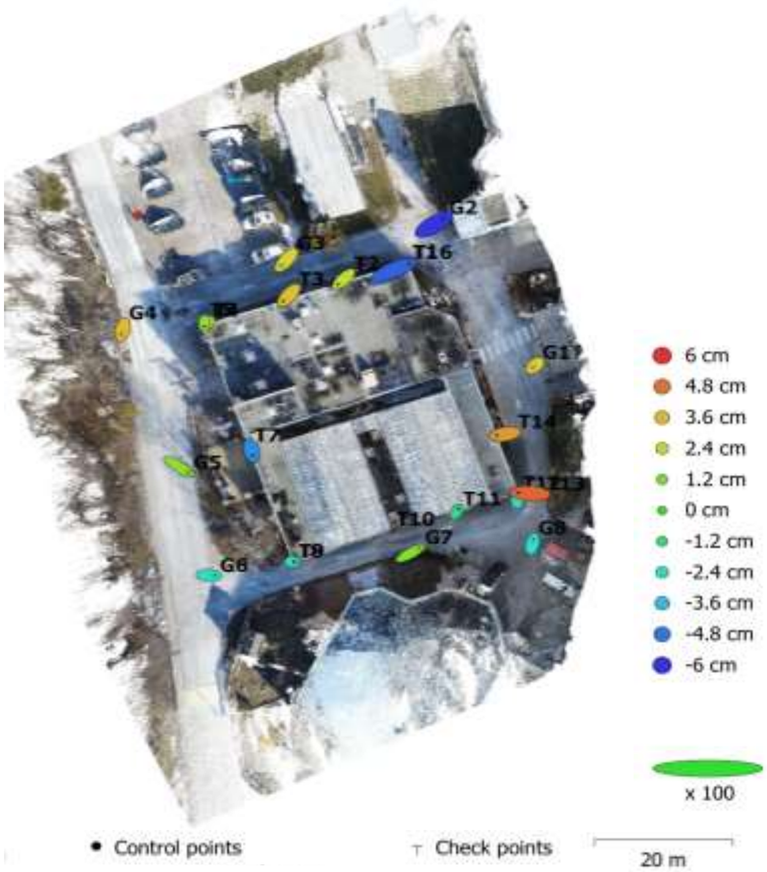
- To verify the accuracy of the data fusion technique, the object targets that are visible in the UAV images are used as check points

Object targets positioning errors results from the 3D model

Point	Positioning Error (cm)			Total (cm)
	East	North	Altitude	
T1	4.4	2.8	-4.8	7.1
T2	-1.6	-1.7	2.5	3.5
T3	-1.6	-1.9	3.5	4.3
T4	-0.6	-0.7	2.2	2.4
T5	-0.1	-1.0	1.7	2.0
T7	0.4	-1.6	-4.4	4.7
T8	0.4	0.0	-2.5	2.5
T11	0.5	0.9	-1.5	1.8
T12	0.1	1.5	-2.8	3.2
T13	-3.4	0.2	5.1	6.1
T14	-2.5	-0.4	4.2	4.8
T16	4.3	2.0	-5.2	7.0
Total	2.3	1.5	3.6	4.5

Ground Control points and Object targets

- Altitude error is represented by the color of the error ellipse. East, North errors are represented by the size of the error ellipse.
- Estimated GCP locations are marked with a dot and the check points with a cross.



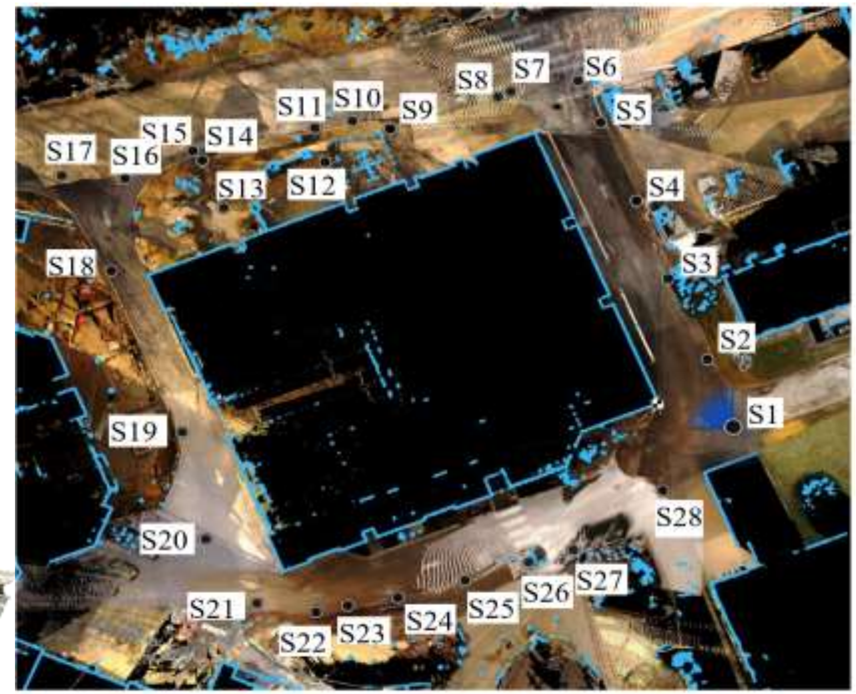
Terrestrial laser scanner

- A total of 28 setups were needed to capture the 360-degree scans with a 0.6mm point cloud precision at a 10 m distance from the scanner.

- The TLS was setup at 28 points around the structure to capture all the details and to create a good overlap between the scans.

- The TLS data, which were acquired from different locations around the building, were processed and different point clouds were created and registered together through object targets system.

Terrestrial laser scanner



Data Fusion

- The point cloud generated from the UAV images are known as unstructured point cloud because they are generated based on features, location, and intensity.

- The TLS point cloud are generated based on the TLS mechanical rotation

Data Fusion

- The UAV and TLS data sets have different characteristics.
- The TLS produces more structured and dense point cloud with some gaps, the UAV images provides a complete 3D data set, including glass surfaces.
- The results of UAV and TLS data fusion show a denser point cloud with no gaps, including the rooftop of the building.
- The data fusion output shows approximately a 5 cm positioning error.

Data Fusion

3D Building during the Winter Season

3D Building during the Summer Season

Summary and Conclusion

- The fusion workflow of UAV and TLS point clouds is presented, which aims to obtain detailed information about the objects of interest.
- The structured TLS-based 3D point cloud have several gaps, glass features, and no rooftop.
- The unstructured UAV-based 3D point cloud, on the other hand, miss objects under canopies.
- Fusing the two point clouds overcomes the limitations of both sensor data acquisitions and enables a complete 3D mapping solution, which includes detailed information about the area and objects of interest.

Thanks!