Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr

Precise monitoring of temporal topographic change detection via unmanned air vehicle

Serkan KARAKIŞ[a], Umut Güneş SEFERCİK[a*], Turhan BİLİR[b] and Can ATALAY[a]

[a]*Bulent Ecevit University, Engineering Faculty, Dept. of Geomatics Engineering, 67100, Zonguldak, Turkey*
[b]*Istanbul University-Cerrahpasa, Engineering Faculty, Dept. of Civil Engineering, 34320, Istanbul, Turkey*

Research Article

Keywords:
Digital photogrammetry, UAV, DiffDTM, Monitoring.

Received Date: 24.10.2018
Accepted Date: 25.01.2019

ABSTRACT

Nowadays, fast developing space-borne and airborne remote sensing technologies became indispensable for land related engineering disciplines such as mapping, geology, environment, mining and forestry. The new technologies, provide more qualified and rapid achievable outcomes, are adopted permanently. The description of the topographic surface became easier by means of very high resolution (VHR), rapid achievable and accurate point clouds acquired by digital photogrammetry and airborne laser scanning (ALS). Optical unmanned air vehicle (UAV), one of the most actual photogrammetric techniques, is much in demand for varied purposes. UAVs provide high resolution data using the advantage of lower flight altitudes. In this study, a construction activity and its environmental influences in Bulent Ecevit University Central Campus were monitored by an optical hand-made UAV. In the application, the temporal change was detected by generating contour-lines, digital terrain models (DTMs) and differential DTMs (DiffDTM) of the topography. By DiffDTMs, temporal changes on the topography were visualized in color height scale where the contour-lines presents the change of morphological structure.

1. Introduction

In recent years, space-borne and airborne remote sensing technologies have been developing rapidly and monitoring of topographic displacements and deformations, depending on construction activities or natural disasters has become possible by temporal change detection analysis. With the development of airborne laser scanning (ALS) technology, three-dimensional (3D) description of the topographic surface became easier by means of very high resolution (VHR), rapid achievable and accurate point clouds that could not been provided by previous remote sensing technologies (Deng et al., 2007; Darwin et al., 2014; Höhle, 2017; Manfreda et al., 2018*a*). Considering high surface description potential, point cloud thought was adapted to photogrammetric image processing following ALS (Teizer et al., 2005; Rosnell and Honkavaara, 2012). Photogrammetric sensing acquires aerial photos by CCD/CMOS sensor-integrated multispectral digital cameras and point clouds can be provided with original colors in correlated parts of stereo imagery (Rosnell and Honkavaara, 2012; Swatantran et al., 2016).

The resolution of point cloud has a significant role on the quality of 3D topographic description and unmanned air vehicle (UAV) imaging (Ai et al., 2015) is the best way to increase the resolution with the advantage of lower flight altitudes. In UAV imaging, the properties of used camera and the terrain slope effect the final 3D model quality (Manfreda et al., 2018*b*).

Citation Info: Karakis, S., Sefercik, U. G., Bilir, T., Atalay, C. 2020. Precise monitoring of temporal topographic change detection via unmanned air vehicle. Bulletin of the Mineral Research and Exploration. 161, 151-156. https://doi.org/10.19111/bulletinofmre.524179
* *Corresponding author: Umut Güneş SEFERCİK, ugsefercik@hotmail.com*

In this study, we aimed to monitor the 3D temporal topographic change in a construction area with a handmade UAV. With this purpose, we preferred a study field in Bulent Ecevit University Main Campus due to avoid official restrictions about UAVs in urban areas.

According to this aim, the paper was organized as follows; in section 2, the properties of the study area is given. Next, utilized materials and used methods were presented in section 3. Results are placed in section 4 followed by the conclusions.

2. Study Area

The selected study area is a place that a new Engineering Faculty is being constructed. It covers approx.100 m × 100 m (1 ha) area and the orthometric height is around 65 m. Figure 1 shows Main University Campus of Bulent Ecevit University and preferred study area on the high resolution (12 Megapixel) image that we obtained by a UAV flight. The area was periodically monitored during the excavation and the stereo-images derived from the first and last flights were used in the applications.

3. Materials and Methods

3.1 Used Materials

The UAV, used in the study, is a handmade octocopter and has very simple equipment. Hence, it can be easily produced and utilized for large variety of applications. The main body was built by carbon-fiber arms and the equipment were mounted on it. The main contents of the UAV consist of brushless motors, a flight control unit, a global positioning system (GPS) for coarse positioning, a data control card, an electronic stability control (ESC), a battery and a remote controller receiver which communicates with outer remote sensing transmitter. The produced UAV and main contents are presented in figure 2.

In the study, 12 Megapixel Canon EOS450D DSLR camera, which can be full-size mounted to the

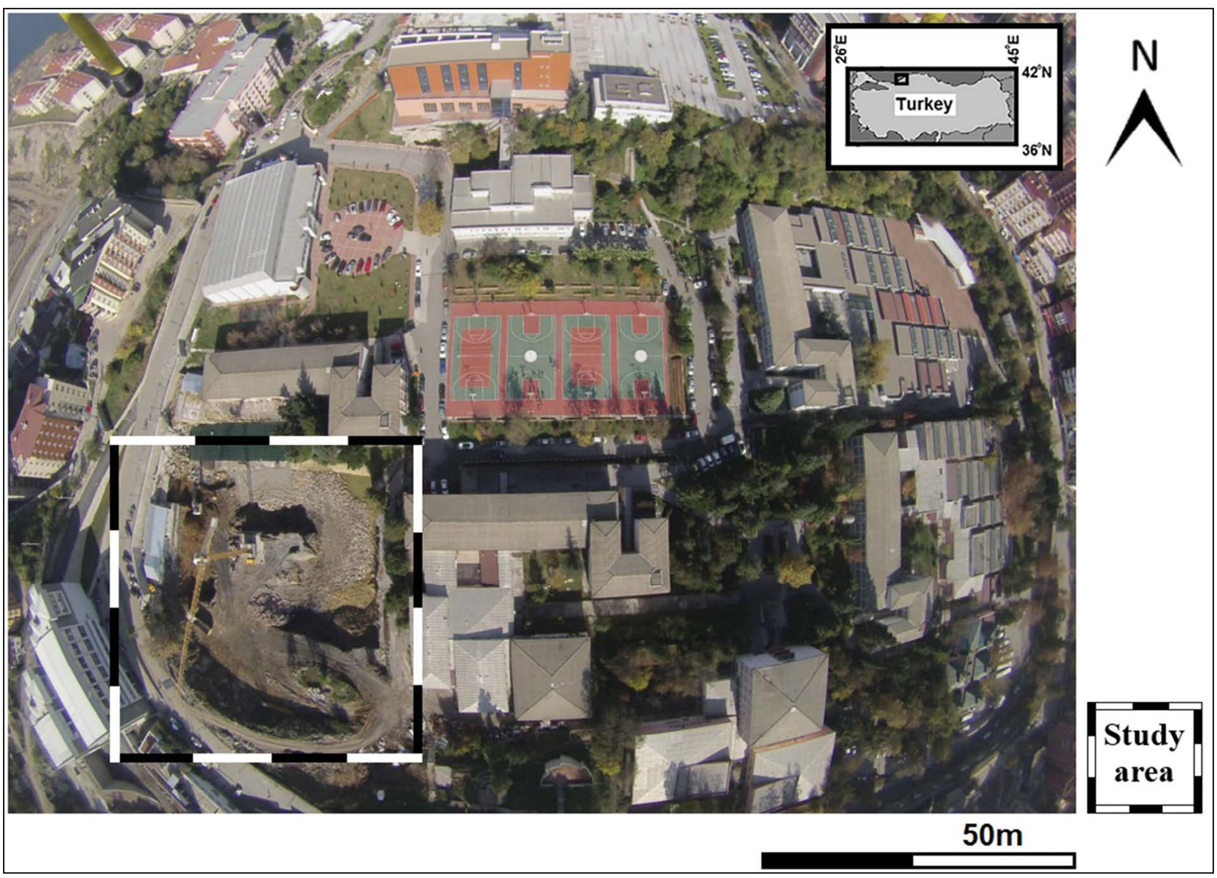

Figure 1- High resolution UAV image of Bülent Ecevit University Central Campus.

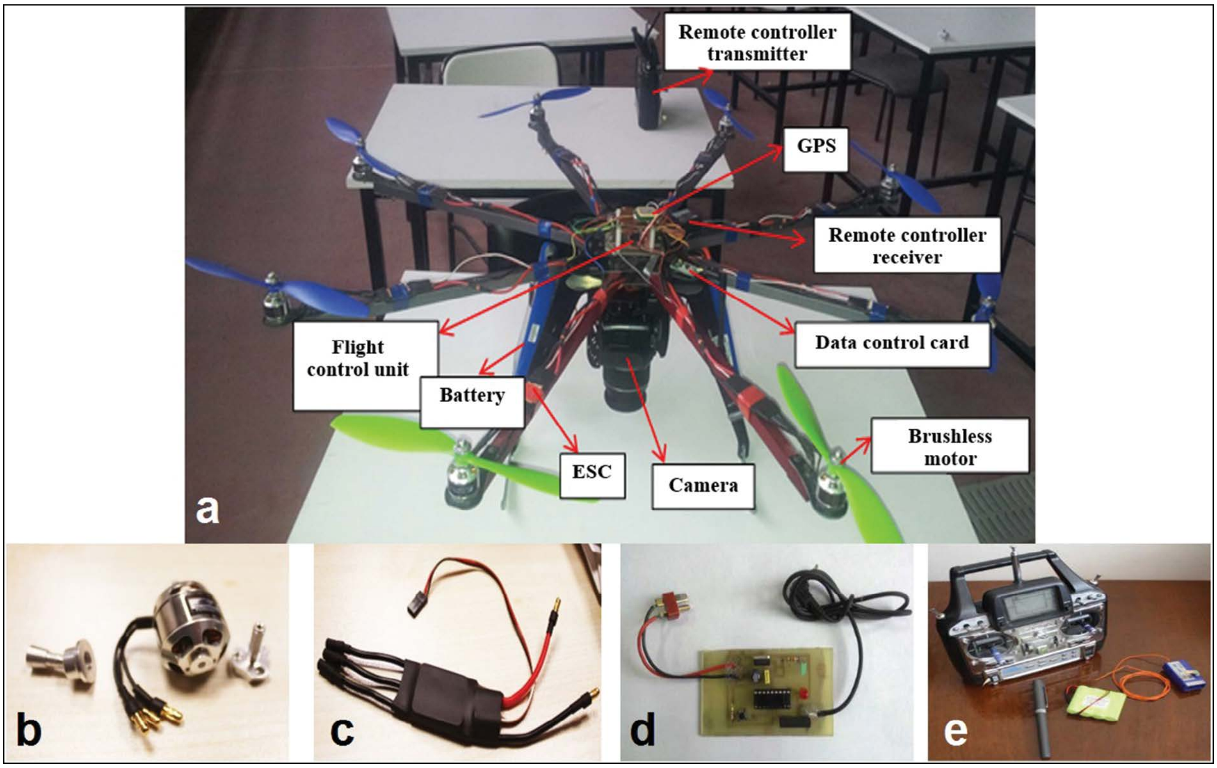

Figure 2- UAV and the main equipment; a) produced octocopter, b) brushless motor, c) electronic speed controller (esc), d) electronic timer, e) remote controller transmitter.

octocopter's body, was used. The properties of the camera are given in table 1.

Table 1- Technical properties of Canon EOS450D DSLR Camera.

Resolution (megapixel)	12
Maximum frame size (pixel)	4272 × 2848
Sensor size (mm)	22,2 × 14,8
Pixel size (μ)	5
Maximum shutter speed (sn)	1/4000
Weight (g)	475
Camera size (mm)	129 × 98 × 62
Processor	Digic III

Octocopter is operated with 8 bands remote controller which transfers data with modulation. Each band increases the movement variation of the UAV. In our UAV, 5 bands were used as motor cycle (take-off and landing), right and left motion, forward and back motion, direction motions and flight mode selections. Other 3 bands were utilized for taking photos and other processes.

The brushless motors used in the UAV are efficient and has regular moment/speed relation. They are operational in risky weather and topographic conditions and do not require permanent maintenances. On the other hand, these motors are costly and controlling of them are not easy. In contrast to brush direct current (DC) motors, switching process is realized electronically in brushless DC motors by ESCs. For the motion control of the UAV, micro controllers were utilized. The missions of the micro controllers can be summarized as; getting data from control unit and sensors and real time processing of derived data. For micro controller processes, open source software Arduino was used. Required edits were performed in "C" programming language (Karakış, 2012).

In UAV flight, the balance of the device was provided by a group of sensors. The main missions of these sensors can be summarized as; providing flight stability and correct maneuvers. In our UAV flights, we used gyro, acceleration and pressure sensors and inertial measurement unit (IMU) which is the essential inertial element in airborne and space-borne missions (Watts et al., 2012; Sørensen et al., 2017). To taking aerial photos, an electronic timer was integrated to the UAV. The taking interval was determined as 1 second considering possible facings of the octocopter during the flight. The 1 second interval was preferred regarding the trial flights.

Considering the payload and required flying time, an 11,1 Volt and 8000 mill ampere hours (mAh) decharge capacity Lithium Polymer battery was preferred to achieve higher energy. By successful integration of all these equipment, the aerial images were achieved with approx. 3 cm ground sampling distance (GSD).

3.2. Image Geometric Correction Methods

For the geometric processing of the aerial stereo-images during photogrammetric processing, 5 ground control points (GCPs) were established and measured on the ground by real time kinematic global navigation satellite systems (RTK GNSS). In the production of 3D model, interior, mutual and absolute orientations were completed. Afterwards, model points were obtained by stereoscopic assessment of the images and contour-lines were generated using the model points.

For determining the temporal change detection in the topography, 10 cm gridded digital terrain models (DTMs) were generated by vector-raster transformation utilizing moving average interpolation method in LISA software considering ground and grade elevations derived before and after the construction. The differential DTM (DiffDTM) was created using DTMs generated by ground and grade elevation data by following equation;

$$DiffDTM = DTM_{grade} - DTM_{ground} \tag{1}$$

4. Results

The generated contour-lines depending upon ground and grade elevations are presented in figure 3 separately. In the figure, approx. 4 m topographic elevation change by excavation is seen. However, the temporal topographic change cannot be detected clearly from contour-lines in most cases because of insufficient contour interval and vector structure. In figure 4, generated raster DTMs before and after excavation are shown with height scales. Raster DTMs present whole area by 10 cm pixels with ±3 cm planimetric and ±5 cm vertical absolute accuracy that's why the correct change of topography can be achieved. The accuracies of the models were estimated by point-based GNSS measurements in the scope of root mean square errors of geolocation differences. Increased number of fringes after excavation is very clear in figure 4b.

Figure 5 shows the DiffDTM of the area with height scale. Considering DiffDTM, a temporal topographic change reaches up to -4.5 m. Using DiffDTM, the achieved areal and volumetric changes are shown in table 2.

Table 2- Areal and volumetric changes in the study area.

Excavation volume (m^3)	5089,9
Filling volume (m^3)	337,8
Excavation area (m^2)	2924,5
Filling area (m^2)	369,2

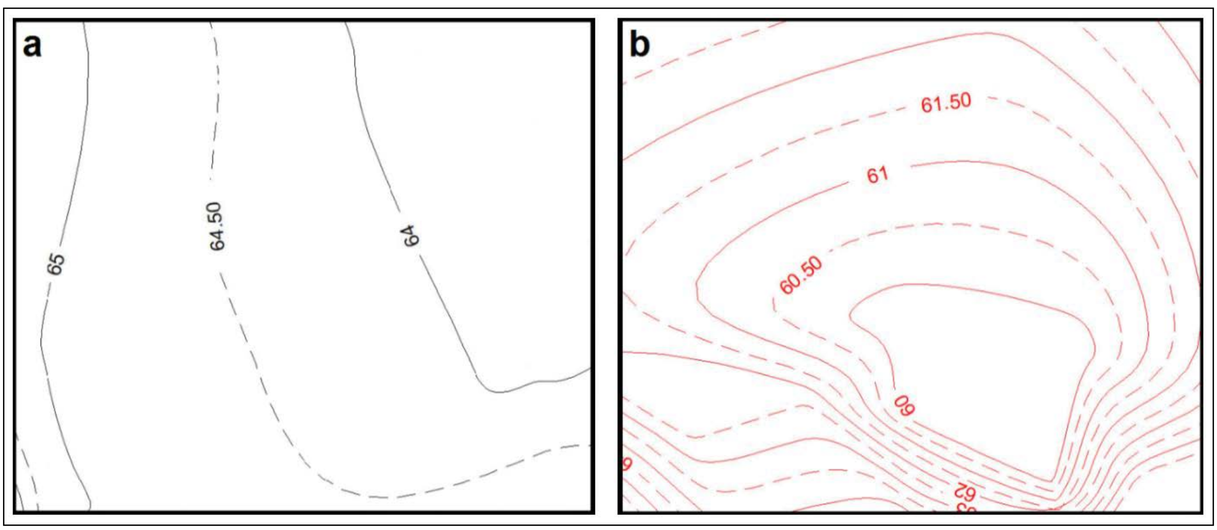

Figure 3- Contour-lines of a) ground and b) grade elevations.

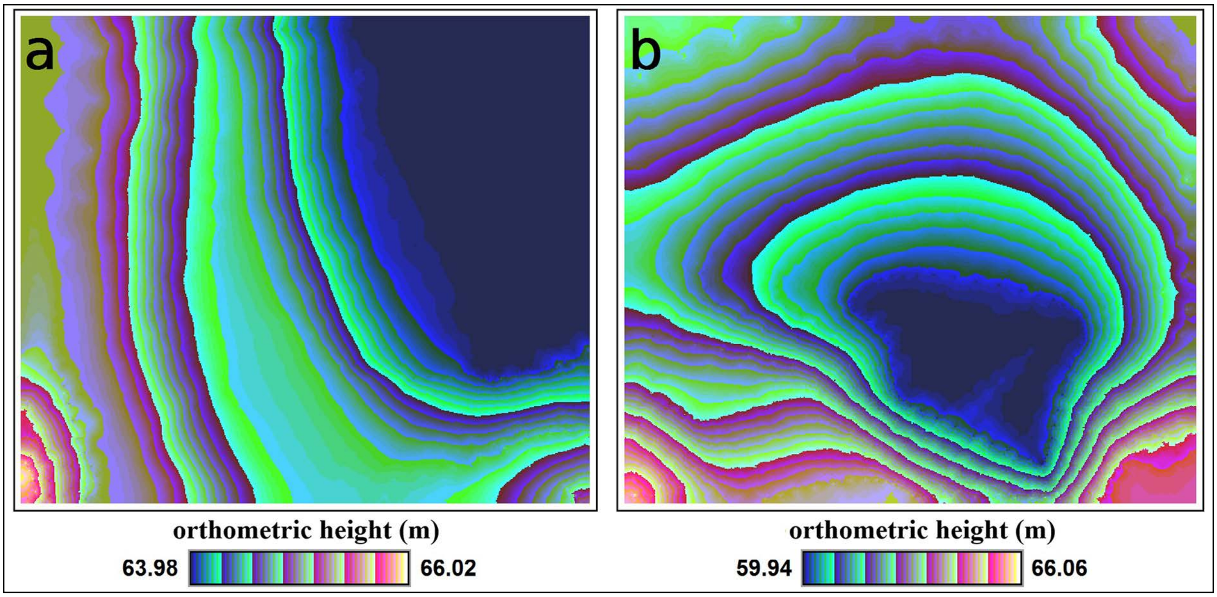

Figure 4- DTMs of (a) ground and (b) grade elevations.

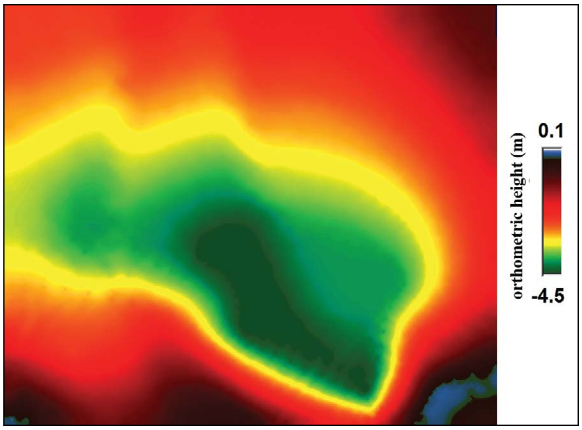

Figure 5- UAV-based DIFFDTM of the construction area.

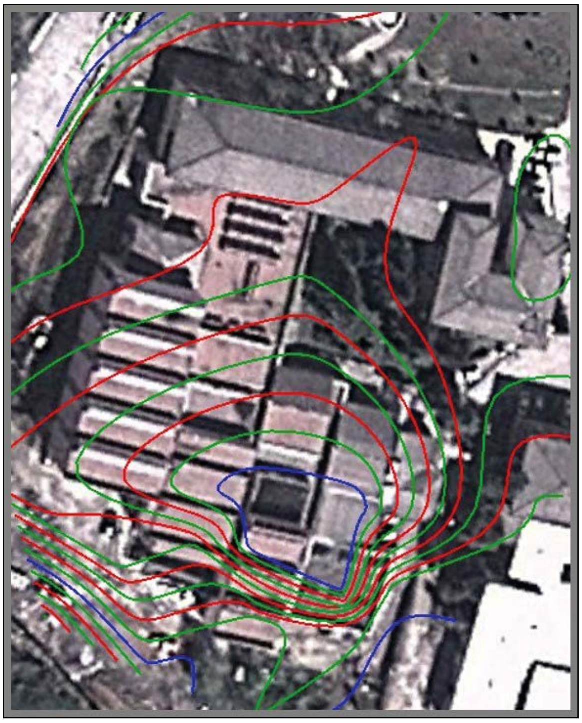

Figure 6- Grade elevation contour-lines on Google Earth.

As can be seen in the results, all of areal and volumetric temporal topographic change information can be easily achieved by a handmade UAV. For visual validation, the grade elevation contour-lines were processed on Google Earth image (Figure 6). By this way, first and last status of the study area can be clearly determined (please compare with figure 1).

5. Conclusion

In this research, high potential of unmanned air vehicle technique on areal and volumetric temporal topographic change detection was demonstrated. The application was performed in a construction area in Zonguldak Bulent Ecevit University Main Campus. The study area was monitored by a DSLR camera equipped handmade unmanned air vehicle during the construction activities. The geometries of obtained stereo models was corrected using ground control points which were measured by real time kinematic global navigation satellite systems. The ground and grade elevation data of the topography were achieved utilizing first and last flight data and digital terrain models were generated separately. By generating the differential digital terrain model, the areal and volumetric topographic changes were clearly calculated. The study demonstrated that unmanned air vehicle technology is very beneficial for precisely calculation of filling and excavation amounts in every demanded period in the construction areas.

References

Ai, M., Hu, Q., Li, J., Wang, M., Yuan, H., Wang, S. 2015. A robust photogrammetric processing method of low-altitude UAV images. Remote Sens 7:2302–2333. doi: 10.3390/rs70302302

Darwin, N., Ahmad, A., Zainon, O. 2014. The potential of unmanned aerial vehicle for large scale mapping of coastal area. IOP Conf Ser Earth Environ Sci 18:. doi: 10.1088/1755-1315/18/1/012031.

Deng, Y., Wilson, J.P., Bauer, B.O. 2007. DEM resolution dependencies of terrain attributes across a landscape. Int J Geogr Inf Sci 21:187–213. doi: 10.1080/13658810600894364.

Höhle, J. 2017. Generating topographic map data from classification results. Remote Sens 9: doi: 10.3390/rs9030224.

Karakış, S. 2012. İnsansız Hava Aracı Yardımıyla Büyük Ölçekli Fotogrametrik Harita Üretim Olanaklarının Araştırılması. Harita Dergisi 147:13–20.

Manfreda, S., McCabe, M.F., Miller, P.E., Lucas, R., Pajuelo Madrigal, V., Mallinis, G., Ben Dor, E., Helman, D., Estes, L., Ciraolo, G., Müllerová, J., Tauro, F., De Lima, M.I., De Lima, J.L.M.P., Maltese, A., Frances, F., Caylor, K., Kohv, M., Perks, M., Ruiz-Pérez, G., Su, Z., Vico, G., Toth, B. 2018*a*. Use of Unmanned Aerial Systems for Environmental Monitoring. Remote Sens 10(4):641. doi: 10.3390/rs10040641.

Manfreda, S., Dvorak, P., Mullerova, J., Herban, S., Vuono, P., Arranz Justel, J.J., Perks, M. 2018*b*. Accuracy Assessment on Unmanned Aerial System Derived Digital Surface Models, Preprints 2018, doi: 10.20944/preprints201809.0579.v1.

Rosnell, T., Honkavaara, E. 2012. Point cloud generation from aerial image data acquired by a quadrocopter type micro unmanned aerial vehicle and a digital still camera. Sensors 12:453–480. doi: 10.3390/s120100453.

Sørensen, L.Y., Jacobsen, L.T., Hansen, J.P. 2017. Low cost and flexible UAV deployment of sensors. Sensors (Switzerland) 17:1–13. doi: 10.3390/s17010154.

Swatantran, A., Tang, H., Barrett, T., DeCola, P., & Dubayah, R. 2016. Rapid, high-resolution forest structure and terrain mapping over large areas using single photon lidar. Sci Rep 6:1–12. doi: 10.1038/srep28277.

Teizer, J., Kim, C., Bosche, F. N., Haas, C. T., Caldas, C. 2005. Real-time 3{D} Modeling for Accelerated and Safer Construction using Emerging Technology. 539–543.

Watts, A.C., Ambrosia, V.G., Hinkley, E.A. 2012. Unmanned aircraft systems in remote sensing and scientific research: Classification and considerations of use. Remote Sens 4:1671–1692. doi: 10.3390/rs4061671.