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REAL-TIME 3D POINT CLOUD MAPPING WITH UAV LIDAR

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ABSTRACT

Accurate and timely availability of LiDAR data is vital in some cases. To make maps and facilitate monitoring of any environmental changes, LiDAR systems can be designed, carried by UAV platforms that can take off without major preparation. In this study, a real-time mapping system was designed that shortens the processes of target-based flight planning, regular trajectory determination and post-flight data processing. With this developed real-time LiDAR mapping system in laboratory, data is obtained instantaneously, so that the change of the area in question can be followed and quick solutions can be produced for the detected problems.

Introduction

In recent years, examining urban areas such as buildings, roads, vegetation, which are the areas where the fastest changes on earth can be Laser Image Detection and Ranging (LiDAR) data acquired by aircraft or satellites has been increasingly preferred (Awad, 2017; Yao, Qin and Chen, 2019). Due to the high cost and inflexibility, the spatial and temporal resolutions of manned aerial LiDAR systems are limited, especially when collecting high-resolution data in small areas (Li *et al.*, 2019). For smaller areas or when a higher density of data is needed, low-cost systems that offer a faster and easier solution are preferred due to their distribution efficiency, lightness, and flexibility (Carter *et al.*, 2012; Shan and Toth, 2012; Dutton, 2015; Toth and Jóźków, 2016). UAV systems supported by Global Positioning System/Inertial Measurement Unit (GPS/IMU) and autopilot systems have become a widely used remote sensing platform in various applications due to their features such as providing high temporal and spatial resolution data (Jiang *et al.*, 2017; Yao, Qin and Chen, 2019; Jiang, Jiang and Jiang, 2020). Due to ongoing improvements in aviation and image sensing technology, and in data retrieval processes have made rapid progress in the development and use of UAV LiDAR systems, covering a wide range of applications from mapping to forestry, agriculture to building, and powerline modeling (Fuad *et al.*, 2018; Sofonia *et al.*, 2019). When the suitability of the UAV LiDAR system for precision-scale mapping is evaluated, the not systematic of the flights, the potential effects of the flight parameters, and the limitations of repeatability and comparability are encountered (Tulldahl *et al.*, 2015). In order to overcome this situation, a series of studies such as long-term flight planning, autopilot systems, regular trajectory determination, post-flight data processing processes have been carried out (Sofonia *et al.*, 2019).

In this study, a real-time UAV-LiDAR mapping system was designed. This study, it was aimed to shorten the target-based flight planning, regular trajectory determination, and post-flight data processing processes. The instantaneous data obtained with this developed LiDAR mapping system using X3D file format and PHP programming language enables to produce fast solutions to the problems to be foreseen. Also this developed system is constantly renewed/improved with the development of web technology. High resolution for 3D point cloud density are allows thanks to acquiring more data from slower and longer flights.

Materials and Methods

The schematic representation of the UAV LiDAR mapping system and its components, the design and construction of which is planned in this study, is given in Figure 1. Accurate and timely can obtainable of LiDAR data is vital in some cases. However some factors such as weather conditions, fog, clouds, especially for high-altitude platforms, flight parameters of the vehicle (airport, runway, preparation time, etc.) during disaster periods may prevent obtaining accurate

and effective data. Ease of use can be achieved by reducing the altitude of the carrier system and extending the flight time for eliminating the effect of weather conditions. By this design, it was aimed to shorten the target-based low-altitude flight planning, regular trajectory determination and post-flight data processing processes.

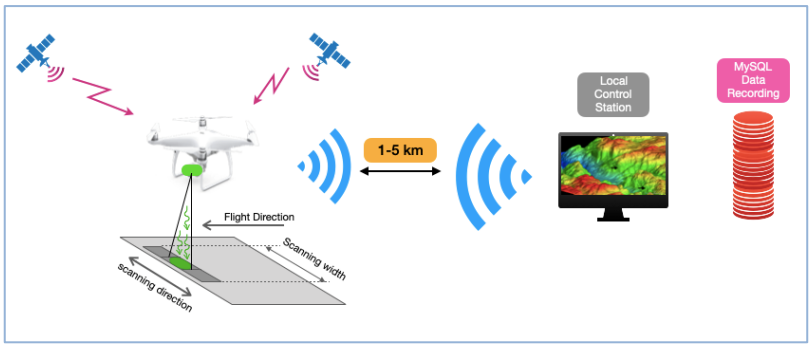


Figure 1. Schematic real-time data transfer system

Purposed with the designed LiDAR mapping system is to transfer the real-time data received from the system to the ground station wirelessly and to obtain the 3D topographic map of the examined region in a very short time. In our design, the 3D point cloud was obtained in real-time by using X3D file format and PHP programming language with the data obtained from the UAV LiDAR simulation system developed in the laboratory environment. X3D (Extensible 3D) is an XML-based and Web3D standardized file format suitable for 3D modeling that can run through a platform-independent web browser (Brutzman and Daly, 2007; Yoo and Brutzman, 2009; Mao and Cao, 2019). LiDAR data measured simultaneously with the coordinate information (GLONASS/GPS/Beidou, Barometer, and IMU data) obtained from the flight control card on the UAV is recorded in real-time with the telemetry device at a distance of 1-5 km to the ground station. In our developed simulation system, the coordinate information in the laboratory environment was obtained with precision Laser Range Finder (LRF) and IMU (6 axis accelerometer and gyroscope sensors).

Results and Discussion

With this modeling carried out in a laboratory environment 3D (x, y, z) point cloud data transmitted wirelessly from the LiDAR platform to the ground control station were presented to the user in real-time via a web platform (Figure 2).

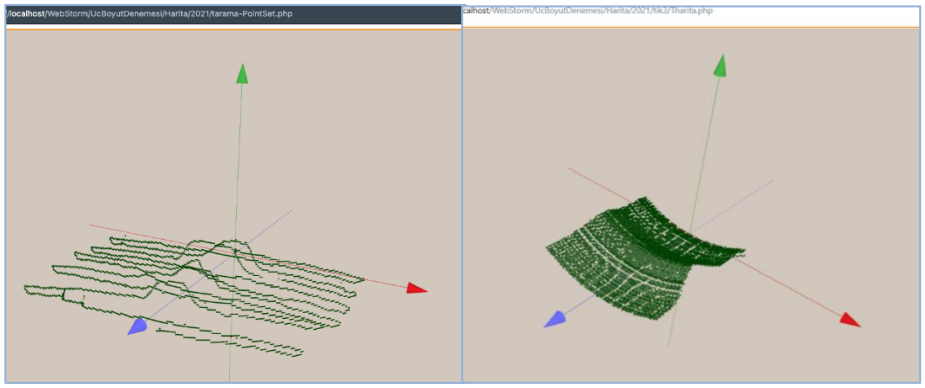


Figure 2. 3D point clouds in X3D scene

As a result of the experimental studies performed laboratory, a system close to the advanced LiDAR systems was designed and the real-time LiDAR mapping simulation results were obtained. All data collection processes were carried out wirelessly and a point cloud was created instantly. The obtained data with profiling and scanning processes carried out by moving the LiDAR at a constant speed on a platform set up in the laboratory environment to move at a constant height were visualized in 3D. This experimental simulation system developed in the laboratory using low-cost equipment has automated data processing controlled with the web as online.

Conclusion

In this study, a LiDAR mapping system was designed that shortens the processes of target-based flight planning, regular trajectory determination and post-flight data processing. Our developed LiDAR mapping system to obtain real-time data transfer has important advantage as providing of re-scanned quickly in cases where missing data detected. This system has

the potential capable of providing effective data production for areas where rapid solutions are needed such as urbanization, disaster investigation and cartography. This simulation study performed in the laboratory environment will integrate to real environment UAV LiDAR systems by using GPS and IMU data in future studies.

Keywords: *UAV LiDAR, Remote Sensing, X3D, 3D Modeling*

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References

Awad, M. M. (2017) 'Toward Robust Segmentation Results Based on Fusion Methods for Very High Resolution Optical Image and LiDAR Data', *IEEE Journal of Selected Topics In Applied Earth Observations And Remote Sensing*, 10(5). doi: 10.1109/JSTARS.2017.2653061.

Brutzman, D. and Daly, L. (2007) 'Event Animation and Interpolation', in *X3D*. Elsevier, pp. 187–220. doi: 10.1016/b978-012088500-8/50009-2.
Carter, J. *et al.* (2012) 'Lidar 101 : An Introduction to Lidar Technology , Data , and Applications', *National Oceanic and Atmospheric Administration NOAA Coastal Services*, (November), p. 76. doi: 10.5194/isprsarchives-XL-7-W3-1257-2015.

Dutton, J. A. (2015) *Topographic Mapping with LiDAR - GEOG 481, e-Education Institute, The Pennsylvania State University*. Available at: https://www.e-education.psu.edu/lidar/ (Accessed: 13 May 2015).

Fuad, N. A. *et al.* (2018) 'Accuracy evaluation of digital terrain model based on different flying altitudes and conditional of terrain using UAV LiDAR technology', *IOP Conference Series: Earth and Environmental Science*, 169(1). doi: 10.1088/1755-1315/169/1/012100.

Jiang, S. *et al.* (2017) 'UAV-based oblique photogrammetry for outdoor data acquisition and offsite visual inspection of transmission line', *Remote Sensing*, 9(3). doi: 10.3390/rs9030278.

Jiang, S., Jiang, C. and Jiang, W. (2020) 'Efficient structure from motion for large-scale UAV images: A review and a comparison of SfM tools', *ISPRS Journal of Photogrammetry and Remote Sensing*. Elsevier, 167(April), pp. 230–251. doi: 10.1016/j.isprsjprs.2020.04.016.

Li, J. *et al.* (2019) 'NRLI-UAV: Non-rigid registration of sequential raw laser scans and images for low-cost UAV LiDAR point cloud quality improvement', *ISPRS Journal of Photogrammetry and Remote Sensing*. Elsevier, 158(October), pp. 123–145. doi: 10.1016/j.isprsjprs.2019.10.009.

Mao, B. and Cao, J. (2019) 'HTML5 Based 3D Visualization of High Density LiDAR Data and Color Information for Agriculture Applications', *ISPRS Journal of Photogrammetry and Remote Sensing*. Elsevier, 169(August 2018), pp. 123–145. doi: 10.1088/1755-1315/169/1/012100.

Shan, J. and Toth, C. K. (2012) *Topographic Laser Ranging and Scanning Principles and Processing*. Second, *Taylor and Francis Ltd.* Second. Edited by J. Shan and C. K. Toth. Taylor and Francis Ltd.

Sofonia, J. J. *et al.* (2019) 'Modelling the effects of fundamental UAV flight parameters on LiDAR point clouds to facilitate objectives-based planning', *ISPRS Journal of Photogrammetry and Remote Sensing*. Elsevier, 149(August 2018), pp. 105–118. doi: 10.1016/j.isprsjprs.2019.01.020.

Toth, C. and Jóźków, G. (2016) 'Remote sensing platforms and sensors: A survey', *ISPRS Journal of Photogrammetry and Remote Sensing*, 115, pp. 22–36. doi: 10.1016/j.isprsjprs.2015.10.004.

Tulldahl, H. M. *et al.* (2015) 'Accuracy evaluation of 3D lidar data from small UAV', *Electro-Optical Remote Sensing, Photonic Technologies, and Applications IX*, 9649, p. 964903. doi: 10.1117/12.2194508.

Yao, H., Qin, R. and Chen, X. (2019) 'Unmanned aerial vehicle for remote sensing applications - A review', *Remote Sensing*, 11(12), pp. 1–22. doi: 10.3390/rs11121443.

Yoo, B. and Brutzman, D. (2009) 'X3D Earth Terrain-Tile Production Chain for Georeferenced Simulation', *Proceedings of Web3D 2009: The 14th International Conference on Web3D Technology*, pp. 159–166. doi: 10.1145/1559764.1559791.