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Drone LiDAR Application For 3D City Model

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Abstract

The availability of spatial information in 3D in a city that will apply the smart city concept is minimal or even non-existent. This makes the information conveyed less clear and less accurate. 3D map presentation is an indispensable component in the visualization of smart cities. The acquisition of spatial information in 3D can use several methods, one of which is the LiDAR (Light Detection and Ranging) drone. The Drone LiDAR is one of the new technologies in mapping surveys. Initially, LiDAR technology used a manned aircraft and had very large dimensions. Technological developments have made LiDAR portable using drones. Data acquisition was carried out using a multirotor-type Drone LiDAR from microdrones with a flying height of 60 meters above the ground. An area of 6 hectares in the Bulaksumur UGM area is the object of research for the 3D city model building. The objects mapped would range from one-story to five-story buildings. The results of data acquisition in the form of a point cloud are then modeled into a 3D building with the micro station software plugin Terra Solid and Terra Model. Modeling is done using automatic and manual methods. The results obtained are in the form of a 3D city model with a LOD 2 level of detail. The amount of vegetation in the mapped area makes the point cloud detail on the front side of the building less dense. However, the accuracy obtained is quite high, ranging from 0,4 to 5,1 cm, making it suitable for making 3D city models with LOD 2 detailed specifications.

Keywords: 3D model, smart city, Drone LiDAR

1. Introduction

1.1 Sub Introduction

The concept of smart city was developed as one of the urban planning concepts in the world in recent years. This concept originally developed since the 1990s when internet connections began to go global since it was first launched in 1969. According to Allwinkle&Cruickshank (2011), it was the development of the internet during that period that made services easier with information that could be accessed through sites provided by the city government. Although it is still limited to a one-way service with only static and limited information about urban areas, land use, and planning, it is undeniable that this is the beginning of the smart city concept.

Entering spatial information in 3D in a city that will apply the smart city concept is minimal or even non-existent. This makes the information conveyed less clear and less accurate. The presentation of the 3D city model is an indispensable component of visualization in a smart city.

Ali Ibadurahman in 2015 conducted research on 3D city modeling using LiDAR data and large Aerial Photo formats. In this study, some building objects can be made 3D and some cannot be made 3D. This is due to misclassification and editing during data processing.

Rebbeca (O.C), et al conducted a study on 3D Building using LiDAR data in 2014. In this study, LiDAR data in the form of point clouds was converted into CAD data and then the building was reconstructed from that data. The complexity of the building will affect the model to the real picture.

Acquisition of spatial information in 3D can use several methods, one of the drones LiDAR (Light Detection and Ranging). The Drone LiDAR is one of the new technologies in mapping surveys. Initially, LiDAR technology used a manned aircraft and had very large dimensions. Technological developments make LIDAR able to be carried using drones.

Acquisition using the Drone LiDAR provides a very dense pointcloud output and can be used as initial data for making 3D buildings being measured. The density of acquisition points can be up to 130 points per square meter, making the 3D map creation process easier to do. In addition, the drone is equipped with a camera that can provide a visual image of the object being measured

Therefore, every city government needs to create a 3D city model to support the 3D smart city applied in the city. The available 3D city models will assist in every decision making so that it is more accurate. Drone LiDARs are an easy and relatively inexpensive solution for the data acquisition process.

2. Materials and Methods

2.1 Data

In this study, the LiDAR data used was the result of an acquisition made on August 25, 2020 in the UGM campus area. Data acquisition uses a multirotor type Drone LiDAR supported by PT. Geotronix as the official dealer of LiDAR Microdrones in Indonesia. In addition, the acquisition using the GNSS and Totalstasion tools is used to compare LiDAR data with actual conditions.

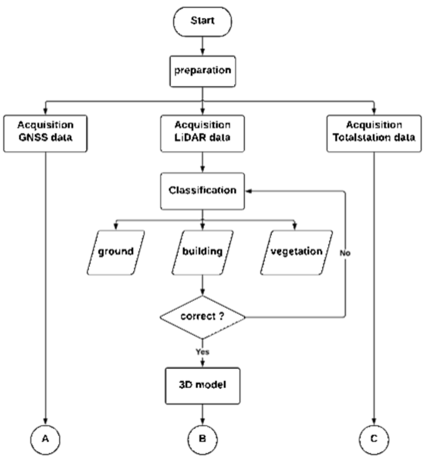
The lidar drone used is a MD LiDAR 1000 type microdrone. LiDAR is able to obtain a point density of 150 points/m2 with a data acquisition height of 60 meters above the ground and a drone speed of 60 m/s. In addition to the LiDAR sensor, there is an embedded camera sensor with 10 MP specifications.

Table 1. camera sensor with 10 MP specifications

Date Acquisition	August 25, 2020
Platform	Multirotor drone LiDAR
Type	MD LiDAR 1000 microdrone
Density	150 pts/m2
Height of Flight	60 m
Speed of Flight	60 m/s

2.2 Stage of Research

Research stages can been in **Figure 1.**



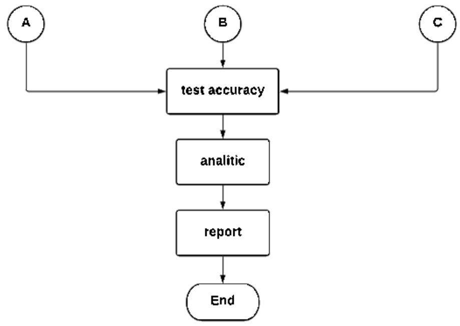


Figure 1. Research stage

2.3 Drone LiDAR

LiDAR is a measurement instrument that does not touch objects directly and produces quantitative 3D digital representations (for example point clouds) of the surface in a certain field of view with certain measurement uncertainties (Vosselman & Dijkman, 2001). One of the technologies with the laser scanning method is ALS. Airborne Laser Scanning (ALS) or another term is Light Detecting and Ranging (LiDAR) is a mapping technology that uses an active sensor remote sensing system that can produce information about the characteristics of the earth's surface. The working principle of ALS is to use active sensor remote sensing technology whose energy source comes from sensors installed on the flying vehicle. The object to be recorded receives the laser and reflects it back to the sensor installed on the flying vehicle (Soeta'at, 2009).

The result of the LiDAR acquisition is a collection of points called point clouds. Point clouds are a collection of points, each of which has 3D coordinate information (x, y and z) and the intensity value of the reflected laser signal (Staiger, 2003). Point clouds are able to represent the geometric shape of a real object in the form of a collection of points. The use of point cloud data obtained from laser scanner tuning can be formed a 3D model that makes it easier to visualize data (Alkan & Karsidag, 2012). LiDAR concept can been in **Figure 2.**

Figure 2. LiDAR Concept (www.microdrones.com)

2.4 Classification of LiDAR Data

LIDAR data can be used as the main source for automatic building reconstruction to meet various application needs in the field of reformation. The obtained point cloud density and increased accuracy provide great potential in extracting topographic objects. However, there were major obstacles to reconstructing walls and roofs of buildings. This is due to the low distribution of the LIDAR points on the vertical facade (He et al., 2012).

Using LIDAR technology, a 3D representation in the form of a point cloud can be used to help generate 3D buildings more effectively and efficiently. Many techniques were developed using LIDAR data input to create automated workflows for urban modeling. To perform 3D building modeling, point cloud classification has an important role. In the classification process, the division of the point cloud into the vegetation, ground and building layers will make it easier to carry out 3D building construction (Zhou and Neumann, 2008).

Classification separates cloud points into layers of vegetation, building and ground; planes are drawn from the building patches and the boundaries of each detected plane. The building model was reconstructed from the classification result boundary points (Zhou and Neumann, 2008; Sun and Salvaggio, 2013).

2.5 3D City Model

3D city model or urban area 3D model is a 3D model that represents an urban area in mathematical form. 3D city models display man-made and natural features including land surface models, building models, vegetation models, as well as road models and transportation systems. According to Ross (2010), a virtual 3D city model is defined as a three-dimensional city-based representation of a real computer that can be navigated interactively on a computer device. A virtual 3D city model basically consists of geospatial data that depicts an urban topography - the building environment and underlying natural features on the one hand and a system that converts the data into an interactive three-dimensional representation on the other.

The most commonly used 3D city model classification is based on the level of detail of the building model or the level of detail (LOD). There are 5 levels of building detail that explain examples of increasing geometry and detail in building models (Biljecki, 2017). The division of the 3D city model classification based on the level of detail of the building model can be seen in **Figure 3.**

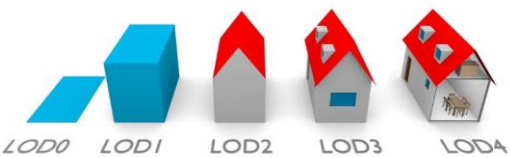


Figure 3. Level of Detail 3D building model (Biljecki, 2017)

The division of 3D city model classification based on the level of detail of the building model is divided into 5 levels, namely LOD0 to LOD4. Figure 5 shows the different geometric shapes of the building model at each different level. The LOD0 building model is a two-dimensional (2D) building model that represents the location of the building model. The LOD0 model is not a 3D building model. The LOD0 building model is enhanced by dragging the model vertically to produce a 3D model of the building that has volume. The results of drawing towards the vertical direction of the LOD0 building model produce a 3D model of the building at the LOD1 level. The LOD1 3D model of the building has a model shape with primitive geometry in the form of cubes or blocks without a roof. Increasing the LOD1 level to the LOD2 level is done by adding a roof part to the 3D model. LOD3 is a 3D model of a building with additional building details such as doors, windows, and other details. The 3D model of the LOD3 building is in a position to resemble the original building being modeled due to the addition of detailed building features. The highest LOD level is LOD4. LOD4 is an increase in the 3D model of the LOD3 building with the addition of interior features in the building (Biljecki, 2017).

2.6 Accuracy Test

The accuracy test is a test carried out on a sample of size data with other data that is considered correct to obtain the accuracy value. This research was carried out by calculating the RMSE distance / height and standard deviation. Root Mean Square Error (RMSE) measures how much error there is between two data sets. In other words, comparing the predicted value and the observed or known value.

The RMSE value test is done by calculating the difference between the calculated distance that is considered correct and the distance from the results of data processing. RMSE is the root value of the average difference in data count between the data that is considered correct and the processed data. RMSE can be calculated by the equation 1 and 2 (Soetaat, 2009).

$$\text{RMSE} = \sqrt{\frac{\sum(\text{D})^2}{\text{n}}} \quad (1)$$

$$D = |R - R_1| \quad (2)$$

Where :

RMSE	: Root Mean Square Error
D	: Difference distance
N	: Distance
r	: Sample

3. Result and Discussion

3.1 Classification of LiDAR Data

Point cloud classification is carried out to determine differences in objects recorded from the LiDAR sensor. Classification is carried out into three main objects, namely land surface, vegetation and buildings. Classification is done automatically by entering several parameter values. LiDAR can be used to determine large-scale urban land cover accompanied by building modeling (Yan et al., 2015). The results of the classification process can be seen in **Figure 4.**

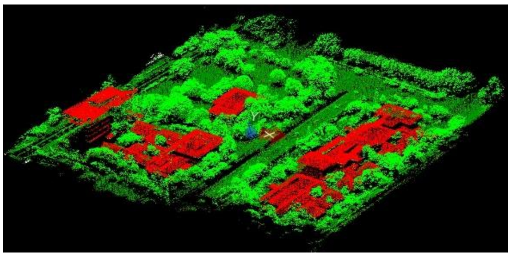


Figure 4. Classification point cloud

In Figure 4 it can be seen that the building has a red point cloud, the difference in color is given only to the building object. This is done to facilitate the 3D digitizing process in the interpretation of building objects. Classification of buildings uses the minimum size parameter: 16 m^2, the use of these parameters is based on the accuracy of the 3D city model at LOD 2. In recent years, many different approaches have been developed to separate ground points from object points, including mathematical morphology, adaptive and robust filtering, and unsupervised segmentation (Yunfei et al., 2008).

3.2 3D Building Model

3D building modeling is done using Microstasion software with TerraScan and TerraModel plug-ins. The available point cloud data is digitized so that it becomes vector data. 3D modeling is done manually. Building digitization is carried out on the edge or boundary of the point cloud as a result of the classification of building objects. The results of the digitization process can be seen in **Figure 5.**

In Figure 5, you can see the results of 3D building modeling by manual digitizing. No buildings are covered with vegetation, making it easier for the 3D modeling process.

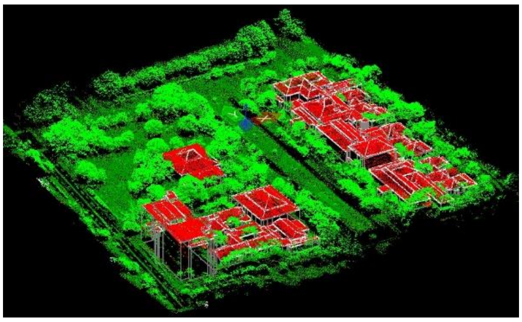


Figure 5. Digitizing 3D Model

The roof of the building looks quite detailed according to the appearance in actual conditions. In the absence of point cloud data on the side of the building, the resulting facade is perpendicular to the formed roof. Visualization of a 3D city model that is formed from the results of 3D buildings and ground surface can be seen in **Figure 6**.

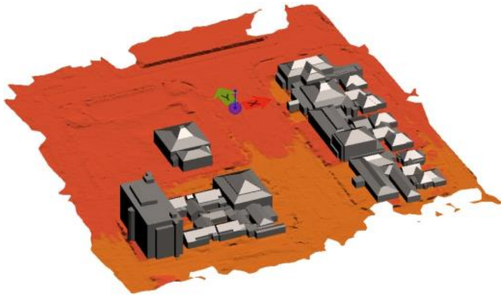


Figure 6. Visualization 3D city model

The resulting 3D city model has a LOD 2 level of detail. This is because there is no information on the facade from the side of the building. However, the roof of the building has a high degree of detail. The quality produced by this 3D city model is in the middle category, it is necessary to add slanted photos from the side of the building to make it high quality.

3.3 Accuracy Test

There are two pieces of accuracy tests conducted in this study. The first is to test the vertical data accuracy of the Drone LiDAR. The accuracy test was carried out by comparing the size of the Drone LiDAR data with the results of the GNSS data observation using the static method. The results of data comparison can be seen in **Table 1**.

The vertical sample points in this study were 6. The results of the vertical LiDAR data test show quite high accuracy, ranging from 2.4 cm to 17.3 cm. The RMSE generated from this vertical test is 8.4 centimeters. Based on the Regulation of the Head of BIG No. 15 of 2014, the vertical test is carried out with a linear error of 90% or often called the LE 90 test. In this study the LE 90 results show a value of 0.1381 so that it is included in the vertical accuracy of class 1.

The second accuracy test that is carried out is the accuracy test of the resulting building model. This test is done by comparing the results of the 3D building model with the results of measurements in the field using Total Stasion. The results of the comparison of these data can be seen in **Table 2**.

Table 1. GPS and LiDAR Data Comparison

Point	X	Y	Elevation (m)		Elevation Deviation (D Z)	$(D Z)^2$
			GPS	LiDAR		
GCP1	431282.356	9140642.899	154.054	154.881	0.173	0.0298
GCP2	431289.716	9140666.780	155.253	155.196	0.058	0.0033
GCP3	431296.536	9140689.957	155.451	155.427	0.024	0.0006
GCP4	431298.099	9140646.123	155.025	154.997	0.029	0.0008
GCP5	431262.053	9140643.114	154.758	154.699	0.059	0.035
GCP6	431310.731	9140747.446	156.053	156.118	0.066	0.0043
					Total	0.0423
					Average	0.0071
					RMSE	0.0840
					Accuracy LE90	0.1381

Table 2. Comparison between actual and model data

No.	Distance (m)		Distance's Deviation (D) (m)	D^2 (m)
	Actual	Model		
1	22.320	22.358	0.038	0.0014
2	6.988	6.993	0.005	0.0000
3	7.451	7.502	0.051	0.0026
4	6.972	6.976	0.004	0.0000
5	22.438	22.390	0.048	0.0023
Minimum Deviation			0.004	
Maximum Deviation			0.051	
			Total D^2	0.0064
			Average D^2	0.0013
			RMSE	0.0357

In table 2 it can be seen that of the five samples it shows that the accuracy of building modeling is very high. One of the things that happened was between 0.4 cm s.d. 5.1 cm. The RMSE obtained was 3.5 cm.

4. Conclusion

The use of the Drone LiDAR for 3D city model data acquisition is very precise, at a relatively low cost and with a high enough accuracy. The level of detail of building modeling obtained is LOD2. The vertical accuracy obtained ranged from 2.4 cm to 17.3 cm and the accuracy of modeling ranged from 0.4 cm to. 5.1 cm.

5. References

Alkan, R. M., & Karsidag, G. (2012). *Analysis of The Accuracy of Terrestrial Laser Scanning Measurements*. 16.

Allwinkle, S., & Cruickshank, P. (2011). *Creating Smart-er Cities: An Overview. Journal of Urban Technology, 18*(2), 1–16. https://doi.org/10.1080/10630732.2011.601103

Biljecki, F. (2017). *Level of detail in 3D city models* [Delft University of Technology]. https://doi.org/10.4233/UUID:F12931B7-5113-47EF-BFD4-688AAE3BE248

He, Y., Zhang, C., Awrangjeb, M., & Fraser, C. S. (2012). *AUTOMATED RECONSTRUCTION OF WALLS FROM AIRBORNE LIDAR DATA FOR COMPLETE 3D BUILDING MODELLING*. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXIX-B3*, 115–120. https://doi.org/10.5194/isprsarchives-XXXIX-B3-115-2012

Ibadurohaman, A. (2015). Pemodelan Kota Tiga Dimensi Menggunakan Data LiDAR dan Foto Udara Format Medium. Laporan Tugas Akhir. Jurusan Teknik Geodesi. Universitas Gadjah Mada. Yogyakarta.

Ross, L. (2010). *Virtual 3D City Models in Urban Land Management—Technologies and Applications*. TU Berlin.

Rebecca (OC), dkk. 2014. "*3D City Modelling from LiDAR Data*". Reaserch Gate, Chapter 10.

Soeta'at. (2009). Pengantar LiDAR : Konsep, Proyek dan Aplikasi. Universitas Gadjah Mada.

Staiger, R. (2003). *Terrestrial Laser Scanning Technology, Systems and Applications*. 10.

Vosselman, G., & Dijkman, S. (2001). *3D BUILDING MODEL RECONSTRUCTION FROM POINT CLOUDS AND GROUND PLANS*. *International Archives of Photogrammetry and Remote Sensing*, *XXXIV-3/W4*, 7.

Yan, W. Y., Shaker, A., & El-Ashmawy, N. (2015). *Urban land cover classification using airborne LiDAR data: A review*. *Remote Sensing of Environment*, *158*, 295–310. https://doi.org/10.1016/j.rse.2014.11.001

Yunfei, B., Guoping, L., Chunxiang, C., Xiaowen, L., Hao, Z., Qisheng, H., Linyan, B., & Chaoyi, C. (2008). *CLASSIFICATION OF LIDAR POINT CLOUD AND GENERATION OF DTM FROM LIDAR HEIGHT AND INTENSITY DATA IN FORESTED AREA*. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXVII*(B3b), 6.

Zhou, Q. Y. and Neumann, U. (2008). Fast and extensible buildingmodeling from airborne lidar data. In Proc. of the 16th Inter-national Conference on Advances in Geographic InformationSystems, ACM GIS 2008.