Modeling existing buildings three-dimensional (3D) using unmanned aerial vehicles: A study case in Binus Syahdan Campus Building

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Abstract. Developments in the field of photogrammetric technology using UAV (Unmanned Aerial Vehicle) make it easier to represent mapping results quickly and accurately. Along with the growing need for spatial use, both horizontally and vertically, have implications for the need of accurate spatial data both in two-dimensional (2D) or three-dimensional (3D) space. 3D visualization and modeling is a representation of the surface of the earth with the aim of supplying the appearance of the earth along with the whole above it more realistic and able to provide a broader perspective compared to 2D visualization or conventional maps. In this study, the drone-based UAV was used, namely DJI Mavic Air to collect geometric data on the Syahdan campus. The digital data that has been recorded by the UAV is then processed into three-dimensional modeling using DroneDeploy software. DroneDeploy software is cloud-based and is generally used for aerial mapping, in this study it is used in making 3D modeling because of its efficient. The elevation data at each building point measured using a drone-based UAV are compared with the as-built drawing of the Syahdan Campus, Binus. The root mean square value of the comparison of elevation distance between 3D model and as built drawing is 0.47 meters.

Keywords: photogrammetry, UAV, drone, 3D modeling, DroneDeploy

1. Introduction

Currently, range-based and image-based survey techniques are used in mapping existing buildings. This building mapping technique is called photogrammetry mapping. In carrying out survey activities of existing buildings using a close-range photogrammetry method [5] [6]. Close-range photogrammetry can function by using software, where it makes easy for users in mapping and image-based modeling activity [7] [8]. Photogrammetry is increasingly developing with the creation methods and various supporting software automatically from aerial photo data, effectively and efficiently by utilizing aerial photographs of Unmanned Aerial Vehicle (UAV).

The use of UAV was first used in the field of archaeological surveys, where the mapping results obtained provide a general description of a location that has never been seen before [4] [9], using either fixed-wing [10] or a rotary-wing UAV [3]. Other applications of UAVs are related to close range modeling or building inspection using rotary-wing type [1] [2] [12]. The data obtained from these measurement methods are digital data. Understanding of the acquisition and interpretation of digital data is very important these days. For this reason, engineers who can operate measuring tools and test the methodology used in digital data retrieval are required. So that the results will be easy for non-technical people to understand and useful in integrating into different scientific fields[11].
One type of UAV that can be used for photogrammetry needs is a drone. Drones are able to produce several images that can be adjusted to the area and height of the flight, where it depends on the desired scale and resolution. The results of the image data will be processed using a software, there are various kinds of software that supports the processing of image data, one of the opensource software that can be used online, namely DroneDeploy. The software is one that has a simple and easy user interface in processing photo data. In this study, a drone-based UAV will be used to do 3D modeling of the BinusSyahdan Campus building, and to test the results of the 3D modeling, the elevation distance from the model to the as built drawing will be compared.

2. Methodology

2.1 Study Area

3D modeling will be carried out on the Bina Nusantara University Syahdan Campus building as shown in Figure 1.

![Figure 1. Syahdan campus building](image)

2.2 Equipment

Aerial photographs of the BinusSyahdan Campus building will be taken with UAV Drone as shown in Figure 2. The drone used is a DJI product, with the "DJI Mavic Air" series which has four propellers with each protector. Table 1 shows the technical parameters of DJI mavic air.

![Figure 2. UAV-DJI mavicair](image)
Table 1. Technical parameters of DJI Mavic Air

| Aircraft                  |        |
|---------------------------|--------|
| Weight (battery & propellers included) | 430 g  |
| Max ascent/descent speed  | 4 m/s/3 m/s |
| Max flight speed (near sea level, no wind) | 19 m/s (sport mode) |
| Max flight time (no wind)  | 21 minutes (at a consistent 6.9 m/s) |

| Camera                    |        |
|---------------------------|--------|
| Operating environment temperature | 0°C - 40°C  |
| Sensor size               | 1/2.3” CMOS |
| Effective pixels          | 12 MP   |
| Resolution                | 4056×3040 |
| Recording FOV             | 85°     |

| Remote Control            |        |
| Communication distance (open area) | CE Compliance: 500 m; FCC Compliance: 4000 m |

2.3 3D Modeling Software

3D modeling will be done using DroneDeploy software. The DroneDeploy software automates drone flights and makes it very easy to capture aerial images. The DroneDeploy software platform processes UAV images using computer vision and convert them into 2D, 3D maps, models and more. Figure 3 shows the DroneDeploy flight plan.

![Figure 3. DroneDeploy flight plan](image)

3. Results and Discussion

3.1 UAV Aerial Photo

Figure 4 shows the aerial photographs obtained using DJI Mavic Air drone, with double grid flight patterns to maximize modeling accuracy. Aerial photographs taken in this study were 318 photos, with front overlap and side overlap settings of 78% and mapping flight speed of 3 m/s, and it took about 20 minutes to complete the flight mission.
Figure 4. Aerial photograph

3.2 Orthomosaic Photo

One of the results of the photo processing using DroneDeploy is in the form of orthomosaic photo arranged from several photos. The results of the orthomosaic photo can be seen in Figure 5. There is defective modeling in Building H (east building). The level of accuracy of orthomosaic photos is greatly influenced by several factors such as the number of photographs, flight height, and the percentage of overlap for each photo. The lower the flight height, the resulting photo is increasingly clear to the intended object, but the coverage area of the photo is small, and vice versa. The percentage of overlap also largely determines the number of photos produced from aerial photography. The greater the percentage of overlap, the more photos will be produced, and the photo processing time will take longer. The orthomosaic coverage can be seen in Figure 6.

Figure 5. Orthomosaic photo
Figure 6. Orthomosaic coverage

3.3 Point Cloud

After orthomosaic photographs are produced, for the needs of three-dimensional modeling, the aerial photo data is converted into a point cloud, which is a three-dimensional visualization consisting of thousands or even millions of georeferenced points. In the three-dimensional modeling of the BinusSyahdan Campus building, point cloud data generated were 21 million points, with a density of 1208.88 points/m$^2$.

Figure 7. Point cloud

3.4 3D Modeling

Point cloud data will then be refined into a three-dimensional modeling with a meshing process, with mesh triangles of 1.4 million triangular polygons.
3.5 Digital Elevation Model

To check the elevation distance, elevation data from the three-dimensional modeling is required. The resulting elevation data is DEM (Digital Elevation Model), with GSD (Ground Sample Distance) accuracy of 3.02cm/pixel. Briefly, GSD in digital photo terms is how big a pixel is on the surface of the image. DEM result can be seen in Figure 9.

From the DEM result, it can be seen that the ground elevation is negative. Therefore, the elevation calibration needs to be done. Elevation calibration is done by changing the elevation value at the take off drone location to 0 m. This point represents the elevation of 0 m from the 3D modeling.
3.6 Elevation Distance Comparison Analysis

The elevation distance check will be carried out on every corner of the building and the roof top, then compared to the as built drawing of the BinusSyahdan Campus Building. Elevation checking in three-dimensional modeling is done by placing coordinate points on each corner of the roof and also roof tops (Figure 11). By placing these coordinate points, automatically the elevation at that point can be known through the results of the DEM. Elevation comparison can be seen in Table 2.

| Label | 3D Modeling Elevation (m) | As Built Drawing Elevation (m) | $|\Delta|$(m) |
|-------|---------------------------|-------------------------------|--------|
| 1     | 19.80                     | 19.40                         | 0.40   |
| 2     | 19.89                     | 19.40                         | 0.49   |
| 3     | 19.46                     | 19.40                         | 0.06   |
| 4     | 19.22                     | 19.40                         | 0.18   |
| 5     | 20.34                     | 20.40                         | 0.06   |
| 6     | 20.42                     | 20.40                         | 0.02   |
| 7     | 16.17                     | 17.00                         | 0.83   |
| 8     | 12.12                     | 12.40                         | 0.28   |
| 9     | 15.89                     | 17.00                         | 1.11   |
| 10    | 13.54                     | 15.00                         | 1.46   |
|       | Total difference          |                               | 4.89   |
|       | Average difference        |                               | 0.49   |
|       | RMS                       |                               | 0.47   |
From the results of the comparison table above, it can be concluded that the largest difference in measurement error is 1.46 m on label 10, and the smallest measurement error is 0.02 m on label 6, and also the average total difference of 0.49 m is obtained, with an RMS of 0.47 m. Measurement errors that are too significant can be caused when recording aerial photographs there are low points around the building, in the form of recorded grass, so that grasses with high elevations are considered as ground during classification, whereas the zero elevation reference is completely from the ground.

4. Conclusion

Based on the resultsshown that the distance difference from 3D modeling and as built drawing ranged from 0.02 meters to 1.46 meters, with an average difference of 0.49 meters, and RMS of 0.47 meters. This is due to the possibility that the 3D modeling is not very accurate, however the 3D modeling generated from this method are in the form of simple model, detailed structures on buildings or objects are not produced in detail on each side of the model, due to limitations in location, time, and the method itself.

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