Rapid mapping of landslide disaster using UAV-photogrammetry

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Abstract. Unmanned Aerial Vehicle (UAV) systems offered many advantages in several mapping applications such as slope mapping, geohazard studies, etc. This study utilizes UAV system for landslide disaster occurred in Jombang Regency, East Java. This study concentrates on type of rotor-wing UAV, that is because rotor wing units are stable and able to capture images easily. Aerial photograph were acquired in the form of strips which followed the procedure of acquiring aerial photograph where taken 60 photos. Secondary data of ground control points using GPS Geodetic and check points established using Total Station technique was used. The digital camera was calibrated using close range photogrammetric software and the recovered camera calibration parameters were then used in the processing of digital images. All the aerial photographs were processed using digital photogrammetric software and the output in the form of orthophoto was produced. The final result shows a 1: 1500 scale orthophoto map from the data processing with SfM algorithm with GSD accuracy of 3.45 cm. And the calculated volume of contour line delineation of 10527.03 m³. The result is significantly different from the result of terrestrial method equal to 964.67 m³ or 8.4% of the difference of both.

1. Introduction
Photogrammetry is a process to obtain an information of an object by measurements on an aerial photograph result of the object. While photo interpretation is defined as an extraction of qualitative information about aerial photographs of an object by human visual analysis and photographic evaluation. The new terminology using Unmanned Aerial Vehicle or called as UAV is a supportive platform for photogrammetric measurements. This standard UAV makes it possible to track position and orientation of sensors that are implemented in local systems or global coordinates [3]. UAV have a high effectiveness in the term a lower cost and faster time than the conventional vehicles. It is suitable to apply for mapping in a small scope. The UAV-Based system has not been optimally used for topology mapping, since it less accurate than terrestrial mapping survey. This because in general, the UAV system is obtained by non-metric camera which has some geometric limitation. However, the use of UAV has some advantages, such as: (a) cost-effective, (b) the accuracy can be improved by camera calibration, (c) fast in mapping production, and (d). The UAV platform has less weight that make it more portable [2]. UAV platforms are nowadays a valuable source of data for inspection, surveillance, mapping and 3D modeling issues. New applications in the short- and close-
range domain are introduced, being the UAVs a low-cost alternatives to the classical manned aerial photogrammetry [5].

This research will experiment and analyze of rapid mapping using UAV at landslide disaster location. One of landslide disaster that happened in Indonesia was landslide disaster in Jombang Regency, East Java [5]. The data used from aerial photography of non-metric camera set on the rotary-wing UAV. Data obtained is photo data that can be processed into orthophoto map. The final result of this research is analyzing of the Digital Surface Model (DSM) data and the landslide volume calculation using SfM algorithm.

2. UAV-photogrammetry System

Currently drones have a variety of shapes, sizes, configurations, and functions. The presence of a camera device with a lightweight and compact size but has good quality. DJI Phantom Aerial UAV Drone Quadcopter one that weighs not more than 2 kilograms where there is already a camera installed safely and neatly. The drone can be controlled by remote control within 1000 meters. Ready To Fly: Complete fuselage ready to be directly flown consists of Aircraft Kit, servo ESCMotor, BrushlessTx/Transmitter/RemotRx Receiver, Propane Rover, Adapter, Propeler, Battery Charger and AutoPilot. Phantom is a drone that have models waypoint navigation and can now be used for photogrammetry. This quadcopter uses the latest IMU, flight control stabilization technology to fly super still along with a 4k stabilized integrated gimbal and camera. This will create accurate point clouds and perfect 3D maps stitched together using software. Waypoint navigation is very important for creating accurate 3D photogrammetry images. The Dji Phantom 3 Advance used the “Draw Waypoints” for it’s autonomous programmed flight.

![Diagram and drawing of Dji Phantom 3 Advance](image)

This system consists of Battery & Propellers Included : 1280 g, Diagonal Size (Propellers Excluded) : 350 mm, Max Flight Time : Approx. 23 minutes, Satellite Positioning Systems : GPS/GLONASS, Sensor : 1/2.3” CMOS, Effective pixels: 12.4 M (total pixels: 12.76 M), Camera Sony EXMOR FC300S, Focal length : 3.64 mm. Lens : FOV 94° 20 mm (35 mm format equivalent), f/2.8, Electronic Shutter Speed : 8 - 1/8000 s, Image Size : 4000 × 3000 and Range distances of up to 3.1 miles (5 kilometers). This type of drone is known as Rotary-wing or Vertical Take-Off and Landing type which is currently commonly used by the public because it does not require special skill in controlling it as well as a lot of market with affordable price. But now it has been equipped with various high-tech features that make it possible to do photogrammetric mapping with ease. Among them is the ability to autopilot the waypoint tracking that will make it easier when making the flight path. As a complement in this system also has many types of data processing from the Open Source (VSFM, MeshLab, etc.) to the license software (AgiSoft, Pix4D, Menci, etc.) to get the results of orthophoto.
3. Data Acquisition
Data acquisition begins with terrestrial measurements. Retrieval of coordinate data for photo GCP and terrestrial measurement control points used the Topcon GPS Geodetic tool for ± 1 hour of each point. The number of points taken was about 6 points (2 control points and 4 GCP points). For height spot measurement is using tachymetry method, there are divided into two-way framework, i.e. basic measurement and detailed measurement. The basic framework or point control is a new point created by the author. Object control point is measured by GPS Geodetic with detail point measurement using Total Station. Observation of detail points taken are angle data, distance and elevation.

| Control Point (name) | Coordinates | Elevasi (meter) | Note       |
|----------------------|-------------|-----------------|------------|
|                      | X-UTM (meter) | Y-UTM (meter)  |            |
| Base                | 9153136.352  | 648068.402      | 122.325    | Musholla   |
| BM-01               | 9153191.402  | 648123.283      | 125.996    | TS-1/GPS   |
| BM-02               | 9153201.676  | 648128.231      | 126.966    | TS-2/GPS   |
| BM-03               | 9153094.941  | 648138.961      | 125.433    | Home Resident |
| BM-04               | 9153121.707  | 648049.012      | 122.514    | Musholla Corner |
| BM-05               | 9153129.140  | 648018.297      | 121.787    | School Corner |

The measurement result shows that the coordinate of the measured area was 0.398 ha. The coordinates result can be made as DSM contours and landslide areas contours. Each color in DSM and each different contour line show the different heights. The next procedure is the acquisition of aerial photograph data. UAV-photogrammetry is divided into two-way frameworks in the field, i.e. take photo data using UAV-Quadcopter and GCP measurement with GPS Geodetic tool. The GCP coordinate data of photo data taken was about 60 photos. Data processed to obtain orthophoto map using image processing software with SfM algorithm with processing time are: align: 1 hour 35 minutes, dense cloud: 3 hours 29 minutes and mesh: 30 minutes.

4. Results and Discussion
Coordinates obtained by photographs can be made as contour and DSM to determine the surface shape of the measurement area. The measurement appearance of rough surfaces, this is due to the many results of the cloud point of the UAV varies due to variations of altitude. Also the appearance of contours that seem short and dashed, due to the value of significant altitude variations are different.

| No | Activity | UAV photogrammetry | Terrestrial (Total Sta) | Note                                      |
|----|----------|--------------------|-------------------------|-------------------------------------------|
| 1  | Tools used | Drone/UAV multicopter | Total Station        |                                           |
| 2  | Personels | 2                  | 4                       |                                           |
| 3  | Time retrieval in the field* | 65 minutes | 175 minutes | *Time required without GPS measurement |
| 4  | Data obtained | Aerial Photo       | Angle, Distance, Elev. |                                           |
| 5  | Numbers of GCP | 4                 | 2                       |                                           |
The differences of the two methods used in this study between UAV-photogrammetry and terrestrial method showed table above. The UAV-photogrammetry method requires fewer personnel and faster data retrieval time than the terrestrial method.

**Table 3.** Table showing comparison volume of UAV-photogrammetry and terrestrial.

| No | Elements                  | UAV photogrammetry | Terrestrial (Total Sta) | Note |
|----|---------------------------|--------------------|-------------------------|------|
| 1  | Spot height (point)       | 8967               | 260                     |      |
| 2  | Volume (m$^3$)            | 10527.1            | 11491.7                 |      |
| 3  | Difference (m$^3$)        | 964.7              |                         |      |
| 4  | Percentage (%)            | 8.4                |                         |      |

Volume differences can be caused by differences in data retrieval methods and also by the differences in the number of measurement points. The differences of measurement points affect volume obtained. The volume obtained by UAV-photogrammetry with 8947 points are 10527.032 m$^3$ and 11491.708 m$^3$ by terrestrial method with 260 points then the volume difference is about 964.676 m$^3$. This study done a point reduction of the UAV-photogrammetry to determine the effect of point count measurement to the volume. The point reduction density was divided into two ways, i.e. 1. based on the nearest point and has the same coordinates with terrestrial point, 2. the points taken have an interval of one meter from the highest to the lowest point. Comparison of points can be seen in Table 6. Table 6 shows that the number of points greatly affected to the volume results.

![Figure 2](image-url)

**Figure 2.** Comparison of the DSM Form of the terrestrial Method (a) and UAV-photogrammetry (b)

Point differences affected not only on volume quantities but also on the shape and topography. The difference can be seen in DSM picture and contour. Figure 2 shows that the terrestrial method has a smooth surface shape and also regular elevation differences. While the UAV-photogrammetry method has a rough surface shape and much small piles of soil formed so that it resembled the original object. In addition, contour shapes with 0.15 m intervals of both methods have different line densities and also
differences in the height or points elevation of both methods. The volume was not only affected by the number of points and different topographic shapes but also the height of the surface measurement. The smooth and regular elevation changes of the surface (contour) from high to low where it describes the landslide form occurred in the area.

![Figure 3](image)

(a) Comparison of the elongated profile graph of the terrestrial method (a) and UAV-photogrammetry (b)

Figure 3 shows the wavy and irregular elevation changes of the surface (contour) from high to low where it described the landslide form occurred in the area. It was caused UAV-photogrammetry method can obtain very dense points. The UAV-photogrammetry and Total Station measurements have different surface heights. In the same elongated line, the highest point on the UAV-photogrammetry is at an elevation of 151 m while at a total station of 158 m. In addition, it also can be seen the surface obtained by both methods are different. The terrestrial method has a smooth surface while the UAV-photogrammetry surface is wavy.

5. Conclusion
A orthophoto of landslide disaster map has been successfully performed using UAV-photogrammetry from 60 photos at scale of 1: 1500 and GSD accuracy of 3.45 cm. In this study the overall time required to obtain an orthophoto map is +/-10 hours including data acquisition, data processing and visualization.

There is a difference between the results of the two methods to determine the volume of the landslide in Ngrimbi village located in Baren and Jombang Regency. The volume and coordinates point obtained by two calculation methods (UAV-photogrammetry and terrestrial method) are 10527.032 m³ by UAV-photogrammetry and 11491.708 m³ by terrestrial method with 964.676 m³ or 8.4% of the difference of both methods. It was caused by the surface difference and the number of points obtained by both methods. This study shows that UAV technology can present disaster maps quickly and accurately. Although that is used is a rotary-wing UAV type is relatively easy operation (does not require runway/VTOL mode), low-cost and available in ready-to-fly unit.

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