3D modelling using structure from motion technique for land observation in *Kelok 9* flyover

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3D modelling using structure from motion technique for land observation in *Kelok 9* flyover

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Abstract. In a modern survey, information on the real condition of the study area is required to support the analysis and interpretation result of a study. However, obtaining information on the real condition in a wide covered area is difficult, particular in an area that hard to access and has varied topographic. The method that can imaging the real condition of a study area is observation using UAV/drone using structure from motion technique. Besides can be observed with a wide area, the detailed condition of the area also can be visualized. Structure from motion (sfm) is the technique that determines the spatial and geometric relationship of the target area through the movement of the camera. In this research, the sfm technique was applied to create the 3 dimension construction of the Kelok Sembilan flyover. The result show, 3D construction has a high spatial resolution in 2.99 cm/pixel measured in Ground Sampling Distance (GSD). Meanwhile, the horizontal relative resolution is 5.97 cm, and the vertical relative resolution is 8.95 cm.

1. Introduction

Kelok Sembilan flyover is a road connecting west Sumatra to Riau province, Indonesia. This route is the main connection that is congested by vehicles from both provinces. However, because the flyover construction is located between two hills that have a high steepness, the area is very vulnerable to land movement and landslides [1]. The visualization of the real conditions of the flyover is required to assist in analyzing and finding solutions to the flyover conditions. Therefore, it is necessary to capture the area and make a three-dimensional model. By the three-dimensional model can be depicted the real conditions of the object.

In this research, the 3D modeling of the Kelok Sembilan flyover constructed using a combination of multiple images. The images are capture using a small drone of DJI phantom 3 with a 20-megapixel camera mounted on the drone. Observing and capturing the image using a drone is a modern tool for presenting the real condition research study to digital space. Besides being easy to operate, the observation using drones is producing high accuracy [2], [3] of an image with low cost [4]. In recent years, the use of drones has spread not only for military needs but also for mapping the areas affected by earthquakes [5], tsunamis and floods [6] agriculture observation [7], and deforestation [8]. In processing drone data, the structure from motion technique was applied to construct the 3D model. The technique work by utilizes multiple of 2-Dimensional images to reconstruct the 3-Dimensional structure of an object through the moving camera.

This research aims to produce the 3D modeling of the Kelok Sembilan flyover with high resolution using the sfm technique. The result projected into WGS 84/UTM 47 coordinate system. Hopefully, the result can be an alternative to present an object in digital space and assist in founding the solution in analyzing the study area.

2. Study area and Drone Images

The area of research is located on Kelok Sembilan flyover at 0° 4'17.75"S and 100°41'54.98"E, Lima Puluh Kota District, West Sumatra. The flyover was built in between two hills with a high slope about 20-78 degrees and a Sanipan river flow in the middle of it. The elevation of the area is around 700-1100 above sea level. The area has a complex topography structure that contains share and tension joint [9], and high rainfall intensity [10]. The topography of Kelok Sembilan is shown in Fig. 1.

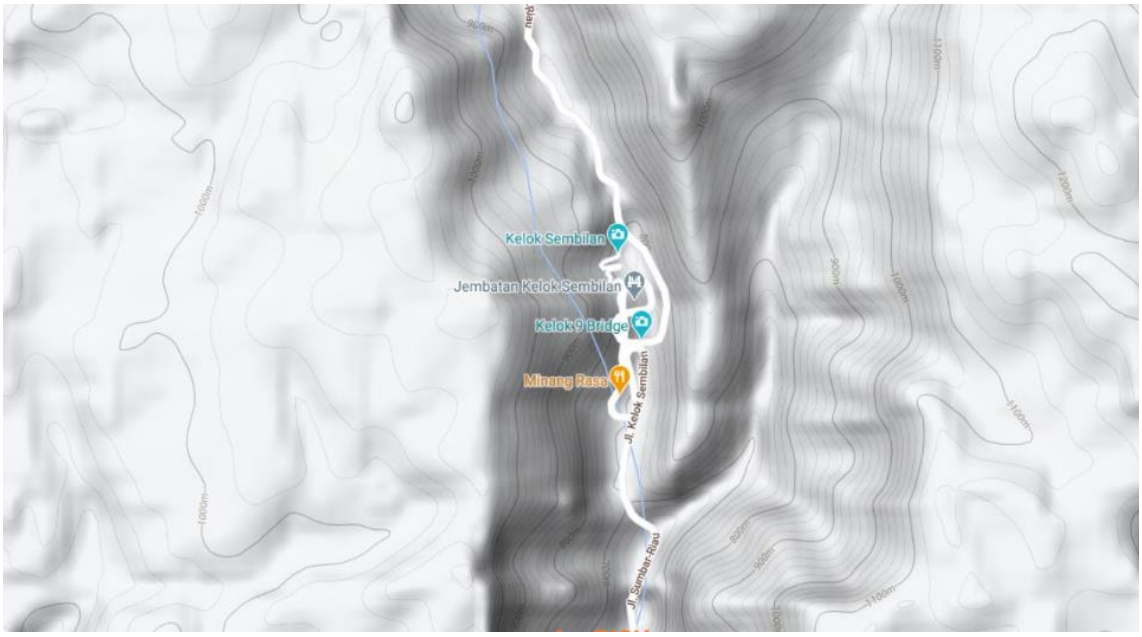

Figure 1. Topography and contour of Kelok Sembilan flyover. The highest area is about 1100 meters above sea level.

Table 1. Drone mission dataset of DJI Phantom 3

Drone mission	Number of Image (scene)	Focal length (mm)	Principal point X (mm)	Principal point Y (mm)	Sensor Dimension (mm)	Flight elevation (m)	angle (^{0})
Mission 1	81	4.27	2.94	2.29	6.3 x 4.7	80	90
Mission 2	75	4.27	2.94	2.29	6.3 x 4.7	80	90

3. Methodology

Structure from Motion (SfM)

Structure from motion is a technique that utilizes the series of images in two dimensions to reconstruct the 3D of an object. Also, the technique can model the high resolution of the digital surface model (DSM). The principle of the technique is to combine multiple images with a high degree overlap from a different angle. In the calculation of the position of an object in 3D (x, y, z) coordinate is using the triangulation technique. The image acquisition plan setting is shown in Fig. 2.

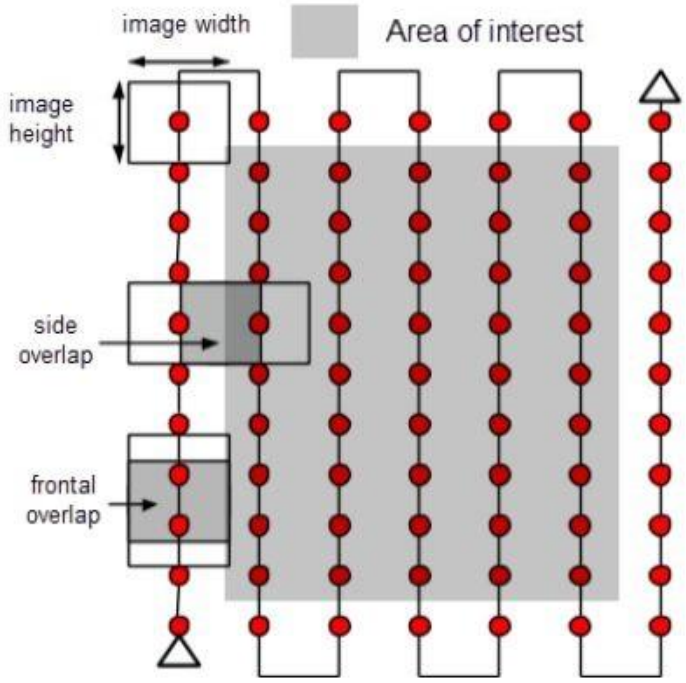

Figure 2. Image Acquisition Plan

The image acquisition plan setting depends on the Ground Sampling Distance (GSD) required and the terrain type of the object. The bad acquisition plan leads to the inaccuracy of the result. Then, the flight position plan and elevation should be considered before the images are taken. Furthermore, camera focal length and sensor width influence the quality of images.

In processing drone images to a 3D model constructed based on the characteristic of each point (keypoint). The high number of overlapping the key point is improving the accuracy of the 3D model. Therefore, to obtain the high accuracy of the 3D model can be maintained by a high number of image overlapping. Ground sampling distance calculations are based on the formula [11].

$$GSD = S_w * H * 100/F_R * imW \quad (1)$$

where GSD is Ground sampling distance, S_w is sensor width of a camera, H is high of the flight, F_R is a focal length of the camera and imW is image width.

In processing using the SFM technique, there are two coordinators involved, namely the camera coordinates when capture images and the world coordinates system. Both coordinates must match each other by doing the coordinate conversion.

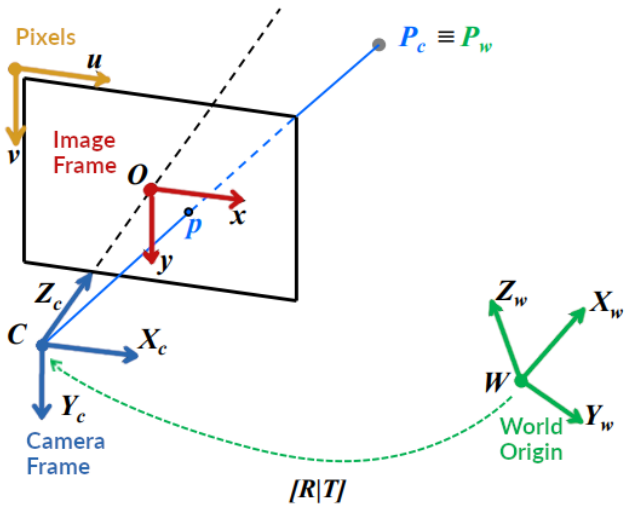

Figure 3. Camera coordinate and world coordinate system [12]

4. Result and Discussion

3D modeling of Kelok Sembilan flyover was constructed using the Structure from motion (sfm) technique. The model synthesis from 156 scenes of DJI phantom drone with 80 meters flight elevation. The resolution of the camera is 4000 x 3000 pixel (RGB) with 6.3 x 4.7 mm sensor dimension. In processing, drone images were projected into the WGS84 coordinate system. The point cloud of the area is shown in Fig. 2.

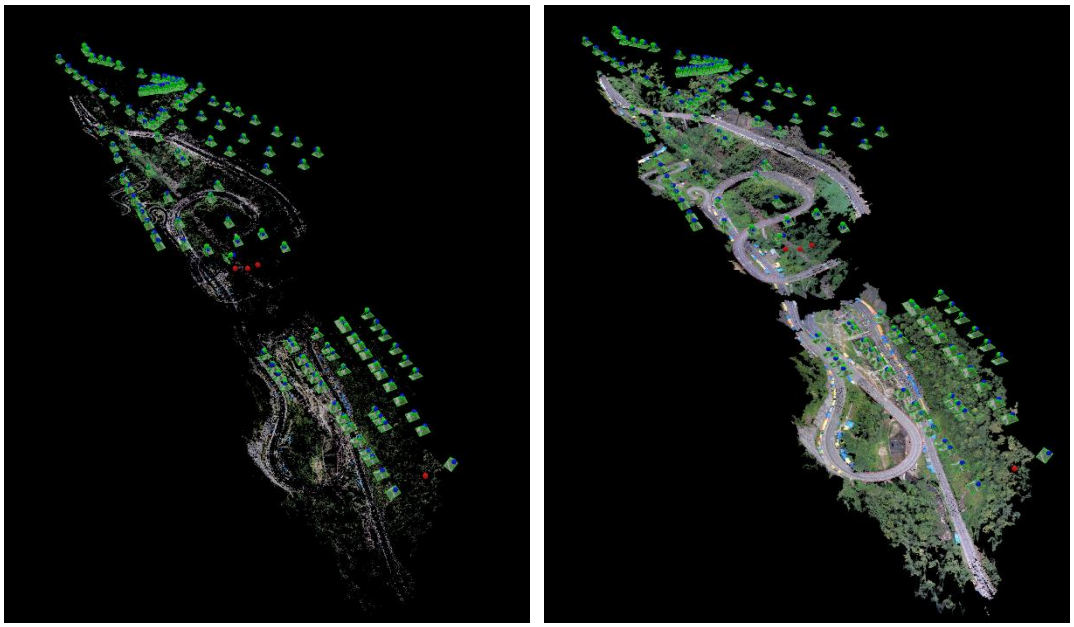

Figure 4. The 3-Dimension Point cloud modeling of Kelok Sembilan flyover

Fig. 3 shows the 3D point cloud modeling with texture size 8192 x 8192 and matching windows 7 x 7 pixel. The point represents in the X, Y, and Z geometric coordinate.

Figure 5. 3D modeling the Kelok Sembilan flyover

5. Conclusion

Structure From Motion (sfm) technique successfully creates the 3 dimension construction of the Kelok Sembilan flyover. The result show, 3D construction has a high spatial resolution in 2.99 cm/pixel measured in Ground Sampling Distance (GSD). Meanwhile, the horizontal relative resolution is 5.97 cm, and the vertical relative resolution is 8.95 cm. The technique has high accuracy in modeling the object from a 2D combination of images.

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