Comprehensive Analysis of UAV Flight Parameters for High Resolution Topographic Mapping

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Abstract. Unmanned Aerial Vehicles (UAVs) are aircrafts without pilot on board, which are controlled by the ground station or transmitter. The ability of UAVs to provide high-resolution imageries and accurate positioning makes it the best platform as compared to satellite images. Therefore, UAVs can speed up the topographic works, especially during data collection. Topographic mapping has been used by many agencies such as the government, private, and military. Furthermore, the geotagged high resolution UAV images can provide accurate results using Ground Control Points (GCPs). UAV flight parameters, such as flight altitude and overlap and sidelap percentages, can affect the topographic map result derived from the UAV images. The optimal flight altitude and overlap and sidelap percentages based on the specific topographic surface need to be investigated to produce an accurate topographic map. The aim of this study is to assess the accuracy of topographic maps from different flight parameters. There are two objectives to achieve the aim; i.e., to produce photogrammetric products from different overlaps and sidelaps as well as analyze the photogrammetric products with ground survey data. The selected flight altitude in this study is 60 m. However, the overlap percentages are 70%, 80%, and 90% and the sidelap percentages are 50%, 60%, and 70%. GCPs and Check Points (CPs) will be established using global navigation satellite system (GNSS) techniques, where the global positioning system (GPS) receiver is capable of real-time kinematic (RTK) to receive real-time data correction from the continuously operating reference stations (CORS) in different locations. This study will analyze the topographic results at different overlap and sidelap percentages using Root Mean Square Error (RMSE). The expected outcome of this study includes the comparison coordinates between CP coordinates and ground survey data coordinates, different digital terrain models (DTM), and different topographic maps.

1. Introduction
Unmanned aerial vehicles, or known as UAVs, are one of the aircraft without a pilot, which are controlled by a ground-based controller [2]. With the latest technology, UAVs are a common aircraft used in the commercial industry, namely engineering work, surveying, and others. With the ability of UAV in providing higher resolution imageries and more accurate positioning than the satellite image,
the topographic survey work in collecting data becomes faster. The other advantages of UAV are it is easy to operate, the image has no cloud obstacle, it has a clear detail and high resolution, cost of production is low, and one of the most preferred for topographic mapping in engineering survey [4]. Topographic mapping is one of the important maps used by all agencies, such as the government, private, personal, and military. Topographic mapping represents information about the ground truth in certain locations. Before the topographic map is produced with the latest aerial photogrammetry technology, the data are collected by using the total station. The data are also represented in a 2-dimension (2D) map. With the new photogrammetry technology, topographic mapping can be produced using UAV with a high-resolution image [1]. The data acquisition process also helps to reduce the time taken in collecting data. A new technology in photogrammetry can generate and represent the data for topographic mapping in a 3-dimension (3D) map [3]. Plus, the positioning of high-resolution image that is produced from UAVs can be more accurate by applying the ground control point (GCP). Based on previous studies, the mapping must have at least five control points to establish a GCP in one orthophoto or topography. The more control points in an image, the higher is the accuracy of the image. For locating the GCP in the study area, the features need to use a permanent object, and the position of the established GCP also needs to cover all the study areas. The GCP is not only put near to the boundary of the study area, but needs to cover the middle or center of the study area. This is important in locating or choosing the position for GCP because this factor will be used for overlapping to produce a mosaic image for topographic mapping and orthophoto [5].

In producing topographic mapping, the flight altitude and overlap need to be considered as a process to produce better result. For flight altitude, the preferred altitudes for testing the optimal altitude are from 20 m to 120 m [2]. The features from an image may not be identified and interpreted if the altitude is increased to more than 120 m, but a large area can be covered for image capture if the flight altitude is more than 120 m. However, a feature can be seen clearly and interpreted easily if the flight altitude is decreased to less than 120 m. Another factor in producing topographic mapping is overlap and sidelay. The optimal overlap and sidelay for producing topographic mapping is 80%–50% and 70%–40%. With the optimal flight altitude and overlap, it can produce the best result for digital elevation model (DEM), orthophoto, and topographic map. Plus, a well-produced topographic map can be validated through Root Mean Square Error (RMSE). From the verified point, it can be analyzed that the coordinate that is shown on the final product of the topographic map has either the same coordinate as the actual coordinate or vice versa.

2. Material and Methods

This study consists of four phases; phase 1 is about the preparation, phase 2 is data acquisition, phase 3 is data processing, and phase 4 is result and analysis. The preparation phase involves obtaining information about the specification and features found in the study area. Accordingly, the study area was selected for this research study. Based on this study, the information of study area has been listed on the features found at the study area location for considering the optimum flight altitude. Furthermore, the software used in this study has also been selected with a compatible hardware that has already been prepared for this study. The selected software are Agisoft, Global Mapper, and PCI Geomatics. All these software have been used for processing until the final products of photogrammetric, such as DSM and DTM, have come out. Another software that is important in this study is Altizure software which helps to prepare the flight mission before collecting the raw data. However, to perform the process and acquisition of the data, hardware have also been used, such as the DJI Phantom 3 Pro as the instrument to collect the raw data of aerial photo and ROG Asus Gaming as a hardware that helps to process the data by using the software. Image acquisition is the planning stage in collecting data. It describes the method in producing flight planning and the type of UAV to be used in collecting the data. Next, the image acquisition sensor that is attached to the body of UAV also needs to be inspected by calibrating the sensor using the camera calibration method. The image acquisition part also includes the GCP distribution in which the GCP position in the study area needs to be designed to make sure that the GCP distribution design covers the study area. Figure
1 illustrates the research methodology of this study.

![Research Methodology Diagram]

**Figure 1.** Research Methodology
3. Result and Analysis

The study area of this study is at the at UiTM Chancellory Shah Alam, Selangor. The size of this area is estimated at 2 ha. To obtain the data for this study, the flight parameter of this study has also been chosen by using three different overlaps, and sidelaps. For flight altitude, one altitude was used to obtain the data, which is 60 m. However, the flight altitude has been set up with three different overlap percentages, which are 70%, 80%, and 90%, and also three different sidelap percentages, which are 50%, 60%, and 70%. All the data collected contain 9 orthophoto datasets with different overlaps, and sidelaps. To process the data, Agisoft software was selected to produce orthomosaic and DSM. The DSM went through the next process of DTM extraction by using PCI Geomatics software. All these processes used five GCP. For the verification point process, a total of 28 check points have been extracted from DTM. This extraction of check point coordinates was compared with the ground survey data Real-Time Kinematic (RTK). All these comparisons were included into the final result of accuracy assessment. The accuracy assessment was computed by using the Root Mean Square Error (RMSE) method to finalize the comprehensive analysis of flight parameter for high resolution topographic mapping using UAV.

3.1 Result of Orthophoto, Digital Surface Model (DSM) and Digital Terrain Model (DTM)

In this study, 9 sets of Orthophoto, DSM, and DTM results from different overlap and sidelap percentages have been processed through Agisoft software and PCI Geomatics software. All of these datasets have been registered with five numbers of GCP. In producing orthophoto by using Agisoft software, all the altitude datasets with different overlap and sidelap percentages were marked with five GCP and verified separately. The verification of all datasets was processed through accuracy assessment by using 28 CP. Figure 2a describes the digital orthophoto after image processing. Apart from orthophoto, DSM are also generated through Agisoft software. This process of DSM was performed on all the datasets. Figure 2b shows the result of DSM. This result of DSM is important because this product will be used for the next phase in producing DTM product. The DTM is generated from the DSM of all datasets by using PCI Geomatics software. The result of DTM is shown in Figure 2c, which is obtained from the PCI Geomatics software. The elevation from the final product of DTM is important because this elevation is the reference for verifying the Z coordinate through accuracy assessment.

![Figure 2. Result; a) Orthophoto b) Digital Surface Model, b) Digital Terrain Model generated](image)

3.2 Accuracy Assessment

The accuracy assessment of the result will be validated through the number analysis of checkpoint X, Y, Z errors, and Root Mean Square Error (RMSE). All the results were represented based on different overlaps, and sidelaps. Figure 3 shows the trending bar graph for the RMSE result of 60 m altitude with different overlap and sidelap percentages. The RMSE result was determined into three types of coordinate, which are X, Y, and Z. According to Figure 3, this RMSE result for 60 m altitude with different overlap and sidelap percentages have been calculated by using 28 check points (CP) for every dataset in which all these CP were derived from the RMSE result. The result was also
inconsistent. The trending bar graph which showed the highest result of RMSE was the dataset of 60 m altitude with 80% overlap and 70% sidelap. The result of this data showed that the RMSE for X was 0.165 m and the RMSE for Y was 0.136 m. For height, the result showed that the RMSE for Z was 0.128 m. However, the lowest RMSE result based on this graph came from dataset of 60 m altitude with 80% overlap and 50% sidelap. It showed that the RMSE result for X was 0.076 m and the RMSE for Y was 0.053 m. For height, the result showed that the RMSE for Z was 0.044 m. In topographic mapping, the height of ground surface is important because a high accuracy of height ground surface will produce a high accuracy of topographic map.

![RMSE Altitude 60m](image)

**Figure 3.** RMSE Altitude 60m with different overlap and sidelap percentage

By referring to the bar graph in Figure 3, Z coordinate, or known as ground level, has been produced by using DTM. The result of the Z coordinate was also concluded from the calculation of RMSE for all the datasets of 60 m altitude with different overlap and sidelap percentages. The RMSE result for Z coordinate Z showed that most of the datasets that received low accuracy came from the dataset of 60 m altitude with 70% overlap and 60% sidelap and also 90% overlap and 60% sidelap. Both datasets received a 0.154 m result. This factor may be caused by the effect of DTM interpolation process. However, the higher accuracy of height was from the dataset of 60 m altitude with 80% overlap and 50% sidelap. The RMSE result showed that this dataset received 0.044 m. Based on the three results shown in Figure 6, the highest result for RMSE came from the dataset of 60 m altitude with 80% overlap and 50% sidelap. The result showed that the RMSE result for X coordinate was 0.076m, Y coordinate was 0.053 m and Z coordinate was 0.044 m. However, the lowest RMSE result came from the dataset of 80 m altitude with 70% overlap and 50% sidelap. The RMSE result showed that the dataset result for X coordinate was 0.052 m, Y coordinate was 0.048 m and Z coordinate was 0.049 m. In producing a good product of topographic mapping, the accuracy of coordinate was not only based on the X and Y coordinate, but the height of elevation ground surface was also important to make sure that the topographic map product received the most accurate result.
4. Conclusions
The aim of this study is to assess the accuracy of topographic mapping from different flight parameters. To assess the accuracy of this study, the flight parameters have been selected, which consisted of three different overlap and sidelap percentages. The altitude used in this study was 60 m. The overlap and sidelap percentages used in this study were 70%, 80%, 90% and 50%, 60%, 70%, respectively. The main objective of using this flight parameter is to produce a photogrammetric product with different overlap and sidelap percentages and analyzed the product through the accuracy assessment for all datasets. The dataset with the lowest RMSE was the dataset of 60 m altitude with 80% overlap and 50% sidelap.

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