Reconstructing 3D model of accident scene using drone image processing

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ABSTRACT

At the current stage, an investigation technique on the accident takes a longer time and this causes longer traffic congestion. The aim of this study is to reconstruct a 3D model of an accident scene using an unmanned aerial vehicle (UAV). The flight parameters that have been chosen are the circular method, the double grid method, and the single grid method. All these designs can produce a good 3D model to achieve the study's objective. The methodology in this study is divided into 4 phases which are preliminary work, data acquisition, data processing, and data analysis. The main results of this study are the 3D model of the accident scene, an orthophoto map layout, and an accuracy assessment of a 3D model of reconstructed accident scene. All these parameters will be tested on accuracy based on the root mean square error (RMSE) value, comparing the UAV data and site measurement data. This objective has been tested for 10 different types of processing and different types of flight parameters. The best result among all the methods is the circular method 5 meters with ground control point (GCP) since this method has the least RMSE value which is 0.047 m. UAVs can replace the site measurement to reconstruct the accident scene.

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1. INTRODUCTION

Accident reconstruction is often a key element in determining the cause and fault of an accident. It can identify contributory negligence on one or more parties due to carelessness, aggressiveness, faulty road conditions, equipment failures, or several other factors. Without the aid of a trained accident reconstruction specialist, a personal injury attorney would have to rely on testimony that is often conflicting and witnesses who are often reluctant and inaccurate. If you are involved in an accident and are injured, it is important that you hire an attorney that has the resources to hire a professional accident reconstruction company to further your case [1], [2]. The reconstruction of an accident scene is very important as the police department needs to be specific, in order to investigate the causes and secure evidence for an accident scene. Historically, the first method that has been used to reconstruct an accident scene is to just use sketching paper. The related department will sketch the accident scene and mark it on the piece of paper. Then, a camera is used to capture the evidence of the scene, and is marked by chalk and measured using a measuring tape [3], [4].

An accident reconstruction is a process of determining the conditions, mechanics, and contributing factors of a collision using scientific methods. It generally requires a working knowledge of physics, vehicle dynamics, mathematics, photogrammetry, and computer applications such as spreadsheets, AutoCAD, simulation or modelling tools, graphics, and photo-management software. Accident reconstruction is a branch of causation forensics that uses science to figure out what has happened in a crash. They are most often used in traffic crashes involving cars, motorcycles, trucks, buses, and pedestrians, but they can also be used in a variety of other situations. They perform an accident investigation using mathematical, physics, and engineering principles. They will shape conclusions about the accident's velocity, crash angles, driver vision, and other causal factors based on these concepts [5], [6].

Photogrammetry is a method for determining the relative scale and position of physical evidence at a crash site using photos. When a physical examination of the affected car is not possible, the crushed vehicle that is seen in the photos can be studied, and property loss can be quantified with great accuracy. They are mostly based on manual calculations, with triangulations and parallel lines that are used to create the collision scene sketch. As a result, the rigidity and accuracy of a road traffic accident scene sketch are mostly dependent on the professionalism of the police forces. These challenges can be solved by using multi-rotor unmanned aerial vehicles that are compact, light, and cost effective [7]–[11].

With enhanced technology, a new method is used to reconstruct the accident scene which is using laser scanning. This method can capture a lot of data with details and accuracy; however, the method is not used by most countries since laser scanning incur a high cost. Accordingly, the best solution to reconstruct an accident scene is to use unmanned aerial vehicles (UAV), which are more relevant and user-friendly [12]–[15].

Laser scanning is an expensive method in the 3D reconstruction of accident scenes. Laser scanner offers a highly dense point cloud during data acquisition which can produce very detailed 3D results. However, this method is quite expensive and takes a long time to complete. The preparation of a laser scanner setting up for data acquisition at the accident scene area is not practical because it is requiring a terrestrial station using a tripod. Therefore, it will cause a delay in the traffic jam hours and hours to complete the scanning. Unlike UAVs, this platform does not require any terrestrial station because the accident scene will capture from a certain altitude. UAV technique could speed up data acquisition and release the traffic jam in a short time. Due to the limitation of UAVs in accident scene reconstruction, this platform has evolved due to the current technology which has been integrated with many obstacle sensors and waterproof structures. The performance of UAVs in developing 3D accident scenes become popular among researchers and many parameters need to be considered to achieve a good 3D result of accident scenes [16]–[19].

Thus, data collection on-site should be a simple, precise, and swift procedure. However, currently, it is mostly a manual procedure done by police forces, worldwide. Although there may be slight differences from country to country, the data collection methods that are used when road traffic accidents occur are very similar. These difficulties can be overcome using a small-sized, lightweight, and cost-effective UAV that is capable of operating in a fully automatic mode or by manual control, which constitutes the technological core of the UAS based on the photogrammetric methodology that has been proposed for road traffic accidents reconstitution. In addition to providing scientific documentation, this technical note intends to supply road traffic authorities and professionals with a set of procedures that are compiled in a UAV-based methodology that has four aims to achieve: accurate, efficient, and cost-effective digital reconstruction and recording of motor vehicle collision events [20]–[22].

There are many advantages of using the UAV in reconstructing the accident scene. Firstly, the conventional method will increase investigation time, which could take hours instead of just minutes when the UAV method is used. The former method will cause many aspects such as traffic congestion and high fuel consumption due to the congestion. Traffic congestion is very risky as it can cause secondary accidents due to emergency hold up. Moreover, a longer investigation time will reduce officers' availability. For example, there are incidents at other places, thus there is a lack of officers to cover another incident. That is why all these problems need to be overcome to improve the timing aspect [23]–[25].

Secondly, the lack of data or images will cause a lack of evidence in court. Sometimes, an officer may overlook some important data. Consequently, judges cannot decide anything since the evidence is not provided by the investigators. Moreover, the conventional method can only be seen in 2D images, which makes it challenging to decide on some important points. There are always limitations of view when looking at the evidence in the 2D view. That is why UAV images are very important because they have no limitation in taking data and can be exported to 3D images. So, the evidence can be seen clearly and precisely within a short time span [26]–[30].

The other problem statement that has been found in this case is the accuracy of data. Using a digital camera or the conventional method does not allow the investigator to re-measure the data after the incident. This is because the investigator does not have raw computation data. Data collection is merely pictures and site measurements. What if the person who is in charge has overlooked some data? Thus, nothing can be done. But this problem can be overcome using UAV 3D image processing, where the investigator can re-check an accident scene database to identify some point of evidence [31]–[33]. The aim of this study is to reconstruct a 3D model accident scene using the UAV.

2. MATERIALS AND METHOD

Methodology explains the detailed workflow of the research methodology, preliminary study, site selection, software selection, data acquisition, flight planning, site procedure, data processing, results, and the analysis of this study. Figure 1 explains the methodology in terms of a flowchart. The flowchart will define the steps in methodology, which are the preliminary work, data acquisition, data processing, and data analysis. The innovative aspect of this study is the assessment of circular, double-grid, and single-grid missions in developing 3D reconstruction of accident scenes. This study also investigated the effect of altitudes (5, 7, and 10 m) in the 3D reconstruction of accident scenes.

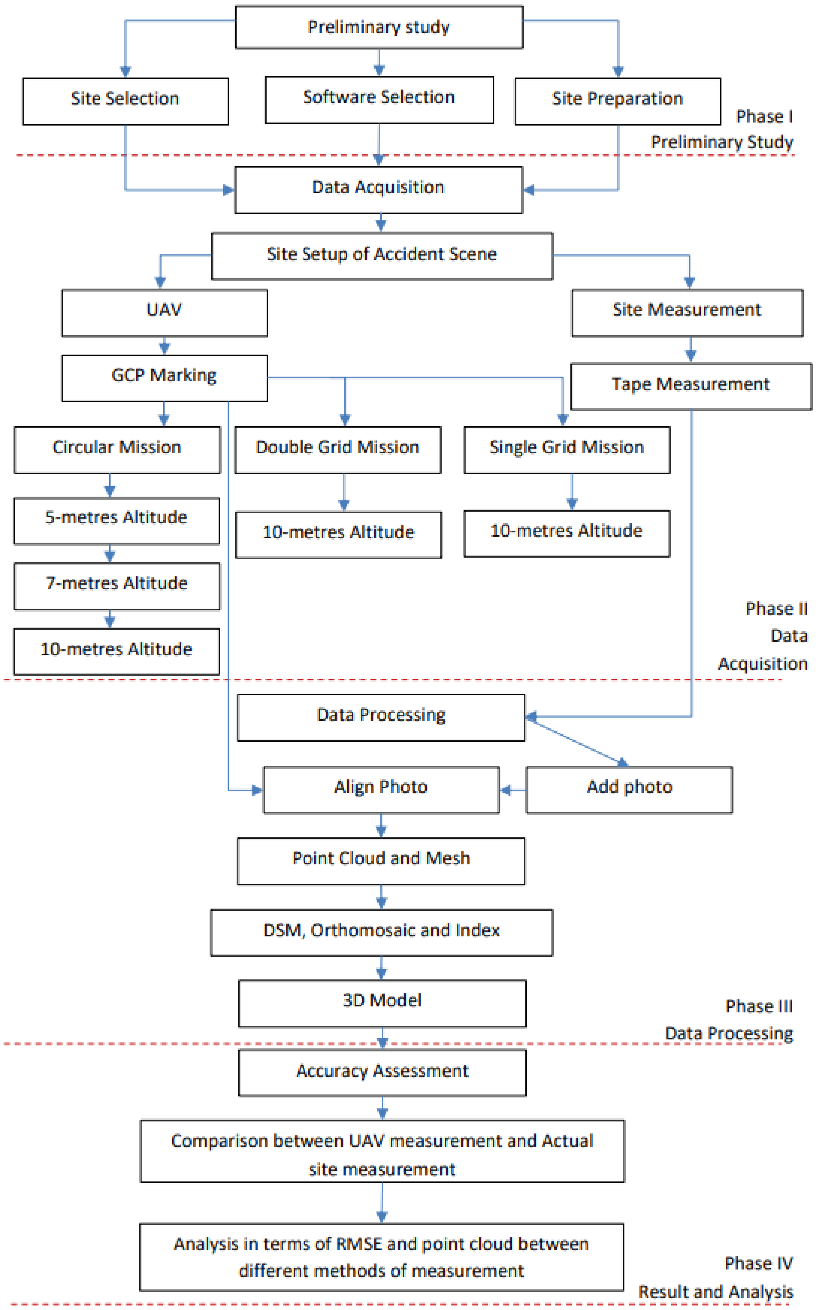


Figure 1. Research methodology of accident scene reconstruction

2.1. Preliminary study

Preparation or planning is very important to ensure that the project flow is clear and well-conducted. A good preparation must include all aspects from the beginning until the production of the final output. Proper planning must be done to avoid problems from happening while collecting data. The important aspect is to plan the method to collect data, to foresee the risks that can happen on-site, the weather, time, traffic flow, and many more. Incoming problems and issues need to be identified to make sure that problems can be handled.

The limitations of this study are the flight patterns and altitudes. Three flight patterns have been used which are double grid, single grid, and circular flight pattern. Three altitudes have been used i.e., 5, 7, and 10 m. The proposed algorithm also cannot be performed during raining situations.

The software that has been used in this project is Pix4D software. This software can help to achieve the objective of this study. This software is used as a post-processing software, where after collecting the data on-site, this software will process the images and ground control point (GCP) using its tools and program until a 3D Model is built, which is the researchers' target in this study.

Site selection is needed to identify and carry out the objective of this project. The characteristic of site selection must be cleared. The criteria that need to be highlighted in order to perform this project is, there must be clear traffic (no obstruction), no obstacles (can fly the drone safely), no building near the site to avoid drone accident while it is flying, paved road for best simulation, and there must be a spacious area for safe flight. The site chosen for the study area is at Padang Kawad, UiTM Shah Alam, Selangor as shown in Figure 2 (3°3'58.17"N 101°29'46.74"E). This site has been chosen as the case study because it has a wide area and is far from crowds. Therefore, it is very suitable to have an accident scene here and to fly the drone since this area has a wide-open space and no restrictions to fly a drone. This area is also very suitable to use global navigation satellite system (GNSS) because it has an open sky.

Figure 2. Padang Kawad, UiTM Shah Alam

2.2. Data acquisition

Data acquisition is a very important phase in this project. This phase will collect the necessary data for this project using a suitable method and instrument. Data acquisition will cover the application that is used in this project, flight planning, site procedures, and the GCP.DJI GO, which is an application on smartphones or mobiles that have been created for DJI Drone users for easier flying management. This application is used for the drone pilot to do calibration before flying their drone. This application has an indicator to monitor and control the drone gimbal, camera, and other functions. This application is the initial application that has been used in this project for the drone setup before linking to the Pix4D application for flight planning. The battery status, global positioning system (GPS) status, and signal must be in good condition before flying to avoid losing or an accident happening to the drone. After all, has been cleared, the PIX4Dcapture application can be opened to set the flight planning mission.

There are 3 flight methods that have been used in this project: the double grid mission, circular mission, and grid mission. There are 5 different types of flight planning. The parameter for flight planning that has been used in this project is circular mission – 5 meters altitude, circular mission – 7 meters altitude, circular mission – 10 meters altitude, double grid mission – 10 meters altitude, and single grid mission – 10 meters altitude. This is because these missions can produce a good 3D model as the output of this project. Good flight planning will produce good results in order to achieve the objective of this project. After the setup on the DJI GO application, the PIX4Dcapture will be opened to set up the flight planning. All aspects need to be cleared such as the battery, memory card, weather, traffic condition, and obstacles before flying the drone. Otherwise, problems will happen while collecting the data. In the PIX4Dcapture application, the researchers can choose a suitable flight mission for any project, as is shown in Figure 3; this application can help to produce 2D, 3D, and video output for any kind of purpose.

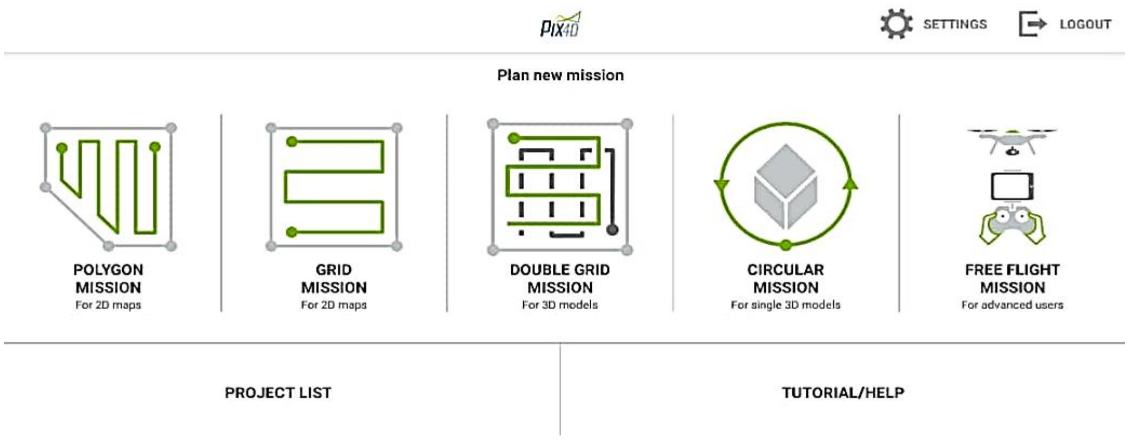


Figure 3. Interface Pix4Dcapture application

After collecting the data or images using the drone, all images need to be checked before proceeding with data processing. Images need to be transferred from the drone to any device such as a laptop to see the images. This is because all images need to be cleared without any obstruction towards the object on the ground. All GCP must also be seen on the images to help geolocate the image. If there are any obstructions on the object or GCP, the data need to be collected again in order to get the best data for processing.

Site procedure is the focus on on-site measurement or conventional data collection. Several equipments need to be prepared and set up before performing the site measurement such as measuring tape, marker, tire mark, cone, caution tape, and simulation vehicle accident incidents. All of the equipment and tools setups are the basic things that occur in a real incident. All methods are also referring to the real-site data collection by the investigator at the accident scene. The measurement that needs to be measured is from center top of the marker to the other marker and the same method is used in the software to get the distance of the accident scene evidence. Figure 4 shows the accident scene setup on site.

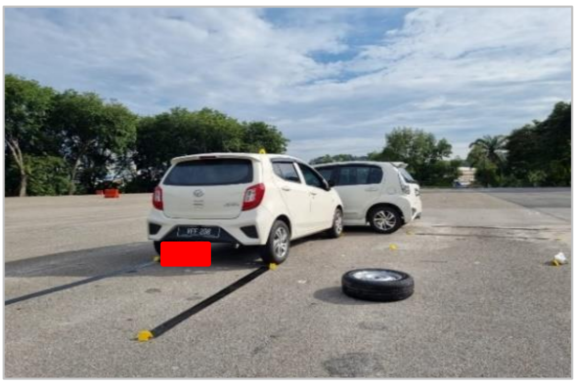


Figure 4. Accident scene setup on site

The GCP is produced to give georeferenced to each image that is collected by the UAV when processing, which will give the exact coordinate to each of the images that is the same as the ground coordinate. To produce the GCP, 3 minimum GCPs must be established, whereby the more GCPs the better, which depends on the site location. The GCP must be well distributed around the site area to obtain a good result. In this project, 4 GCPs are used to secure good control for this project. Before flying the drone, the pre-mark needs to be located on the GCP for post-processing. Each GCP will get coordinate 50 using the GNSS instrument. The GNSS will give a coordinate to each GCP using the real-time kinematic Network (RTKNet) method. The Network RTK is used to get the coordinate on the GCP. This is because network RTK can provide good accuracy within a short time span. As such, it is very suitable for this project as to settle down in an accident scene a short time for investigation is needed. Also, a short time is required for the Network RTK, the accuracy can be achieved with rapid static measurements accuracy which is at the centimeter level. The difference is the rapid static method needs some post-processing and could take a longer time to perform, whereas the network RTK is real-time data on-site.

2.3. Data processing

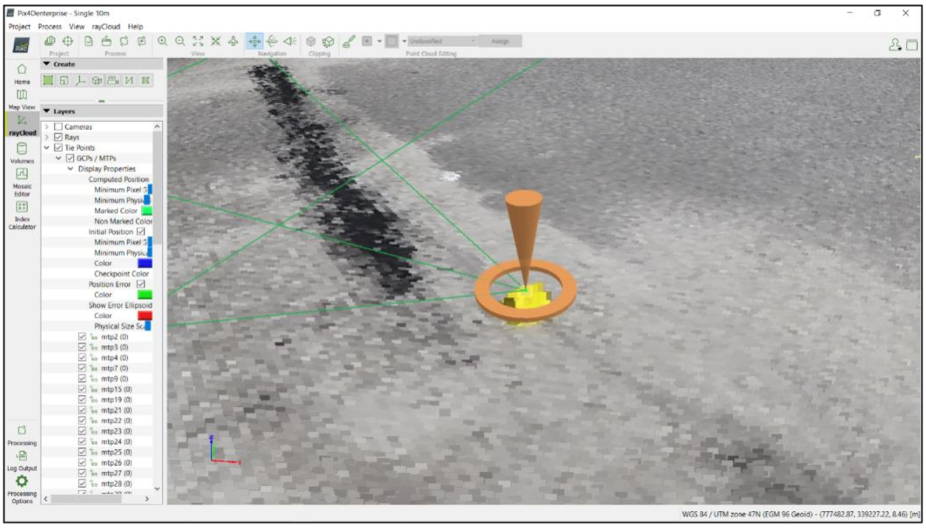
Data processing is an important phase after data collection. The PIX4D Mapper software is used in this phase. The steps that occur in data processing are to add images and align images, build mesh, and point cloud, digital surface model (DSM) orthomosaic and index, and a 3D model as the output. Aligning the photo is the initial process in this project after data acquisition. Using the Pix4D Mapper software, the first step is to add all the images that have been obtained from the UAV. The software will automatically define the position of the images since all the images have coordinated themselves based on the built-in GPS onboard. So, it is easier to arrange the images, without the need to setup manually. After loading the images, some information about the images needs to be checked in the image properties tab. Aspects that need to be checked include image enable, coordinate system, geolocation accuracy, and details about the images. After that, the output coordinate system is defined. In this project, the datum and coordinate system that has been chosen is world geodetic system 1984 (WGS84). The GCP will be added to the software. In the Pix4D software, there are 2 procedures to insert the GCP. The first is prior to starting the initial process which is together with the added images. The next is after the initial processing. Both procedures are correct and dependent on the data processor. The result from the GNSS measurement of the GCP will change into .txt or .csv before being added to the Pix4D Mapper software. All coordinates must be in WGS84 coordinates since the software only supports format latitude, longitude, and height. Then, the coordinate that has already been inserted must be matched with the images. Hence, all the images that have been pre-marked must be selected based on their true coordinate. After which the GCP is added, the processing needs to re-optimize or reprocess if the GCP is added after the initial processing. This is because the software needs to be run again to process the GCP. This step is not applied if the GCP is added together with the images or before the initial processing. Then, the result for the initial processing will appear again and needs to be checked, whether there are any errors that have occurred. The GCP report will show error occurrences while locating the GCP.

After the initial processing is completed, point cloud and mesh can be processed using the tick process box for this option. The densified point cloud is a set of 3D points that reconstruct the model. The X, Y, Z position and the color information is stored for each point of the densified point cloud. The 3D textured mesh is a representation of the shape of the model that consists of vertices, edges, faces, and the texture from the images that are projected on it. It is useful to present and visualize the model, share it, and upload it to online platforms. All setting is dependent on the specification device. For the output, there are many options depending on the project requirement. In this project, the measurement can be made in this software itself for a 3D Model. For a 2D image, images can be exported to the CAD Software for the preparation plan.

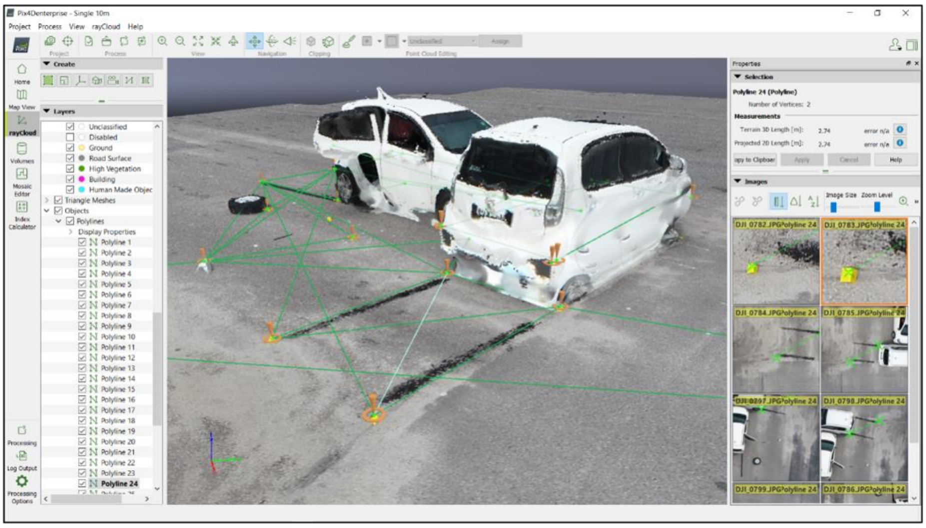
DSM, orthomosaic, and index are the last steps of processing before completing the 3D model for this project. DSM is a 2.5D model of the mapped area. It can be exported as two different types of files which are the raster GeoTIF and point cloud (*.xyz*, *.las*, *.laz*). Each pixel of the Raster GeoTIFF file and each point of the point cloud contain (X, Y, Z) information. They do not contain color information. The orthomosaic is a 2D map. Each point contains X, Y, and color information. The orthomosaic has a uniform scale and can be used for 2D measurements. Each index is associated with an index map. For each pixel on this map, the value of the pixel is derived from the associated reflectance map.

There are 2 types of data that have been collected to perform as analysis in this project. The first data is the UAV data, and the second data is the site measurement data which has used the conventional method. The UAV data is obtained by making the measurement using a 3D model that has been created while processing. The quality of this study was determined by comparing site measurements to the UAV product measurements obtained from the Pix4D Mapper software. To assess the range of acceptable data for this investigation, the standard deviation was determined. Outlier data was defined as data that fell beyond the standard deviation range and could not be included in the root mean square error (RMSE) computation. In this study, the RMSE may be used to measure the accuracy of the UAV products.

To obtain a measurement in the Pix4D software, the method is to use a polyline function that is inside the software. The measurement must be the exact method with measurements 61 that have been taken on site. This is because in obtaining the best exact measurement comparison, the analysis can be carried out to either achieve the objective or not. The procedure to obtain the measurement in the software is repetitive to all methods that have the same location and line. After the processing, the collection of measurements can start using the polyline function at the created section on the ray cloud view. The polyline must be between the 2 markers that have the same line with the site measurement. If the location of the point is not the same as the site measurements, the researchers' data are different, and the result is failed. The point location on the marker can be double-checked based on the images on the right window to ensure that the polyline is located correctly in its position. Otherwise, the location must be adjusted to get the best distance data. Each polyline that is created will automatically give distance data, which are created automatically by the software. Thereby, after the created line, distance data need to be recorded to make a comparison with the actual site measurements. Data is recorded in Microsoft Excel for easier calculation. The same step is applied to other processing that is using different flight planning. Figure 5 shows an example of how the point of the polyline that is located at the markers in Figure 5(a), which is applicable for all methods of measurement using the Pix4D software and some measurement that are created using the Pix4D software with distance measurement in Figure 5(b).



(a)



(b)

Figure 5. Measurement in Pix4D software (a) point location on marker and (b) site measurement

The final plan is the output for most of the survey work. Similarly, with this project, a plan needs to be produced to give an overview and understanding of the site accidents to the audiences. The plan will show the orthomosaic that is produced using the Pix4D software, some measurements, accuracy, and conclusions of the result. This plan can be used in court as a reference for an explanation since it has been simplified. AutoCAD software is used to produce the final plan since it is an application for commercial computer-aided design and drafting. This software can be used for displaying, designing, and editing, with technologies that allow for simpler and faster sketching, drafting, and editing.

A RMSE is a measure of the difference between locations that are known and locations that have been interpolated or digitized. RMSE is derived by squaring the differences between the known and unknown points, adding those together, dividing that by the number of test points, and then taking the square root of that result. Outlier data was described as data that fell outside the standard deviation range and could not be used in the RMSE calculation. The RMSE may be used to determine the precision of the UAV products. The standard deviation is used to describe the dispersion of the sample data, and the RMSE is used to indicate the data's accuracy. The RMSE is carried out by using (1).

$$RMSE = \pm\sqrt{\frac{\sum(n1-n2)^2}{N}} \quad (1)$$

where *n1* is observed value, *n2* is actual value, and *N* is number of measurements.

3. RESULTS AND DISCUSSION

In this project, 4 GCPs were established around the accident scene. Pre-mark are used on the ground to locate the GCP points. The GCPs were distributed cover the accident area. GNSS are used in the GCP observation, which uses the MyRTKnet Server by the Department of Survey and Mapping Malaysia (JUPEM). The coordinate GCP system uses the WGS84 since the software is used to process images, i.e., Pix4D using the WGS84 as the format coordinate system. Table 1 shows the results of the GNSS observation of all GCPs in the WGS84 coordinate systems format (latitude, longitude, and elevation).

Table 1. Coordinate and elevation of GCP

GCP	Latitude (º)	Longitude (º)	Elevation (m)
1	3.066154125	101.496442	22.200
2	3.066081261	101.496357	22.216
3	3.066150219	101.496297	22.258
4	3.066227472	101.496383	22.204

In this project, the accuracy assessment is defined using the RMSE formula. It is a suitable formula to make a comparison between 2 data. There are 10 different results of RMSE since there are 10 different types of processing. A good RMSE definition is when the RMSE value is near 0 m, then the data is very good. Figure 6 and Table 2 show all the processing measurements that have been used to compute the accuracy assessment and the result of data comparison between the site measurements data and UAV processing data with RMSE for circular 5 meters, in their respective order.

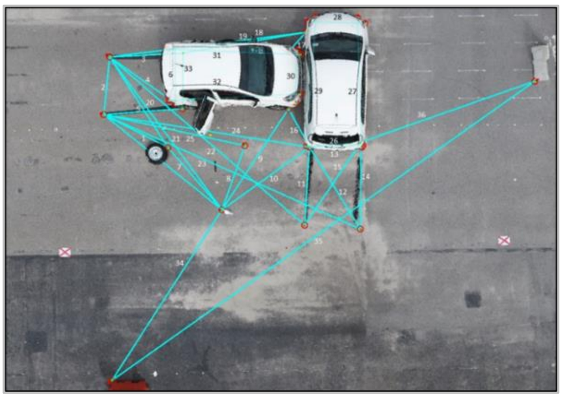


Figure 6. Layout of all measurement on Pix4D software

Table 2. Accuracy assessment of circular method 5 m

Measurement	Site Data (m)	Software Data (m)	Difference (m)
1	2.110	2.060	0.050
2	1.596	1.630	-0.034
3	2.052	2.050	0.002
4	2.492	2.540	-0.048
5	2.212	2.250	-0.038
6	1.549	1.550	-0.001
7	2.290	2.220	0.070
8	1.910	1.950	-0.040
9	3.378	3.450	-0.072
10	3.028	3.080	-0.052
11	2.169	2.250	-0.081
12	2.694	2.750	-0.056
13	1.452	1.490	-0.038
14	2.404	2.450	-0.046
15	2.781	2.870	-0.089
16	1.238	1.260	-0.022
17	0.750	0.780	-0.030
18	3.521	3.560	-0.039
19	5.539	5.640	-0.101
20	3.010	3.060	-0.050
21	5.110	5.070	0.040
22	7.260	7.340	-0.080
23	7.871	8.030	-0.159
24	5.839	5.950	-0.111
25	4.034	4.130	-0.096
26	1.520	1.460	0.060
27	3.410	3.500	-0.090
28	1.650	1.580	0.070
29	3.450	3.580	-0.130
30	1.450	1.490	-0.040
31	1.550	1.540	0.010
32	3.510	3.480	0.030
33	3.410	3.500	-0.090
34	5.930	5.900	0.030
35	14.880	14.92	-0.040
36	5.290	5.270	0.020
		RMSE 0.067	

From the results, parameters circular 5 meters with GCP has the least RMSE, which is 0.047 m compared to the other parameters. Thus, the circular 5 m with the GCP method is the best method to reconstruct an accident scene since the error is very small when compared to the actual and UAV value. The factor contributing to this result is the high 3D densified points which are 8,941,091, and a clear view of the triangle mesh to help analysis of data. On the other hand, the result of the data without GCP are almost the same, inclusive of GCP. RMSE on the circular method 5 meters is 0.067 m. This means, to get precise data, GCP is needed.

The circular method for 7 and 10 meters can also be used to reconstruct a 3D model of the accident scene since the RMSE result is quite close to 0 m. The results for both with and without GCP are close, i.e., without GCP the result for circular 7 and 10 meters are 0.075 and 0.083 m, respectively. As for the data with GCP, the result for circulars 7 and 10 meters are 0.062 and 0.064 m, respectively. The result of point cloud and triangle mesh is also clear and easy for data analysis. That means the result is acceptable for data analysis. However, circular 5 meters with GCP is still the best result for reconstructing the 3D model. Circular 7 meters or 10 meters can be used if the height of the vehicle is high such as a lorry or busses that needs high flight altitude since the result has proven that accuracy does not have a big difference with the circular 5 meters.

The double grid 10 meters method also have the best result in terms of RMSE, which is 0.061 m with GCP and 0.086 m without GCP. But this method is not suitable because it cannot produce a good point cloud and triangle mesh for a better view on processing. The same goes for the single grid method, the result is close to other 3D methods, but the result in point cloud and triangle mesh in the software is very bad. Hence, it is not suitable for the 3D viewer. The double grid method can be used if the accident occurs at a small area that does not have an impact on surrounding objects such as near trees or buildings. As such, the double grid method can be used to collect evidence of the accident site. For the RMSE line graph, if the graph is nearest to 0 axes, that means the data is good. Figures 6 and 7 show the Bar graph results for RMSE that has been applied to all parameters results and the differences between processing- with and without GCP for circular 5 meters flight parameters in their respective order.

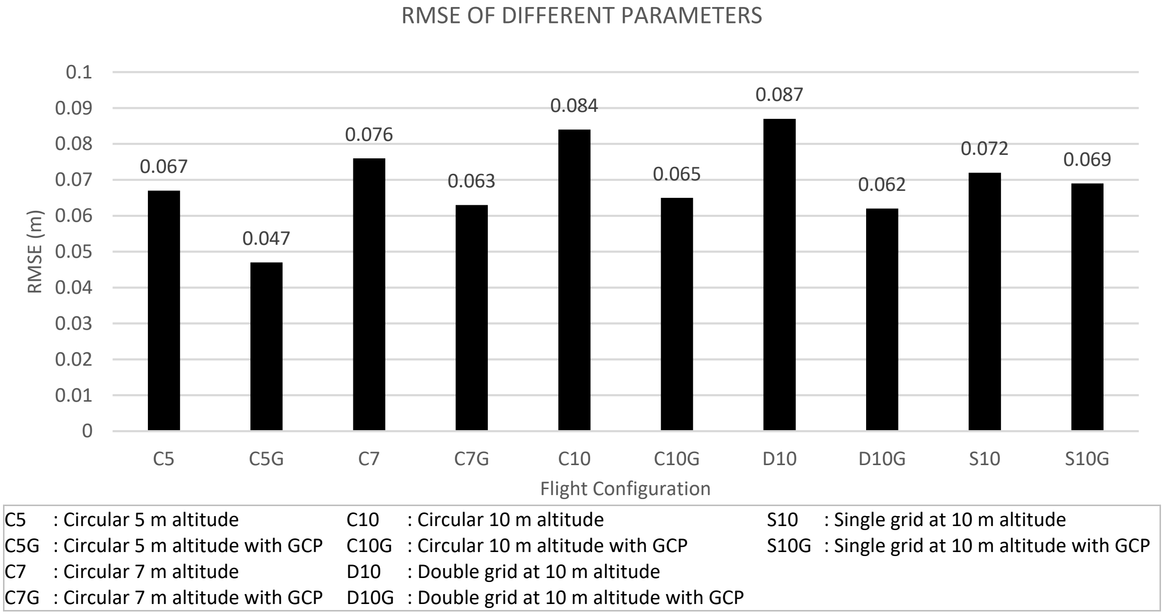


Figure 6. RMSE on all parameters

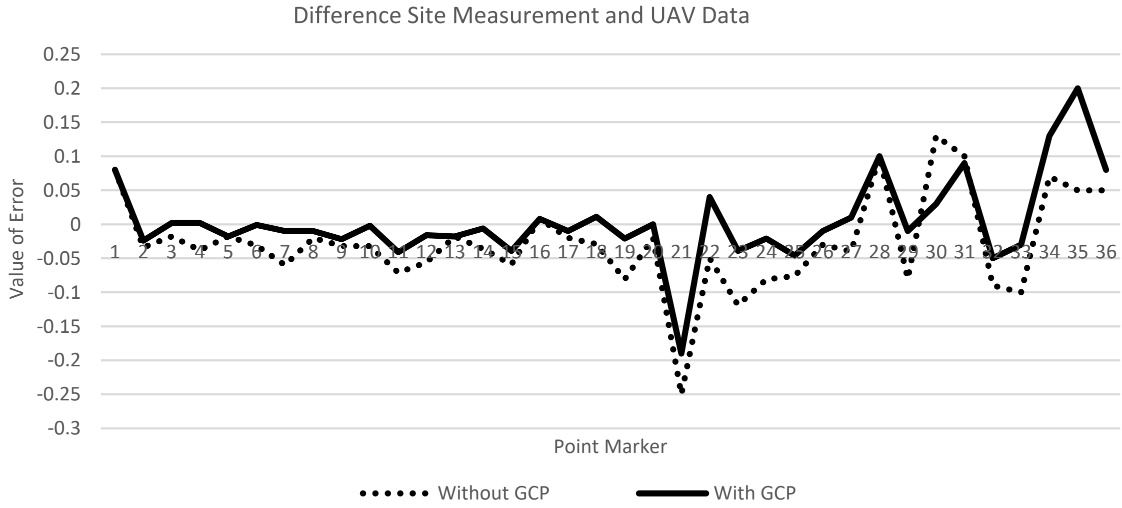


Figure 7. Difference value of error of circular 5-meter flight parameter

Based on the obtained results, there is no significant difference between the data with and without GCP. Those results explain that the investigator can choose not to use GCP in the measurement of data collection. The small difference does not give a big impact on the measurement of evidence on site. The tolerance of the measurement is still small and acceptable, which is in centimeter level. But the use of GCP is still needed to obtain better data and the exact coordinates of the site area.

Amin *et al*. [24] stated that the accuracy for the POI technique was 0.059 m and the waypoint technique was 0.043 m. Desai *et al*. [34] mentioned that the scale errors of 3D reconstructed accident scene using the waypoint technique was about 0.039 m. Almeshal *et al*. [35] achieved the accuracy of 3D accident scenes was about 0.047 m. This study has produced 3D results of accident scenes with an accuracy of 0.047 m for the circular technique and 0.06 m for the double grid technique. Therefore, the results achieved in this study were nearly similar to the previous studies.

The only factor that contributes to the small differences between the GCP data and those without GCP data is, this project fly at open space area. Thus, there is no obstruction on a site with a clear sky view. Therefore, GNSS onboard can receive correction without obstruction on multipath. Besides that, the factor that contributes to the small difference between GCP data and those without GCP data is due to the small area coverage. That is why there is no difference in data since the distribution of errors on GPS is constantly using the same satellites. Furthermore, the observation has also taken a short period of flight time, i.e., around 1 minute.

The final product of this project is the drawing plan, which is produced using AutoCAD software. The drawing plan consists of the orthophoto that is produced after processing. The drawing paper size needs to be large to get a better view of the accident scene. Moreover, evidence and features of the surrounding can be seen clearly if the paper size of the drawing plan is large. A suitable paper size is A1 to represent the collected data on the accident site. Figure 8 shows the drawing plan for aerial photogrammetry using the double grid 10 meters method.

Figure 8. Final plan for double grid 10 meters parameters

4. CONCLUSION

In conclusion, three different flight designs in this study: the circular method, the double grid method, and the single grid method, have proven that the best flight design uses the circular method. This is because it has the least RMSE value, which is 0.047 m, compared to the other methods, whereby the double grid has an RMSE of at least 0.062 m, and the single grid method has an RMSE of at least 0.069 m. The best flight altitude is at 5 m height from the ground; this has been proven with the accuracy assessment result for 5 m that has the least RMSE value which is 0.047 m compared to 7 and 10 meters altitude whereby the RMSE value is at 0.063 and 0.065 m, respectively. This study has tested 10 different types of processing and different types of flight parameters (including RMSE), i.e., circular method 5 meters (0.067 m), circular 5 meters GCP (0.047 m), circular 7 meters (0.076 m), circular 7 meters GCP (0.063 m), circular 10 meters (0.084 m), circular 10 meters GCP (0.065 m), double grid 10 meters (0.087 m), double grid 10 meters GCP (0.062 m), single grid 10 meters (0.072 m) and single grid 10 meters GCP (0.069 m). The best result among the methods is the circular method 5 meters with GCP since this method has the least RMSE value that is near to 0 m value which is 0.047 m. As a final remark, UAVs can replace the site measurement for the reconstruction of the accident scene. The usefulness of GCP seems to be unimportant for the small area; the investigator can choose to use it or not since it can reduce the investigation time. For the common type of vehicle, the circular 5 meters with GCP is the best parameter to achieve the best result if the measurement data is using UAV. This study could be used by the forensic department, highway authority, road safety department, insurance agent, local authority, police department, and law enforcement in improving their data acquisition technique, record, and database in the 3D accident scenes.

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