

SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

THE USED OF UAV-BASED PHOTOGRAMMETRY FOR DISCONTINUITY

MAPPING AT HUME CEMENT QUARRY, MALIM NAWAR PERAK

By

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Dissertation submitted in partial fulfillment of the requirement for the degree of

Bachelor of Engineering with Honors

(Mineral Resources Engineering)

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May 2018

DECLARATION

I hereby declare that I conducted, completed the research work and written the dissertation entitled “**The use of UAV-Based Photogrammetry for Discontinuity Mapping at Hume Cement Quarry, Malim Nawar Perak**”. I also declare that it has not been previously submitted for award of any degree or diploma or other similar title of this for any other examining or university.

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LIST OF ABBREVIATIONS

3-D	Three Dimensional
2-D	Two Dimensional
UAV	Unmanned Aerial Vehicle
m	Meter
FPS	Frame Per Second
K	Thousand
GPS	Global Positioning System
GLONASS	Global Navigation Satellite System
DSE	Discontinuity Set Extractor
UCS	Unconfined Compressive Strength
RQD	Rock Quality Designation
mm	Milimeter
DSM	Digital Surface Model
DTM	Digital Terrain Model
DEM	Digital Elevation Model
d	Distance
km	Kilometer
LiDAR	Light Detection and Ranging
GCP	Ground Control Point
PNG	Portable Network Graphic

TIFF	Tagged Image File Format
JPEG	Joint Photographic Expert Groups
txt	Text
CSV	Comma Separated Value
UTM	Universal Transverse Mercator
WGS	World Geodetic System
EPSG	European Petroleum Survey Group

LIST OF SYMBOLS

$<$	Less than
$>$	More than

**PENGGUNAAN FOTOGRAMETRI UNTUK PEMETAAN
KETAKSELANJARAN BERDASARKAN UAV DI KUARI HUME
MALIM NAWAR PERAK**

ABSTRAK

Kajian ini bertujuan untuk melakukan pemetaan struktur geologi ketidakselanjaraan, melalui kaedah analisis fotogrametri dan untuk memahami kriteria yang diperlukan untuk pemetaan geologi. Kenderaan Tanpa Pemandu (UAV) digunakan untuk pemetaan geologi kawasan sementara perisian Agisoft Photoscan 3-D, MATLAB, CloudCompare dan Rocscience digunakan untuk menganalisis fotogrametri sebelum dibandingkan dengan pemetaan konvensional. Tapak kajian terletak di Hume Cement Gopeng Plant dan sebanyak 26 kaji selidik tingkap telah dikenal pasti terdiri daripada keseluruhan kuari dengan setiap tingkap mempunyai kira-kira 30 m panjang. Secara keseluruhan, terdapat 26 tingkap yang dipetakan di tapak kajian dan gambar rajah rose digunakan untuk menunjukkan set bersama yang dominan di setiap tingkap. Jadi, dapat disimpulkan bahawa orientasi utama pembentukan ketidakselanjaraan untuk tapak kajian ini adalah dalam arah NNW-SSE pemetaan. Selain itu, kaedah fotogramteri juga memberikan hasil yang lebih dipercayai berbanding dengan pemetaan conventional, manakala keputusan gambarajah roset untuk kaedah UAV menunjukkan persamaan berbanding pemetaan conventional. Sebagai kesimpulan, kaedah fotogramteri adalah disyorkan dengan kelebihan UAV menggunakan teknologi drone kerana ia membolehkan pencirian lebih tepat bagi sesuatu jisim batu.

**THE USE OF UAV-BASED PHOTOGRAMMETRY FOR
DISCONTINUITY MAPPING AT HUME CEMENT QUARRY,
MALIM NAWAR PERAK**

ABSTRACT

This study aimed to conduct the geotechnical mapping of discontinuities, to analyze the photogrammetry method and to understand the criteria needed for geological mapping. An Unmanned Aerial Vehicle (UAV) was used for geotechnical mapping while Agisoft Photoscan 3-D, MATLAB, CloudCompare and Rocscience Software was used to analyze the photogrammetry method as comparison with conventional mapping. The study site is at Hume Cement quarry site where 26 survey windows were identified comprise the whole quarry pit with each window involved approximately 30 m parameter length. In total of 26 windows, rose diagram was used to represent the dominant joint set in each window. So, it can be concluded that the major orientation of the discontinuity feature for this study site is in NNW-SSE direction. Furthermore, photogrammetry method also provides a more reliable result compared to conventional mapping, while the results of rosette diagram for UAV method showed a similarities compared to the conventional mapping. As a conclusion, photogrammetry method with advantages of UAV using drone technology is recommended because it allows more accurate characterization of rock mass.

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Recently, there are a lot of drawback encountered which threaten lives. Most of the event are due to the geography of the earth which are unpredictable effect to the community and surrounding. Surface of the earth may consists of different type properties and characteristic laid on it. It may also vary from place to another down to depth and across distance.

Previously, there is a lot of case study regarding to the problem such as formation of a sinkhole in limestone formation, flow of water on surface of quarry site during a rainy days, land subsidence, erosion and slope failures. This situation had come across globally and become main topic to be discussed more on it. Eventhough Department of Minerals and Geoscience has their own skills and expert, yet it needs an observation from time to time and further studies on the suspicious activity and suspected area.

Due to lacks of investigation on research about the properties of rocks and field site, it brought the topic on general study of the major causes to the problem arise nowadays. In geology point of view, discontinuity can give a lot of valuable information on various probability that may occur due to the reaction that occurs over the time. For example, most of the sinkholes occur locally due to the decrease in groundwater levels and tremors factor. The main reason for the formation of the infiltration hole is the dissolving of lime rocks by acidic water. The rainwater that

absorbs carbon dioxide in the air, will form a carbonic acid solution that will be filtered through fractures, also including base rocks. This process will slowly dissolve limestone. Through the geological circulation, when the soluble limestone content along this zone is high, the fractures will form. This also includes base rock and soils on these fractures that will fall into these cavities known as sinkholes. Thus, deep understanding on discontinuity of limestone formation is crucial and importance for better improvement and solution.

1.2 PROBLEM STATEMENT

Most karstic limestone hill in Kinta Valley located in remote mountainous areas. Nowadays high technology approach has improved the acquisition of geotechnical data to access and obtain a high-resolution images of rock face by means of Unmanned Aerial Vehicle (UAV) with photogrammetry. Over a decade, there are several techniques has been used in the mapping the discontinuities of rock mass by conventional mapping. In contrast, assessment and monitoring by using UAV photogrammetry is said to be more difficult and complicated as the information obtain needed to process by using several software before it can be completely modelled to be analyse.

The great advantage of actual UAV systems is the ability to acquise a high resolution image and providing a detail information to allow 3-D photogrammetry to be modelled as the photo contains a coordiante which increase the accuracy for data collected. Indeed, UAV feature real-time capable of fast data acquisition, transmission and, possibly, processing it. Thus, the result from the study will be analysed with the available geological structure to determine the method used will

provides a high accuracy and better result for the mapping of the discontinuities of a limestone rock mass.

1.3 STUDY AREA

The study area held at the Hume Cement Gopeng Plant which is a member of the Hong Leong Group located at Lot 300254, Jalan Gopeng Kota Bharu, Kota Bharu Gopeng, 31610 Gopeng, Perak Darul Ridzuan, Malaysia. About 10 survey windows were identified comprise the whole quarry with each of the window is approximately 30m length.



Figure 1.1: Location of the study area in Malim Nawar Perak. (Google)

Generally, the geology of the study area at the quarry site is predominantly underlain by the Khantan limestone formation. The khantan limestone formed during (Sillurian-Denovian) age is generally part of the Kinta Valley limestone bedrock. Khantan rock formation is generally made up of phyllite, slate, shale and sandstone.

1.4 OBJECTIVE OF THE RESEARCH

In this project, there are several objectives that are aimed to achieve. They are:

1. To study the geotechnical mapping of discontinuities by using an Unmanned Aerial Vehicle (UAV).
2. To study the photogrammetry method by using Agisoft Photoscan 3-D, MATLAB and Rockscience software and compare with conventional mapping.
3. To understand the criteria needed for geological mapping while maintaining a high accuracy and precision data produced.

1.5 RESEARCH METHOD

In this project, high resolution images taken from the drone either automated or conventionally fly will be the source data for the geological mapping. This research starts with locating the interest study area and design the flight route. Next is the process of setting up the drone set (DJI Phantom Pro 4 Plus) equipped with a 1-inch 20-megapixel sensor capable of shooting 4K/60fps video and burst mode stills at 14 frame per second (fps) which needed to be calibrated prior to start aerial

survey. Process of taking picture can be done in such conventional and automatic to provide higher accuracy on multiple angle and elevation. Configuration of ground control network been marked thoroughly covering the whole study area. An absolute reference system were collected by using global positioning system (GPS-Garmin Montana 680). Next step is the extraction of acquisition data into Agisoft 3-D photoscan for the 3-D mapping and the use of MATLAB, for the determination of the properties of the rock joint formation. Data from the point cloud (Photogrammetry) will provide such information in scalar vector form to calculate the discontinuity set using Discontinuity Set Extractor (DSE). From the calculation of the analyses data, a lot of information on discontinuities relations from DIPS software can be detailed recorded and modeled in 3-D.

1.6 THESIS OUTLINE

This project comprises of five chapters. First chapter of introduction will be introduce on the background of the project, problem statement, geology of the study area, objective and research method. Chapter two will be focused more on to the relevance literature reviews link-related to this research project. On chapter 3, methodology of how the research project to be conducted is explained thoroughly. All steps and recommendations will be provided in order to obtain high accuracy of promising results. Next, the data acquisition will be further discussed on chapter 4. Conclusion and some recommendation will be stated at the last of the chapter.

CHAPTER 2 LITERATURE REVIEW

2.1 GEOLOGY OF STUDY AREA

The geology of the quarry site is located at the north part of the Kinta Valley which represents various form of shaped and most of the limestone formation in Malaysia has undergoes the process of karstification having a complex tectonic structure (Zabidi *et al.*, 2016). These variation might cause from the development and deposition of the process of the sedimentation itself where the formation of the tectonic structure may vary in their discontinuities such (bedding plane, foliation-cleavage, fractures, joints, faults and shear zones) during the lithification process. Kinta limestone formation was believed had formed during (Sillurian-Devonian) which subdivided into calcareous facies which interbedded with the argillaceous rock facies include shale, schist, phyllite and rare quartzite. Some of the interbeds are conglomerate, chert, and sparse volcanic in place. Hume cement quarry rock faces generally made up of yellow to yellowish brown, massive to highly bedded, heavily jointed of limestone rock strata.

Locally, the kinta limestones at the Malim Nawar is generally a white, pale grey and slightly yellowish rock. A hematitic inclusion were found at the quarry site which limestone in red colour are a rare event in several location. It is a secondary iron minerals, hematite covering the limestone surface which have been formed by the action of furreginous solutions on the limestone. According to the Annual Report of the Geological Survey for 1926, mentions that at Malim Nawar posed a small lenticular beds of shale interbedded with the limestone though cannot visibly in the

quarry face (Ingham and Bradford, 1960). The grain size of the limestone may vary from fine-grained to coarse-grained but it generally metamorphosed by the adjacent granite. However, according to (Rastall, 1927) a finer-grained saccharoidal type is more common in this quarry site. Meanwhile, there are several classification system of intact rock that usually based on the strength and/or deformation properties (Unconfined Compressive Strength) where (ISRM, 1978c), (Canadian Geotechnical Society, 1985) adopted. The table 2.1 below shows the classification system of sedimentary rocks according to their formation process.

Table 2.1: Classification of Sedimentary Rocks (Zhang L., 2006).

Method of formation	Classification	Rock	Description	Major mineral constituent
Mechanical	Rudaceous	Breccia	Large grains in matrix	Various
		Conglomerate		
	Argillaceous	Claystone	Micro-fine-grained plastic texture	Kaolinite, quartz. Mica
		Shale	Harder laminated	
		Mudstone	compacted clay	
	Arenaceous	Sandstone	Medium, round grains in silica matrix	Quartz, calcite (sometimes feldspar, mica)
		Quartzite	Quartz	
Gritstone		Medium, angular grains in matrix		
Breccia		Coarse, angular grains in matrix		
Organic	Calcareous	Limestone	Fossiliferous, coarse or fined grained	Calcite
	Carbonaceous (siliceous,	Coal		

	ferruginous, phosphatic)			
Chemical	Ferruginous	Ironstone	Impregnated limestone or claystone (or precipitated)	Calcite, iron oxide
	Calcareous (siliceous, saline)	Dolomite, Limestone	Precipitated or replaced limestone, fine grained	Dolomite, calcite

2.2 DISCONTINUITIES

Generally, discontinuity is a term for most type of joints, weakness zone, weak bedding planes, fault and weak schistosity planes of a rock mass which having a low or zero tensile strength (ISRM, 1978). Fractures and discontinuities is the amongst the most important in geological structures from the hydrological view which allows storage and movement of fluid through them. The discontinuity itself makes the difference on the rock mass properties, therefore, it is crucial to understand the engineering properties of the rocks and characterize the discontinuities in details.

2.2.1 Description of Discontinuities

From an engineering point of view, the type of rock involved are the basic information need to be gather, yet the type and frequency of the joints are the most important to be studied. The characteristic of the discontinuities can be describe under 10 paramater based on (ISRM, 1978) :

1. Orientation: Discontinuity attitude in space. Can be describe by the dip direction (azimuth) and dip of the line of steepest declination in the plane of discontinuity.
2. Spacing: The perpendicular distance between adjacent discontinuities where normally refers to the mean or modal spacing of a set of discontinuities.
3. Persistence: The discontinuity trace length as observed in an exposure that may give a crude measure of the areal extent or penetration length of a discontinuity. Termination in solid rock or against other discontinuities reduces the persistence.
4. Roughness: The inherent surface roughness and waviness which relates to the plane of a discontinuity. Both of the roughness and waviness contribute to the shear strength. If the waviness is in large-scale may also alter the dip locally.
5. Aperture: The perpendicular distance between adjacent rock walls of a discontinuity, in which the intervening space is air or filled with water.
6. Filling: Material that usually weaker than the parent rock and separates the adjacent walls rock of a discontinuity. Typical filling materials are sand, silt, clay, breccia, gouge, and mylonite. Thin mineral coatings and healed discontinuities such as quartz and calcite veins also includes.
7. Seepage: The water flow and free moisture that visible in the rock mass as a whole or individually in the discontinuities.
8. Wall strength: The equivalent compressive strength of the adjacent rock walls of discontinuity. It may be lower than the rock block strength that

due to weathering or alteration of the walls. Wall strength is an important component of shear strength if rock walls are in contact.

9. Number of sets: The number of discontinuity set comprising the intersecting in discontinuity system. It may be further divided by individual discontinuities.
10. Block size: Dimension of the rock block from the same orientation discontinuity sets that intersect and resulting from the spacing of the individual sets. The block size and shape may further influence from the different individual discontinuities.

2.2.2 Types of Discontinuities

Discontinuities and their origins formed from the deformation of rocks where crustal plates collide or shear past each other. It is where the plutonic intrusions are emplaced, where the regional subsidence or uplift occurs, and other means of stress in the earth occurring long time ago. Mechanism of deformation include also bending of strata that creates a fold structures, extensile cracking causing joints and so do shear rupture yield faults.

1. Faults

The term along which dragging of abrasive rock has an imprinted scratches and grooves and deposited rock powder or angular fragments which often altered to clay so called fault gouge (clay) and fault breccia (recemented).

2. Bedding planes/ strata

Most sedimentary strata were deposited initially planar surface that was horizontally or nearly horizontal (Goodman, 1993). It is generally high persistence features, although sediments laid down rapidly from water currents or heavily laden wind that may contain cross or discordant bedding.

3. Joints

Joints are the ordinary citizen of rock mass because they are the most common and most geotechnically significant discontinuities in rocks. It refers for the regularly recurring fracture surfaces that usually planar, cutting across the rock with constant orientation and having a mean spacings up to several meters. Joint sets are known for the group of roughly parallel or sub-parallel to a single plane until they intersect to form a joint system.

4. Cleavage

Discontinuities often frequently form parallel to bedding planes, foliations or slaty cleavage that may be term as bedding joints, foliation joints or cleavage joints. Fracture cleavage also known as false cleavage and strain slip cleavage that describe a welded parallel discontinuities dependent of any parallel alignment of minerals (Zhang L., 2006).

2.2.3 Discontinuities Orientation

Orientation is usually measured from true north and there are several ways of recording the information on strike of the discontinuity (most preferable) and dip direction. Most of the engineering practices quote the orientation data in form of dip

direction /dip (dip angle). Orientation from engineering point of view provides an importance as the presence of other deformation condition. It can be measured on site scanline and plotted on stereonets to measure the pole contour concentration and various discontinuity sets present.

A number of algorithms based on statistical or fuzzy-set approaches are available for numerically a difficult clustering orientation data (Einstein and Baecher, 1982). Mean orientation of a number of the discontinuities can be calculated from the direction cosines. Sampling bias on orientation can also be considered.

2.2.4 Discontinuity intensity

It can describe in different term in measures in one, two or three dimension, including discontinuity spacing, linear, areal and volumetric frequency, Rock Quality Designation (RQD), discontinuity trace length per unit area of rock exposure, and discontinuity area per unit volume of rock mass.

2.2.4 (a) Spacing and linear spacing

Discontinuity spacing is a distance between the adjacent discontinuities measured along a conventional sampling line mapping (scanline). If the sampling line is normal to the discontinuity planes, the set spacing then called the normal set spacing (Priest, 1993). The terminology used by (ISRM, 1978) for describing the magnitude of discontinuity spacing as shown in table 2.2 below.

Table 2.2 : Classification of discontinuity spacing (Zhang L., 2006).

Classification of Discontinuity Spacing	
Description	Spacing (mm)
Extremely close spacing	< 20
Very close spacing	20 - 60
Close spacing	60 - 200
Moderate spacing	200 - 600
Wide spacing	600 - 2000
Very wide spacing	2000 - 6000
Extremely wide spacing	> 6000

2.2.5 Causes of Discontinuities

Engineering properties of type of discontinuity plays a major role in rock behaviour where they are related to the geological history. They are faults, bedding planes, joints and cleavage. They appeared in different type of engineering structure usually patternly in group. Discontinuity are created due to stresses which may have a diverse origin such as:

- a) The tectonic stresses that related to the deformations of rocks.
- b) The residual stresses cause by event that long happened before the fracturing.
- c) The cooling of magma or dessication of sediments causing contraction due to shrinkage.
- d) The surficial movements of landslides or glaciers.
- e) The erosional unloading of deep-seated rocks.

f) The weathering process such as dilation and dissolution.

It is noted that there are a lot of problem that can caused by a different types of discontinuities formation in the rock mass.

2.3 PHOTOGRAMMETRY

Photogrammetry is science based innovation with mathematical principal remain unchange over a time of history and improvement. Yet, the application for production purposes have drastically move forward along with the development of the technology (Linder, 2016). The principal of the photogrammetry is about the acquisition of data for 3-D results such DSM/DTM, contour lines, textured 3-D models, vector data, and to extract the redundant set of tie points with a geo-referenced images captured. Recently, there are several open-source software which helped the automated identification (e.g. PhotoModeller Scanner, MeshLab, CloudCompare and Agisoft Photoscan 3-D) had been commercially used with sufficient amount of sensitively data to be prepared.

Photogrammetry also is a great tools to provides a quantitative data from a single photo, 2-D into three-dimensional coordinates. Each images taken can give a different position in different perspective which can tells us the previous and future information regarding the type of problems to work on so-called *stereoscopic viewing* in photogrammetry (Linder, 2016).

2.3.1 Elementary in Photogrammetry

2.3.1 (a) Perspective projection

In a long sunny day, the camera has to be in a great performance to maintain a sharp image. Basic knowledge to implement is the collinearity of the three points defines rays which can be said 3-D points in the object spaced are transformed via perspective projection into 2-D image plane.

2.3.1 (b) Scale and coverage

Map scale is very important to deliver the information on such map having a scale of 1:12,000 if 1 unit on the maps corresponds to 12,000 units on the ground or on the projection surface. A simple characterization of scale on vertical photographs over flat terrain through the ratio of image distance (image plane) to object distance (terrain).

2.3.1 (c) Image coordinate system

Image coordinate system defined as having its origin at Fiducial Centre (FC), where the x-axis direction explicitly define as either through a side fiducial mark or bisecting the lines joining at the corner. The y-axis lies at the right angle to the x-axis in the image plane producing a right-handed coordinate system. Camera calibration is acquire prior picture taken, though the principal distance is equal to the focal length for areal camera.

Therefore, we are able to analysed the 3-D coordianates of the points with a referenced points by calculating their intersection and allows photogrammetric matching more accurate to recognized the problems mainly in mining industry on discontinuities of a rock. This valuable sort of information can provide an enermous outcome of improvement to the study such as in blasting activity, groundwater determination, and slope stability as the data acquisition is properly calculated and detailed accordingly to the local and historical geo-information.

2.3.2 Types of photogrammetry

There are several types of photogrammetry available for various type of application available according to the distance from camera to object.

1. Close range photogrammetry : $d < 10$ m
2. Terrestrial photogrammetry : $10 \text{ m} < d < 100$ m
3. Aerial photogrammetry : $2 \text{ km} < d < 10$ km
4. Space photogrammetry : $30 \text{ km} < d$

2.3.3 Photogrammetry product

2.3.3 (a) Orthophoto

Photomap is a photographic map with a uniform-scale photograph where it is possible to measure directly on the map which is generally known as orthophoto. It aslo may serve as a base map onto which other map information can overlain this

photomap. An orthophoto also can be inserted/ merge onto Google Maps to view the changes available across the year.

2.3.3 (b) Digital Surface Model

DSM can captures the natural and built features on earth surface. For example, DSM can determine runway obstructions in the approach zone of encroachment. DSM also can measure where and how much vegetation is encroaching along a transmission line. A view of how a proposed building would become an obstruction through the uses of DSM.

2.3.3 (c) Digital Elevation and Terrain Models

DEM (Digital Elevation Models) is known as a bare-earth raster grid with referenced to a vertical datum or control points. It allows hydrogeologist to delineate watersheds, calculate flow accumulation and direction of waterflow. An areas prone to avalanches are with high slope areas with some sparse vegetation can be usefull by viewing through DTM (Digital Terrain Models) while planning a road cut or bench. It also help in mining scope where one can determine a lot of information through the DEM results such as the (geological feature of the location, an optimization in blasting and drilling activity and bench slope stability).

2.4 UNMANNED AERIAL VEHICLE

Unmanned Aerial Vehicle innitially has been introduced during World War I in the early of 1915-19 to efficiently conduct an air operation in military. It is a system

that can be controlled from ground operator flying on a preprogrammed and returned to 'home', more correctly known as "drones" (C. Gerken, 1991). The innovative and growth of UAV increases from years to broad commercial applications in environmental monitoring, mapping, surveillance and reconnaissance and airborne communications down to search and rescue, fire detection, agricultural imaging traffic monitoring as well as mining engineering (Alvis *et al.*, 2007).

However, in recent years UAV has developed in a more better useful and worth for the price itself as there were continuously upgraded into a devices that can multitask and subsequently reduce payload for more technical works. Inventor had made the UAV as a platform nowadays a valuable source of fast data acquisition and mapping in a low-cost system compared to later digital mapping system like LiDAR. A simple rotary or fixed wings UAVs allows professional camera onboard capable of taking an aerial photograph vertically which operates automatic or semi-automated and conventional modes with GPS-driven and intelligent sensor to provide a high quality of images with high level of accuracy for photogrammetry mapping and 3-D modelling.

A typical image-based field surveying with a UAV systems require a flight planning, ground control points (GCPs) for geo referencing, image acquisition, camera calibration and image orientation, image processing for 3-D information extraction (Remondino *et al.*, 2011).

2.4.1 Accuracy

Accuracy though give some questionable reason for a drones that can create highly accurate data. However the accuracy is dependent on several factors involved:

- I. Camera: A better data can be producible from a better and bigger sensors that have less noise, less blur effect and less of a rolling shutter effect.
- II. Lens: A less lens distortions (barreling or fisheye) will result in better images.
- III. Drones: Gimbals that equipped on the drones keep the camera pointing correctly will give out a better data acquisition.
- IV. Altitude: The more higher drone fly, the less accurate things like elevation will be as it is harder to differentiate the relative between two distances the further you are.
- V. Image resolution: The higher the resolution of the image will result in better data.
- VI. Number of photos: According to Law of Large Numbers”, to produce less error, the more images taken, the greater number of GPS locations to work with.
- VII. Higher overlap in imagery: The higher the overlap in images, the more key-points we can detect providing more GPS data will have for each pixel that will increase the accuracy.
- VIII. Atmospheric conditions: GPS is very sensitive that can may affected by atmospheric conditions such as (temperature, air density, pollution and clouds), Ionospheric conditions as well as solar flares.

- IX. Buildings: Taller structures will block GPS signals across it as well as reflect them that will causing multi-path interference which causes inaccurate data.

Motion blur is caused by fast-moving (too fast) or vibration from drones lead to the decrease in shutter speed. Thus, by flying slower or higher will help reduce motion blur. It is also crucial to ensure autofocus is on and there are no dust particle on the lense by adjusting the camera settings conventionally in the DJI GO application.

Furthermore, ground control points can greatly improve the global accuracy of drone mapping and ensuring the latitude and longitude of any positions on map corresponding with actual GPS coordinates accurately resulting in a very precise mapping.

2.4.2 Mapping method

There are several mapping method available for photogrammetric purpose. They are as describe in the table 2.3 below.

Table 2.3: Features of aerial, close range and UAV photogrammetry (Eisenbeiss, 2011)

	Aerial	Close range	UAV
Planning	Automatic, semi-automatic	Conventional	Automatic, semi-automatic, conventional
Data acquisition/ flight	Assisted, conventional	Autonomous, assisted, conventional	Autonomous, assisted, conventional
Size of the area	km ²	mm ² – m ²	m ² – km ²

Image resolution/ GSD	cm - m	mm – dm	mm – m
Distance to the object	100m - 10km	cm – 300m	m – km
Orientation	Normal, (oblique)	Normal, oblique	Normal, oblique
Absolute accuracy of the initial orientation values	cm – dm	mm – m	cm – 10m
Image block size/ number of scans	10 – 1000	1 – 500	1 – 1000
Special applications	Large scale areas (mapping, forestry, glaciology, 3D city modelling)	Small scale areas and objects (architectural and industrial photogrammetry)	Small and large scale areas, also inaccessible areas and dangerous objects)

2.4.3 Classification and Specification

Unmanned Aerial Vehicle used in this study is a very updated and latest version of equipment in this era. It is provided by a successful company in Japan produces a high technology drone for multi-advantages for various application. Figure below shows the drone specification used in this study.

CAMERA	
Sensor	1" CMOS Effective pixels: 20M
Lens	FOV 84° 8.8 mm/24 mm (35 mm format equivalent) f/2.8 - f/11 auto focus at 1 m - ∞
ISO Range	Video: 100 - 3200 (Auto) 100 - 6400 (Manual) Photo: 100 - 3200 (Auto) 100- 12800 (Manual)
Mechanical Shutter Speed	8 - 1/2000 s
Electronic Shutter Speed	8 - 1/8000 s
Image Size	3:2 Aspect Ratio: 5472 × 3648 4:3 Aspect Ratio: 4864 × 3648 16:9 Aspect Ratio: 5472 × 3078
PIV Image Size	4096×2160(4096×2160 24/25/30/48/50p) 3840×2160(3840×2160 24/25/30/48/50/60p) 2720×1530(2720×1530 24/25/30/48/50/60p) 1920×1080(1920×1080 24/25/30/48/50/60/120p) 1280×720(1280×720 24/25/30/48/50/60/120p)
Still Photography Modes	Single Shot Burst Shooting: 3/5/7/10/14 frames Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias Interval: 2/3/5/7/10/15/20/30/60 s

Figure 2.1: UAV classification (Baiwang, 2006)

AIRCRAFT		INTELLIGENT FLIGHT BATTERY	
Weight (Battery & Propellers Included)	1388 g	Capacity	5870 mAh
Diagonal Size (Propellers Excluded)	350 mm	Voltage	15.2 V
Max Ascent Speed	S-mode: 6 m/s P-mode: 5 m/s	Battery Type	LiPo 4S
Max Descent Speed	S-mode: 4 m/s P-mode: 3 m/s	Energy	89.2 Wh
Max Speed	S-mode: 45 mph (72 kph) A-mode: 36 mph (58 kph) P-mode: 31 mph (50 kph)	Net Weight	468 g
Max Tilt Angle	S-mode: 42° A-mode: 35° P-mode: 25°	Charging Temperature Range	41° to 104°F (5° to 40°C)
Max Angular Speed	S-mode: 250°/s A-mode: 150°/s	Max Charging Power	160 W
Max Service Ceiling Above Sea Level	19685 feet (6000 m)	GIMBAL	
Max Wind Speed Resistance	10 m/s	Stabilization	3-axis (pitch, roll, yaw)
Max Flight Time	Approx. 30 minutes	Controllable Range	Pitch: -90° to +30°
Operating Temperature Range	32° to 104°F (0° to 40°C)	Max Controllable Angular Speed	Pitch: 90°/s
Satellite Positioning Systems	GPS/GLONASS	Angular Control Accuracy	±0.02°
Hover Accuracy Range	Vertical: ±0.1 m (with Vision Positioning) ±0.5 m (with GPS Positioning) Horizontal: ±0.3 m (with Vision Positioning) ±1.5 m (with GPS Positioning)	INFRARED SENSING SYSTEM	
		Obstacle Sensory Range	0.6 - 23 feet (0.2 - 7 m)
		FOV	70° (Horizontal), ±10° (Vertical)
		Measuring Frequency	10 Hz
		Operating Environment	Surface with diffuse reflection material, and reflectivity > 8% (such as wall, trees, humans, etc.)

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

The fundamental task for presenting the validity of the result are being discussed in this chapter briefly. Though, knowledge based information on the site of investigation and the software to be introduced are totally crucial in data acquisition planner. Method being used in this research was photogrammetry analysis using Agisoft Photoscan to generate 3D models and point clouds, Mathworks® (MATLAB) for the discontinuity analysis and the use of Unmanned Aerial Vehicle (UAV), DJI drone for the acquisition of high precision of images.

3.2 PLANNING AND INVESTIGATION

Desk study and preliminary steps are due to study the site of interest in depth. Thus, an informative geological area of Malim Nawar need to be assured accordingly. This reduced time and provides some rough idea on the area to be investigated as well as gives more chances to predict and set up the survey successfully.

3.2.1 Principal aerial survey mapping

The great advantages of using the DJI Phantom Pro 4 Plus was the intelligence of the products that reduce workloads and promising a high-end professional imagery. This brought the local or old days of aerial photograph becomes barely in-hand controlled with all built-in high technology aircraft fitted with camera for professional-grade aerial imaging.