DEVELOPMENT OF MAPPING PROCEDURES USING DIGITAL IMAGERY DERIVED FROM UNMANNED AERIAL VEHICLE SYSTEM

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Abstract

Digital photogrammetry is one of the important data source in GIS. Aerial photogrammetry is mainly used to produce topographic or thematic maps and digital terrain models. Digital images can be created by a variety of input devices and techniques, such as digital cameras, scanners, coordinate-measuring machines, seismographic profiling, airborne radar, and others. In aerial photogrammetry, the aerial photographs are acquired using a special camera known as metric camera or large format camera (230mm x 230mm) and fixed wing aircraft. Metric cameras have stable and precisely known internal geometries and very low lens distortions. Therefore, they are very expensive devices and the cost for acquiring aerial photographs is very expensive too. To acquire aerial photographs of a small area, it is not economical to use common large format aerial camera. Hence, other alternative has to be used. Nowadays, people from all around the world have started using small format camera for acquiring aerial photographs. In this study, the unmanned aerial vehicle (UAV) system in the form of very small airplane (2.7 kg) known as CropCam UAV (Canada) is used to acquire small format aerial photographs (i.e digital image) of an area for mapping. Sufficient number of ground control and check points are established using Global Positioning System around the studied area. The digital images are processed using digital photogrammetric system to produce photogrammetric output such as map or orthophoto. In this study, the mapping procedures between large format aerial photographs and small format aerial photograph are compared. In general, the mapping procedures of large format and small format camera are the same. For small format camera many photographs are required to cover the same area covered by large format camera. Hence, more time is required to produce the aerial photograph. However, small format camera has great potential to be used in various and diversified applications such as map revision of small area, crash accident on highway, land slide (environmental disaster), Geographic Information System (GIS) applications and others.

Keywords : Unmanned aerial vehicle, digital photogrammetry, small format aerial photo.

1.0 BACKGROUND OF STUDY

A digital image is a representation of a two-dimensional image as a finite set of digital values, called *picture elements* or pixels. The digital image contains a fixed number of rows and columns of pixels. Pixels are the smallest individual element in an image. Digital images can be created by a variety of input devices and techniques, such as digital cameras, scanners, coordinate-measuring machines, seismographic profiling, airborne radar, and more

An unmanned aerial vehicle (UAV) is an aircraft with no onboard pilot. UAVs can be remote controlled or fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. UAVs are currently used in a number of military roles, including reconnaissance and attack. They are also used in many civil applications such as fire fighting where a human observer would be at risk, police observation of civil disturbances and scenes of crimes, and reconnaissance support in natural disasters. There are a wide variety UAV shapes, sizes, configurations, and characteristics. The earliest UAV, the Hewitt-Sperry Automatic Airplane was developed during and after World War I. During the Second World War, a number of remote-controlled airplane advances were made in the technology rush. These were used to train anti-aircraft gunners and to fly attack missions.

With the maturing and miniaturization of applicable technologies as seen in the 1980s and 1990s, interest in UAVs grew within the US military. UAVs were seen to offer the possibility of cheaper, more capable fighting machines that can be used without risk to aircrews. Initial generations were primarily surveillance aircraft, but some were fitted with weaponry (such as the MQ-1 Predator, which utilized AGM-114 Hellfire air-to-ground missiles). An armed UAV is known as an Unmanned Combat Air Vehicle (UCAV).

1.1 Current scenarios

In Malaysia, the Department of Surveying and Mapping Malaysia (Jabatan Ukur dan Pemetaan Malaysia, JUPEM) is the responsible government organisation for the production of topographic map, orthophoto, digital terrain model (DTM), cadastral plan, orthometric height (levelling). Solar almanac, tide table and others. In the production of topographic map or orthophoto, it is produced using aerial photogrammetry method. In aerial photogrammetry, the aerial photographs are acquired using a special camera known as metric camera or large format camera (230mm x 230mm) and fixed wing aircraft. The cost for acquiring aerial photographs is very expensive.

Sometime, the project area is not very big. It is not economical to use common large format aerial camera to acquire aerial photographs of a small area, hence, other alternative has to be used. Nowadays, people from all around the world have start using small format camera for acquiring aerial photographs. Small or light platform such as helicopters, gliders, balloon and others are used. In Malaysia, the technology of using small format camera for acquiring aerial photographs is still new and need to be ventured or explored. This technology has great potential to be used in various and diversified applications such as map revision of small area, crash accident on highway, land slide (environmental disaster), Geographic Information System (GIS) applications and others.

2.0 RELEVANT PREVIOUS STUDIES / LITERATURE REVIEW

2.1 Digital Photogrammetry and UAV

Non-metric camera can also be used for aerial photography, apart from metric camera. Non-metric camera includes video camera and digital camera. The aerial photographs produced by using non-metric camera can be used for various applications such as for map revision in GIS, research work and any application which does not require high accuracy. The non-metric camera especially the digital camera offers several advantages compared to metric camera. Some examples of the advantages are ease of use, handy, cheap and the images are in digital form which is ready to be used.

The development of digital photogrammetry has been going parallel with the development of remote sensing (Konecny, 1985). Digital photogrammetry involves the practice of using pixels and image processing techniques to arrive at geometric information. (An Introduction to Non-Topographic Photogrammetry – ASPRS). Recently however, according to Unmanned Aerial Vehicles (UAVs) have emerged as viable platforms for the acquisition of high-resolution aerial imagery (Lewis, 2007).

Unmanned Aerial Vehicles (UAVs) are automatically piloted by an embedded system named "Flight Control System". Nowadays, many of those systems are commercially available. An Unmanned Aerial Vehicle identifies an aircraft that can fly without pilot; that is, an airframe and a computer system which combine sensors, GPS, serves and CPUs. UAV is capable to fly in an autonomous way and operates in a wide range of missions and emergencies that can be controlled from a ground base station. UAV consists of the airframe, flight computer, payload, the mission/payload controller, the base station and the communication infrastructure. Figure 1 shows the main components of a UAV system.

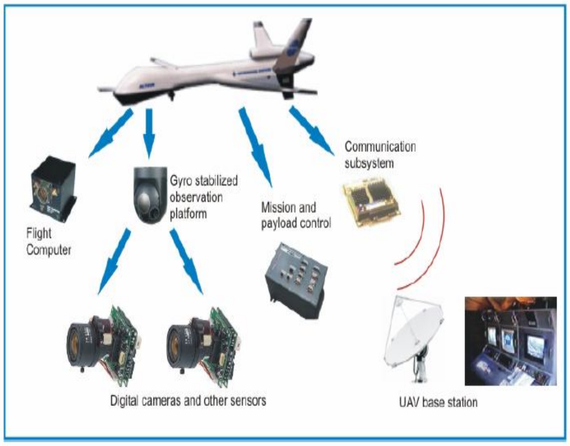

Figure 1: Main components of a UAV system.

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The UAV airframe is a simple, lightweight, aerodynamically efficient and stable platform with limited space for avionics. The flight computer is a computer system designed to collect aerodynamic information through a set of sensors (accelerometers, gyros, magnetometers, pressure sensors, GPS, ETC.), in order to automatically direct the flight of an airplane along its flight-plan via several control surfaces present in the airframe. The payload consists of sensors composed of TV cameras, infrared sensors and thermal sensors to gather information that can be partially processed on-board or transmitted to a base for further analysis.

The mission/payload controller is a computer system onboard of the UAV that has to control the operation of the sensors included in the payload. A computer system on the ground designed at the base station to monitor the mission development and eventually operate the UAV and its payload. The communication infrastructure is a mixture of communication mechanisms (radio modems, microwave links) that make sure continuous link between the UAV and the base station.

Modern digital airborne sensors are also usually mounted with a GPS (Global Positioning System)/ IMU (Inertial Measurement Unit) system. GPS technology assists mapping projects by using a series of base stations in the project area and a constellation of satellites providing positional information accessed by the GPS receiver on-board in an aircraft. GPS and IMU information can be extremely beneficial for mapping areas where limited ground control information is available (e.g. rugged terrain). They also assist in the triangulation process by providing highly accurate initial orientation data, which is then further refined by the bundle adjustment procedure.

2.2 Aerial Surveying and Mapping

Aerial photography must be carefully planned to secure a good result. The essential material is procured from the aerial photographs, which are the fundamental significance for the accuracy and completeness desired in the map. The most important task of aerial photogrammetry is to constitute an aid in production of topographic maps. Maps on various scales are produced according to procedures. A primary requisite for rational utilization of photogrammetry is that the type and the tolerances of the map desired are clearly determined at an early stage of the working procedure.

2.3 Small Format Aerial Photography

Conventional large-format aerial photographs, taken from heights of several 1000m and at scales of 1:20,000 to 1:40,000, have resolution on the order of 1-4 m. In order to achieve submeter resolution, a variety of small-format techniques have been developed for aerial photography. Figure 2 shows an example of orthophoto of large format aerial photo (source : Anuar Ahmad, Digital Photogrammetry : An Experience Of Processing Aerial Photograph Of UTM acquired Using Digital Camera).

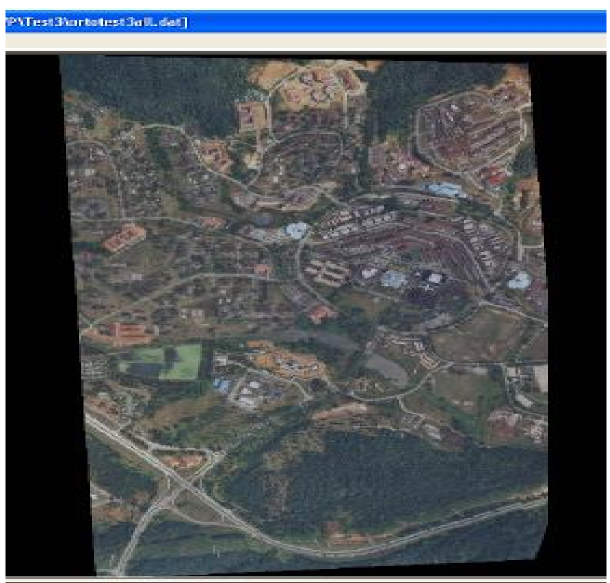

Figure 2 : Example of orthophoto of large format aerial photo.

Small format aerial photography (SFAP) has experienced rapid development, spurred by innovations in platforms and camera systems as well as increasing demand for high resolution, large scale imagery in diverse application. SFAP is typically acquired at low height (few 100 m), which results in high-resolution and large-scale images at smaller coverage area. UAVs are popular for their abilities to coordinates simultaneous coverage of large areas, or cooperate to achieve goals such as mapping. The capabilities of UAVs continue to grow with advances in wireless communications and computing power.

2.4 CropCam UAV

CropCam is a product from Canada. It is a new, self-guided plane that creates GPS-based (Global Positioning System) digital images so you can keep an eye on your crops. You can scout disease, view crop development and stop problems before they get out of control. CropCam is inexpensive and easy to use with preset flight plans that can cover up to 160 acres per launch. Images are accessible within hours and provide latitude, longitude and altitude coordinates.

The CropCam is a radio controlled model glider plane equipped with a Trimble GPS, a miniature autopilot and Pentax digital camera. Hand launched and automatic from take off to landing, the CropCam provides high resolution GPS based images on demand. Simply stand at one corner of your field and hand launch the 6 pound CropCam plane. The powerful miniature autopilot and Trimble GPS, does the rest navigating in a pattern over the field. Both the CropCam and the camera perform automatically to take GPS based digital imagery. After the flight the CropCam will land at the spot it started. Figure 3 shows the CropCam used in the study.

Figure 3 : The CropCam UAV

Images acquired at 2100 feet above the ground have a spatial resolution of approximately 15 cm. However, increased spatial resolution can be achieved by simply programming the CropCam to fly closer to the ground. With this 4 feet length and 8 feet wing span (weight about 6 pounds) CropCam we can fly 160 acres, 320 or 640 acres in one flight in approximately 23-27 minutes depending on wind, offer real time video with ability to capture images from ground station, flying times up to 55 minutes, and also we can stitch images. Pentax Optio A30 digital camera is used with the CropCam UAV. It is a compact digital camera with 10.0 effective megapixels and enhanced anti-shake functions, making high-quality images possible. Figure 4 shows the picture of Penrax Optio A30 digtial camera.

Figure 4 : Pentax Optio A30 digtial camera

3.0 RESEARCH METHODOLOGY

The aim of this study is to develop mapping procedures using digital imagery (small format aerial photograph) using digital imagery derived from Unmanned Aerial Vehicle (UAV) System. In this study, the unmanned aerial vehicle (UAV) system in the form of very small airplane (2.7 kg) known as CropCam UAV (Canada) will be used to acquire aerial photographs (i.e digital image) of an area for mapping. Sufficient number of ground control and check points will be established using Global Positioning System around the studied area. The digital images will be processed using digital photogrammetric system to produce photogrammetric output such as map or orthophoto. The accuracy of output then will be determined. The flow chart of the research methodology is showed in Figure 5.

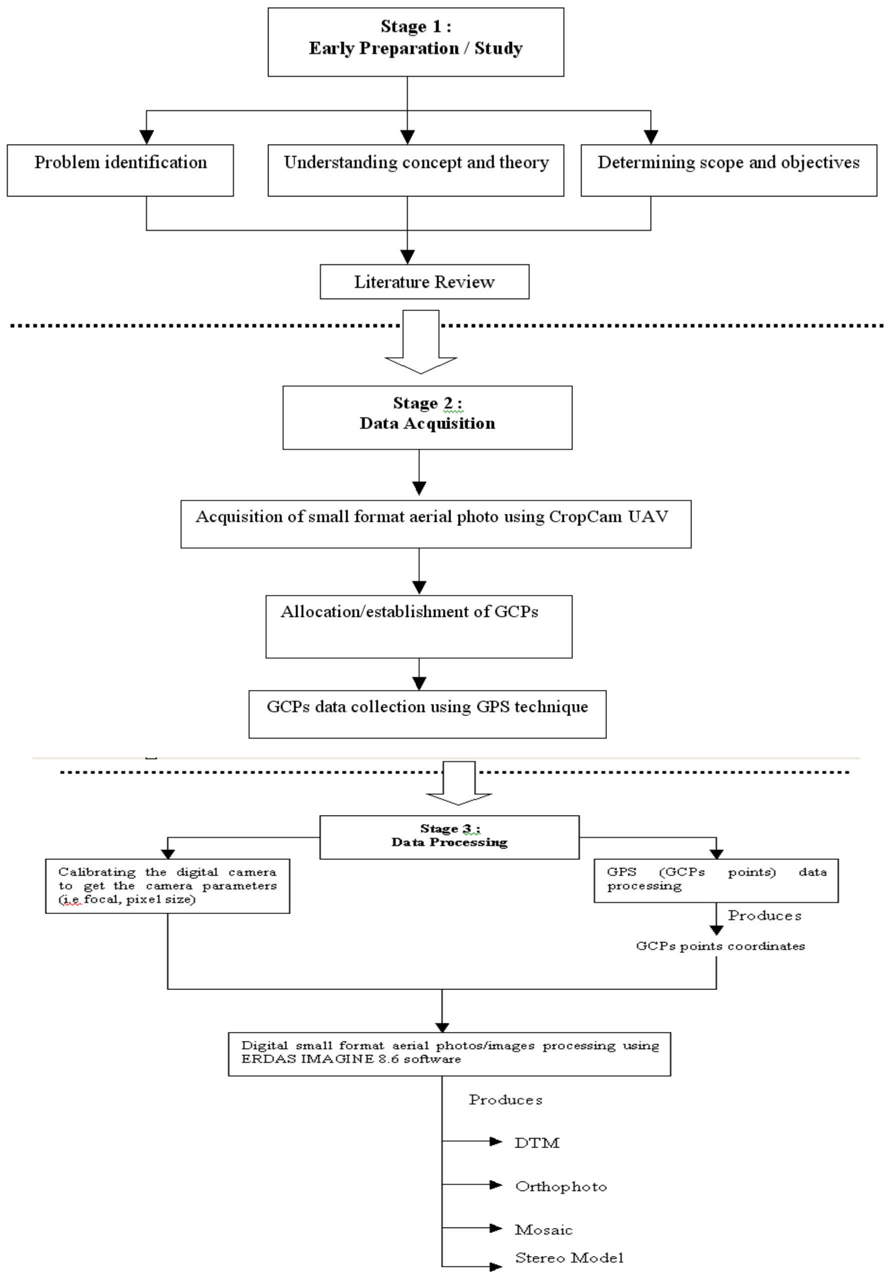

Figure 5 **:** The flow of the research methodology

3.1 Study Area

In this study, initial study area is in Ladang UPM and it's surrounding in Puchong, Selangor. This study area is approximately 1.6km x 0.5 km. For the study area, 16 aerial photographs were captured using the CropCam UAV and small format digital camera. Figure 6 shows the flight line used to acquire the digital images. These digital small format aerial photographs were acquired by JuruPro Sdn, Berhad. The aerial photographs were acquired with 60% overlapped and acquired in July 2008. The CropCAM was flown at an attitude of 300m. In this paper, the results of two processed aerial photograph are discussed.

Figure 6: The study area (Puchong, Selangor)

4.0 DATA ANALYSIS & RESULTS

4.1 GPS Ground Control Points (GCPs) and Tie Points

GPS technique with sub-millimeters accuracy is used in the establishment of the ground control points (GCPs). The GCPs are then entered for the small format digital aerial photo in ERDAS IMAGINE 8.6 software before generating automatic tie points. Images used for processing include Image 0029 and Image 0030 (Figure 7). The distribution of the GCPs are shown in Figure 8 while Figure 9 shows the distribution of the points in graphics view. After finished digitized the GCPs, triangulation process is carried out. The distributions of the GCPs and tie points on the aerial photos are shown in Figure 8. The RMSE for the process of triangulation is ±0.247m.

Image 0029 Image 0030

Figure 7: Small format aerial photo

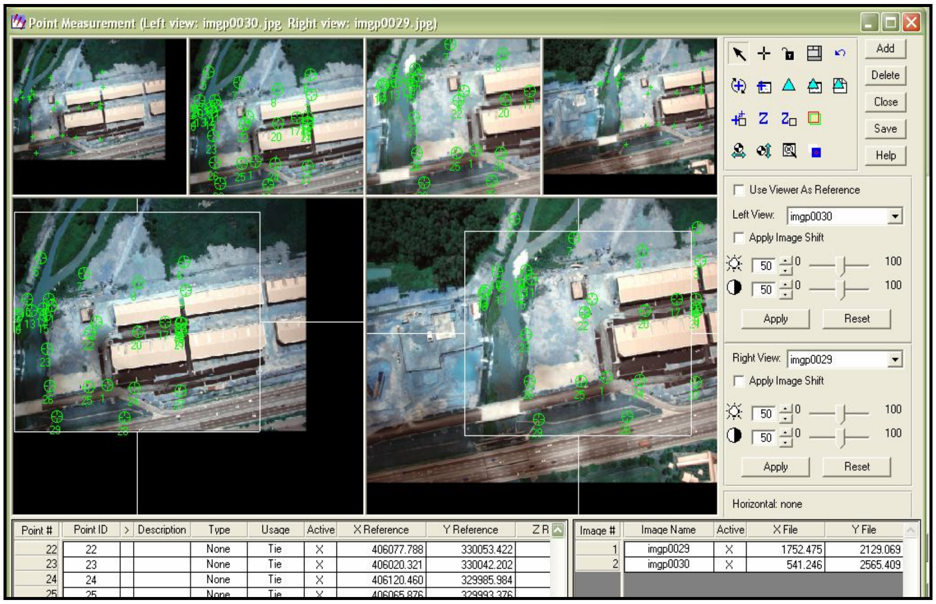

Figure 8 : The distribution of GCPs and tie points

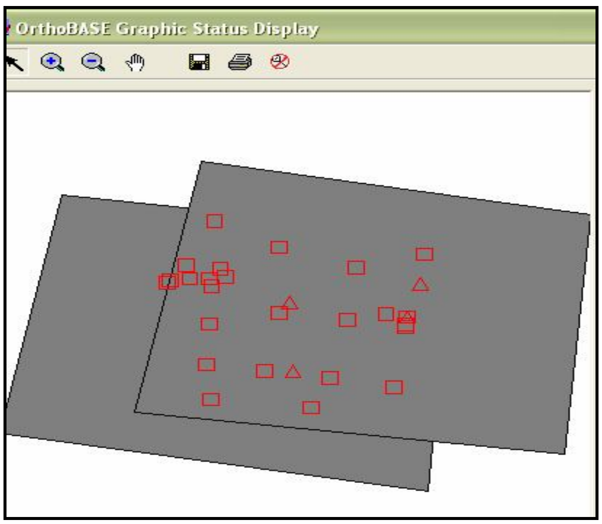

Figure 9 : The distribution of the GCPs and tie points in graphic view.

4.2 Digital Terrain Model (DTM)

After the triangulation process, the DTM can be obtained. The DTM of the study area is obtained by using the Erdas Imagine software and by defining the required ground interval. Figure 10 shows the DTM of the study area.

Figure 10 : The DTM of the study area.

4.3 Orthophoto

For the production of an orthophoto, a DTM is required. The DTMs produced in Section 4.2 are used to produce orthophoto. Orthorectification is carried out in order to rectify the images or producing a georeferenced images to a local datum and projection. Figure 11 and Figure 12 showed the orthophoto generated from the digital images 0029 and 0030 respectively.

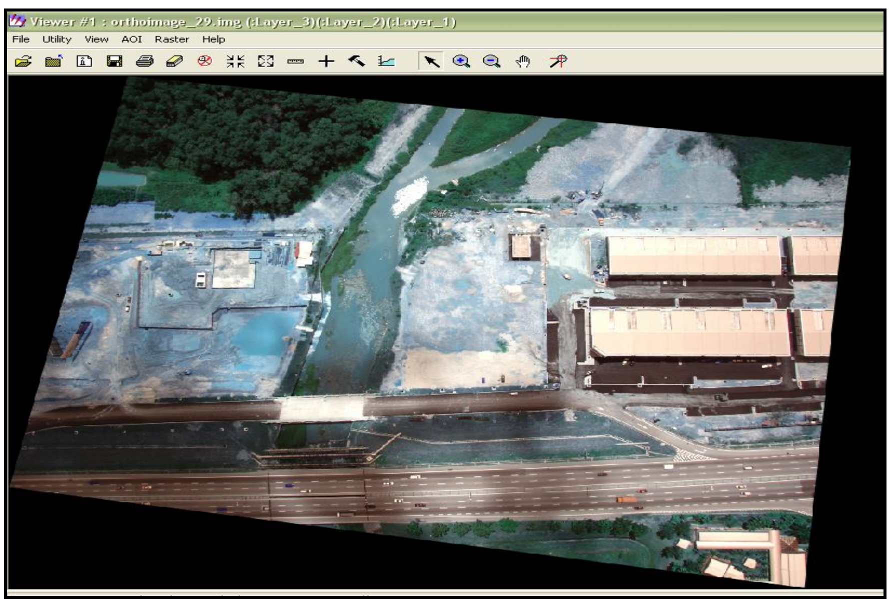

Figure 11 : Orthophoto of image 0029

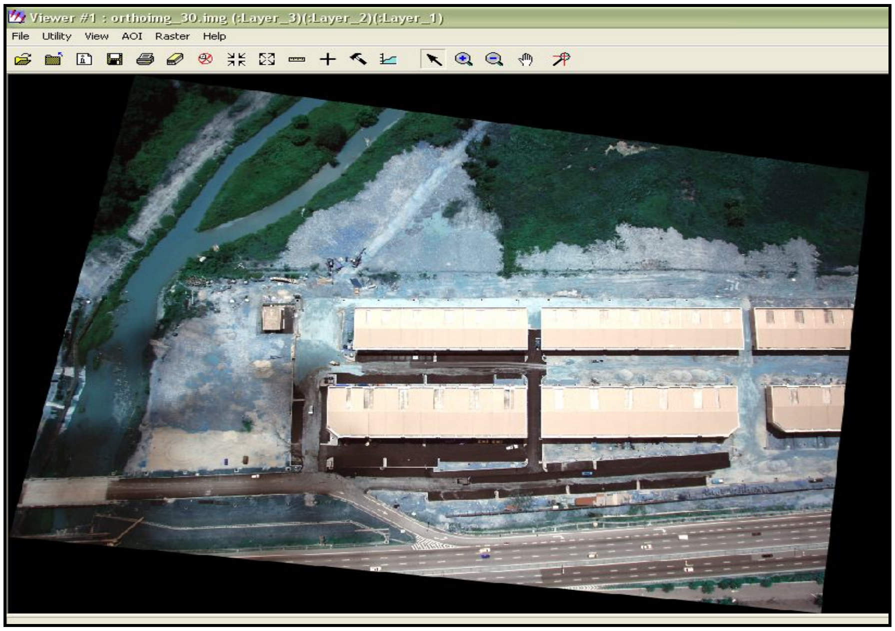

Figure 12 : Orthophoto of image 0030

4.4 Mosaic

The next process is to mosaic the individual orthophoto (Figure 11 and 12) to form an orthophoto. With multiple images stitched or mosaiced into a single image the process of georeferencing is required to allow for the integration of the imagery into a GIS (Lewis, 2007). Figure 13 shows the mosaic of the orthophoto of Image 0029 and Image 0030.

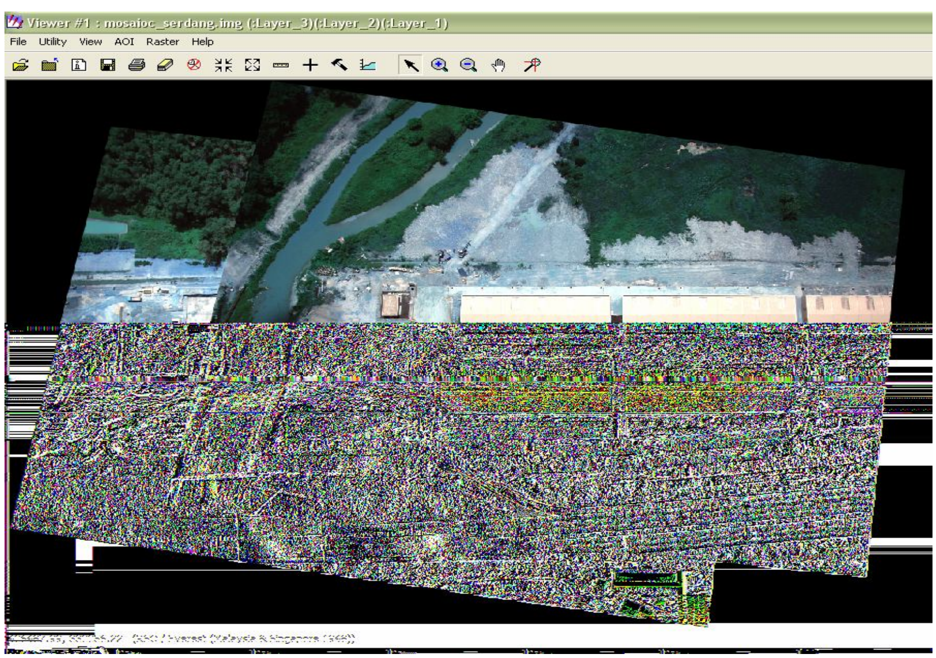

Figure 13 : Mosaic of the orthophotos

4.5 Stereo model (3D)

Figure 14 shows the stereomodel (3D) of the study area. In the stereomodel, user can view the overlap between the two digital images with common points among them. In the stereo module, the digitizing process can be performed. This module allows the user to produce several layers and provides the use of several types of symbol for different features (Figure 15).

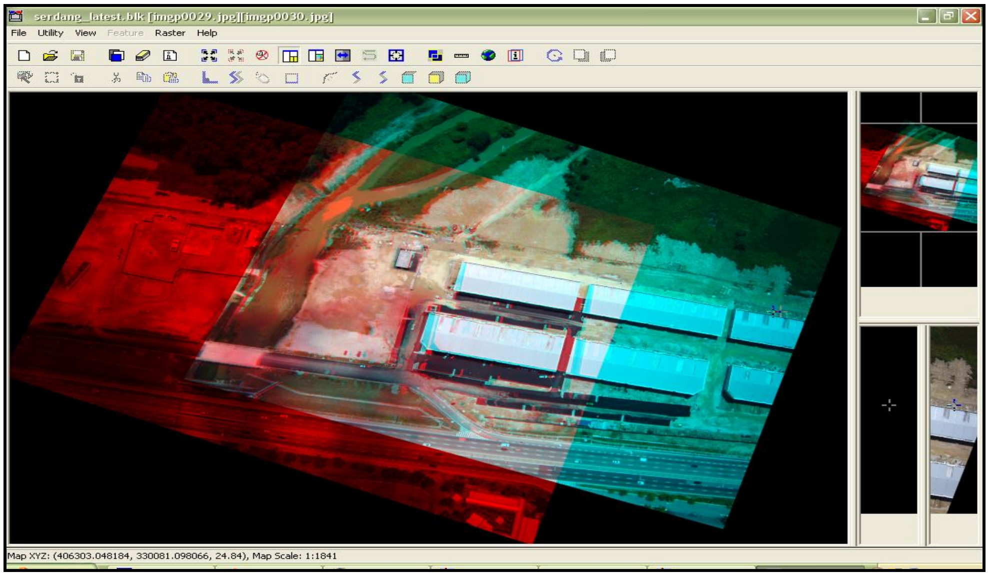

Figure 14 : Formation of stereomodel

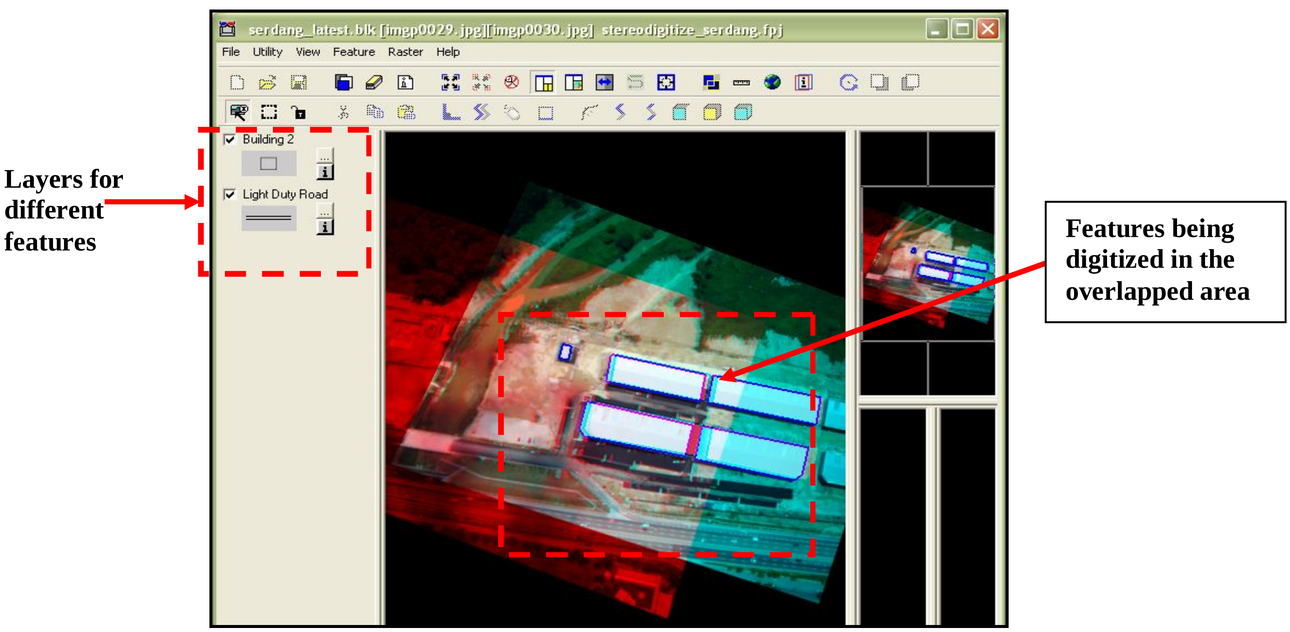

Figure 15 : Digitizing process in the stereomodel

5. 0 CONCLUSIONS

From this study, it was found that the digital small format aerial photography can be used in the production of orthophoto. However, the area covered by using small format aerial photo is smaller compared with the common large format aerial photo. As for the visualization, the visualization of the small format digital images is much better than the large format aerial photo. This is because of better resolution of small format digital aerial photo compared to the large format metric camera. The accuracy of the digital images is good which proved that the digital small format aerial photo can be used in photogrammetry. Finally, this study shows that digital camera has the potential to be used in aerial photogrammetry. But users must bare in mind that the small format aerial photo is suitable for small study area. The potential applications of small format digital camera and UAV include weed surveys and mapping, precision agriculture (crop yield and health monitoring, pest scouting)**,** mine site rehabilitation and so on.

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