DIGITAL PHOTOGRAMMETRY: AN EXPERIENCE OF PROCESSING AERIAL PHOTOGRAPH OF UTM ACQUIRED USING DIGITAL CAMERA

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ABSTRACT

In GIS, aerial photograph can be used as a source of input to the system. The aerial photograph can be in the form of metric or non-metric imagery. In aerial photogrammetry, for most applications aerial photograph acquired using large format (230mmx230mm) is used. However, sometime there is a need to use small format aerial photograph which can be acquired using small format camera. Digital camera is a small format camera that can be used to acquire aerial photograph (non-metric imagery). This paper discusses about the experience of processing aerial photograph which is acquired using a high resolution SLR digital camera and a digital photogrammetric system. For the non-metric digital images a digital camera was used to acquire more than ten digital images to cover approximately the same area covered by a pair of photograph of a metric camera. For the digital camera, it was calibrated using a test field after the acquisition of aerial photography. Ground control points were established using Global Positioning System (GPS). After setting up the stereomodel using digital images of the digital camera, on screen digitizing was carried out. Then the results were exported to a CAD software or Geographical Information System (GIS) software for further action. From the experience of processing the non-metric imagery using the digital photogrammetric system, it was found that the system is capable of processing the digital images easily, could be used for photogrammetric education, research and consultation work. This system could be used not only by photogrammetrist, however, it could also be used by other professionals such as engineers, planners, scientist and others.

1.0 INTRODUCTION

Most countries in the world have produced their topographic map for decades using aerial photogrammetry. Metric camera has been used for the purpose of mapping since the invention of the aircraft. Today, metric camera based on film is still being used for mapping by most mapping organizations in the world. For example, in Malaysia the Department of Surveying and Mapping Malaysia (DSMM) is the organization that is responsible for acquiring aerial photographs for the purpose of producing topographic map. In this digital era, DSMM uses Leica Helava DPW770 digital photogrammetric workstation to produce topographic map and orthophoto for big cities only. Recently, in DSMM the digital photogrammetric system has been upgraded to ‘total station’ (i.e comprise of three different fields which include photogrammetry, remote sensing and geographical information system (GIS)). The upgraded version is known as Leica Photogrammetric System (LPS) which uses ERDAS as the engine. Universiti Teknologi Malaysia has nine (9) Leica Helava DPW770 digital photogrammetric workstations which were installed in 2001 and these systems are used for education, research and consultation works.

In Malaysia, apart from DSMM there are few private companies that used metric camera for aerial photography. These companies produced aerial photography not for topographic mapping but for other purposes such as for construction work, alignment study, producing thematic maps and others. Today, some developed countries in the world such as Germany, Japan and others have started using digital metric camera for the purpose of mapping. However, not many mapping organizations afford to purchase the digital metric camera due to its' high cost. In future, DSMM will use the digital metric camera for mapping but this will take some years.

In aerial photogrammetry, normally large format metric camera (i.e 230mm x 230mm or 9 inches x 9 inches) is used to produce aerial photograph and cover large area (depend on the scale of photography). In Malaysia, DSMM only uses large format metric camera and it is normally used to produce aerial photograph at the scale of 1:50 000 for topographic mapping. Other aerial photographic scales are also produced such as at 1:25 000 and 1:10 000. Apart from large format metric camera, small format metric camera can also be used for aerial photography. DSMM does not use small format aerial camera for mapping. Small format metric camera offers several advantages compared to large format metric camera. The first advantage is it is light in weight, handy and easy to use. Other advantages include it can be used for small area, budget is limited, suitable for large scale mapping and dedicated for special purposes.

Apart from metric camera, non-metric camera which include video camera and digital camera can also be used for aerial photography (Mills and Newton, 1996a, 1996b). However, the aerial photograph is not used for topographic mapping but it could 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 of the advantages include ease of use, handy, cheap, the images are in digital form which is ready to be used and does not need aircraft. The digital camera can be placed in a balloon, light aircraft such as the microlight, and other platform (i.e based on their application). The use of digital camera has been reported by several researchers in different applications (Fraser and Shortis, 1995; Miyatsuka, 1996; Mills, Newton and Twiss, 1997; Anuar Ahmad, 2000; Anuar Ahmad and Siti Hamisah Tapsir; 2001; Mohd. Farid Mohd. Ariff *et al*., 2003). In this study, a large format metric camera and a non-metric camera (i.e Canon SLR digital camera) were used in an aircraft to acquire the photographs of Universiti Teknologi Malaysia (UTM) main campus in Johor Bahru. The objectives of the study are to test the capabilities of a digital photogrammetric workstation and to compare the results of metric and non-metric digital imageries. In the following section, some of the characteristics of the digital camera will be discussed.

2.0 DIGITAL CAMERA

In photogrammetry, digital camera can be categorized as non-metric camera since it was not designed for photogrammetric purposes. Some of the characteristics of digital cameras are there is no fiducial mark in the digital images, the camera calibration parameters are not stable, small format and others. The digital camera can also be categorized as (i) "Single Lens Reflex" (SLR) (i.e the lens of the camera is focusable and changeable) and (ii) compact. For SLR digital camera, the user has the full control on the camera such as controlling the focus, aperture and shutter speed. For compact digital camera, it uses the concept of point and shoot and it has the zoom facility.

According to Shortis and Beyer (1996), digital camera can be categorized as digital still camera (in short, digital camera) and analogue video camera. Digital camera could be used to acquire single image at a particular instance and the image could be stored in the camera on-board. For analogue video camera, it can be used to acquire continuous image as electronic signal at the rate of 30 frames per second. However, a frame grabber is required to transform the frame from analogue signal into digital form. Both types of digital camera and analogue video camera could be used for close range photogrammetric applications. However, the use of digital camera is preferable since digital images could be obtained directly, digital images could stored on-board, easy to operate and not necessary to use direct current. Today, there are many makes and model of digital cameras available in the market and could be used for many purposes such as to produce report, leisure use and other purposes.

Digital cameras are produced with different sensor sizes and resolutions. Sensor size can be defined as the dimension of width and height of sensor array in millimeter or inches. Sensor resolution can be defined as the number of horizontal pixel multiplied by vertical pixel. A digital camera could further be categorized as low resolution (if the number of pixels is less than 500, 000), medium resolution (number of pixel between 500, 000 to1.5 million) and high resolution (number of pixel is beyond 1.5 million)(Shortis and Beyer, 1996). In this study, a digital cameras known as CANON SLR was used. This digital camera can be categorized as high resolution (Resolution (Raw) = 2160 x 1440 pixels or 3.1 Megapixels in grayscale or 9.3 Megapixels in colour). Figure 1 shows the Canon EOS D30 SLR digital camera (produced in 2000/01).

Figure 1: Canon EOS D30 SLR digital camera

3.0 DIGITAL PHOTOGRAMMETRIC WORKSTATION (DPW)

The development of the digital photogrammetric system begins about the same time as the analytical plotter. The basic concept was developed at the end of 1950s and early 1960s. The development of the digital photogrammetric system continues along the analytical plotter. However, in 1970s and 1980s most photogrammetric works were carried out using analytical plotter. At the end of 1980s some of digital photogrammetric systems are available in the market but still at its' infancy. As the development in computer hardware, software, digital image system and scanning continues, new generation of digital photogrammetric system which utilizes high performance computer was developed. In mid 1990s, there are few makes of digital photogrammetric system or better known as digital photogrammetric workstation (DPW) are available in the market. Towards the end of 1990s, many mapping organization and academic organization uses DPW. Some examples of DPW are Leica Helava DPW770, DVP, PHODIS, VirtuoZo and others. Some of the manufacturer of DPWs also developed high precision photogrammetric scanner to scan photographs for their system such as Leica-Helava DPW770 and PHODIS.

In brief, DPW comprise of system hardware which include high performance computer, big RAM and large storage. Some of the system uses multiple processors to increase the computation speed. In DPW, high capacity tape or optical disc is used for off-line storage of the digital imageries. For operator control, 3D mouse or special designed mouse is used for the planimetry and vertical movement. Even some of the DPWs provide the user handwheel and footwheel. For viewing the stereoscopic model in 3D several stereo viewing systems can be used such as the polarizing system, alternating shutters and split screen with stereoscope. Apart from hardware, the DPW operates based on their own software. Most DPWs also are equipped with aerial triangulation software/program. Today most of the operation of the system can be carried out automatically.

DPW uses digital images to produce several photogrammetry output automatically such as digital terrain model (DTM) and orthophoto. DPW can use digital images from aerial photogrammetry and terrestrial (including close range) photogrammetry. Even some of the DPW can be used to process satellite imageries. With the advent in computer hardware and software, the DPW continues to develop and today some of the DPWs are known as 'total station' (i.e capable of processing photogrammetry and remote sensing imageries plus provides the GIS environment in one system). For example, the Leica Helava DPW770 now is known as Leica Photogrammetric System (LPS). VirtuoZo also provides the same concept. Perhaps in future more DPWs will used the 'total station' concept which provide the user more options and the cost of the system will reduced.

In February 2005, Faculty of Geoinformation Science and Engineering, Universiti Teknologi Malaysia acquires 15 DPWs known as DVP. As mentioned above, the DVP is capable of processing digital imageries from aerial photogrammetry, close range photogrammetry and satellite imageries (including high resolution imageries such as QuickBird). Also this system has the same characteristic as other DPW mentioned above. In this study, DVP will be used to process the digital image from the large format metric camera and the digital image from the digital camera. The results of using this system are shown in Section 5.0

4.0 METHODOLOGY

4.1 DATA ACQUISITION

4.1.1 Digital Camera Calibration

In this study, a test field of dimension 2m x 4m was built at Faculty of Geoinformation Science and Engineering, UTM. This test field is a flat wall painted with black paint. On the wall 11 sticks of plywood were drilled into the wall and on each stick nine (9) retro-reflective targets of rounded shape were placed. At the center of the test field, two retro-reflective targets were placed. The size of the retro-reflective target is 10mm. The coordinates of the retro-reflective targets were determined using theodolite intersection method and the results were used as reference value. The test field was used to calibrate the digital camera. Figure 2 shows one of the photographs taken from the center of the test field using the Canon EOS D30 SLR digital camera.

For the purpose of calibration, 12 photographs of the test field were acquired from six (6) camera locations (Figure 3). The focus of the digital camera was set at infinity focus and the automatic function was disabled. At each camera location, two photographs were acquired where one is in landscape position and the other one is rotated 90 degree from its' original position i.e portrait position. During photography the camera flash is switched on and a piece of tissue paper was used to block the flash light so that not much light will be transmitted. If the flash is not covered then 'over saturated' will occur (too much light) which might cause deterioration of the calibration results. The object to camera distance is approximately 3.0 meter. Also during photography, convergent photographs were acquired where the optical axis of the digital camera always pointing towards the centre of the test field and the dimension of the test field should occupy as much as possible the format of the digital camera. Convergent configuration was employed since it will strengthen the geometry and with the purpose to recover focal length successfully (Fryer, 1996). Photography was done within short period of time. The photographs of the test field were acquired after the acquisition of aerial photographs.

Figure 2: A photograph of the test field

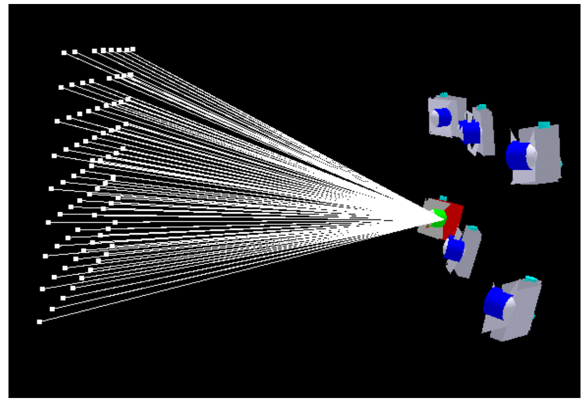

Figure 3: Location of digital camera in space

4.1.2 Acquisition of metric and non-metric photography

In this study, the photographs of UTM main campus were acquired both using the large format metric camera and small format Canon EOS D30 SLR digital camera. For the large format metric camera, a Wild RC30 metric camera with wide angle lens was used to acquire the aerial photographs. The photographs were acquired by DSMM in November 2001 at the scale of 1:10 000. After the photography, the colour film was developed and scanned at 1000dpi using the photogrammetric scanner that is available in the DSMM.

For the Canon SLR digital camera, the aerial photographs (in digital form) were acquired by placing the digital camera inside an aircraft. The photographic session was carried out by a company and a series of digital images (approximately 30 images) were acquired to cover roughly the same area covered by a pair of large format aerial photograph. The digital images were acquired at an approximate 50% overlapped. Since the format of the digital camera is small then the ground coverage is small too. Figure 4 shows one pair of photograph acquired using the digital camera.

Figure 4: A pair of photograph acquired using the Canon EOS D30 SLR digital camera

4.1.3 Establishment of Ground Control Point

In photogrammetry, normally the ground control point (GCP) is established after the aerial photography has been carried out. There are several methods that can be used to establish the GCP. The most popular and widely used method is the Global Positioning System (GPS). For the large format photograph 10 GCPs were selected which enclosed the overlapped area. For the digital images an approximate of 30 images are required to cover roughly about the same area covered by large format photograph. Inthis paper the results from two digital images which consist of some part of the overlapped area will be shown. As for the two digital images, 10 GCPs were also established using the GPS method. For the establishment of GCPs, rapid static method was used using the GPS Trimble Receiver.

4.2 DATA REDUCTION

4.2.1 Digital Camera Calibration

After all the photographs from the digital cameras have been downloaded individually into the computer, image measurement is carried out. All the photographs of the test field were measured semi-automatically using a close range photogrammetric software. This software can be used to determine the 3D coordinates of the points on the object (i.e retro-reflective targets) and the camera calibration parameters. The coordinates for the centre of the retro-reflective targets of the test field were determined using 'weighted mean' technique. The results of the camera calibration are tabulated in Table 1.

4.2.2 Processing metric and non-metric digital imageries

In this study, DVP was used to process the digital images of the large format metric camera and the digital camera. Figure 5 shows the digital photogrammetric workstation DVP. This system uses two monitors and for stereo viewing special glasses is provided. The DVP was used to produce digital orthophoto and to produce some vectors. Also in this study, only a pair of digital images was used to create the 3D stereoscopic model. In DVP, the 3D stereoscopic model was setup within short period after familiarizing with the system. After the formation of the 3D stereoscopic model, on screen digitizing was carried out to digitize some features in the model. The next step is to create DTM and finally create digital orthophoto. Then the vectors and the orthophoto could be exported to other format such as CAD and GIS formats. The same procedure was repeated to process the digital image of the digital camera.

Figure 5: The digital photogrammetric workstation DVP

5.0 RESULTS

From this study, two sets of results were produced. The first results comprise of camera calibration parameters obtained from calibrating the digital camera and the second results comprise of digital orthophoto obtained from the digital photogrammetric workstation DVP.

5.1 Camera Calibration Parameters

Table 1 shows the estimated parameters together with their standard deviation of camera calibration parameters of one of the calibrated digital camera. The camera calibration parameters consist of the focal length (c), principal point offset (x_p, y_p), radial (k_1, k_2, k_3) and tangential (p_1, p_2, p_3) lens distortion, "affinity"(b_1) and different in scale factor (b_1).

Table 1 : Camera calibration parameters of the digital camera

CANON	**DIGITAL**	**CAMERA**
Parameter		**Std. Deviation**
c (mm)	21.5420	7.422e-003
x_P (mm)	-0.0637	9.226e-003
y_P (mm)	0.0962	8.300e-003
k_1	2.16643e-004	1.211e-005
k_2	-7.69223e-007	1.029e-007
k_3	1.43590e-009	3.219e-010
p_1	3.12711e-005	7.288e-006
p_2	1.33241e-005	6.395e-006
b_1	1.82536e-004	5.376e-005
b_2	-1.86719e-005	5.556e-005

5.2 Digital Orthophoto

Figure 6 (a) shows the digital orthophoto produced using DVP for the large format metric camera while Figure 6 (b) shows the digital orthophoto displayed in ArcView GIS software together with some vectors. The DVP is also capable of processing non-metric imagery including digital image from the digital camera. Figure 7(a) shows the digital orthophoto of the digital camera and Figure 7(b) shows the digital orthophoto displayed in ArcView GIS software together with some vectors too. Figure 8 shows part of the features digitized using the digital photogrammetric system DVP. For future work, aerial triangulation concept will be used especially for the digital camera so that more digital images could be used to cover roughly the same area as the large format. Then ground survey method could be used to produce a plan (including spot heights) of the same area covered by the large format aerial photograph and use it as a reference. A plan could also be produced from the digital images of the large format metric camera and the digital camera using DVP. Subsequently, analysis could be carried out by comparing the plan produce from DVP with the reference plan.

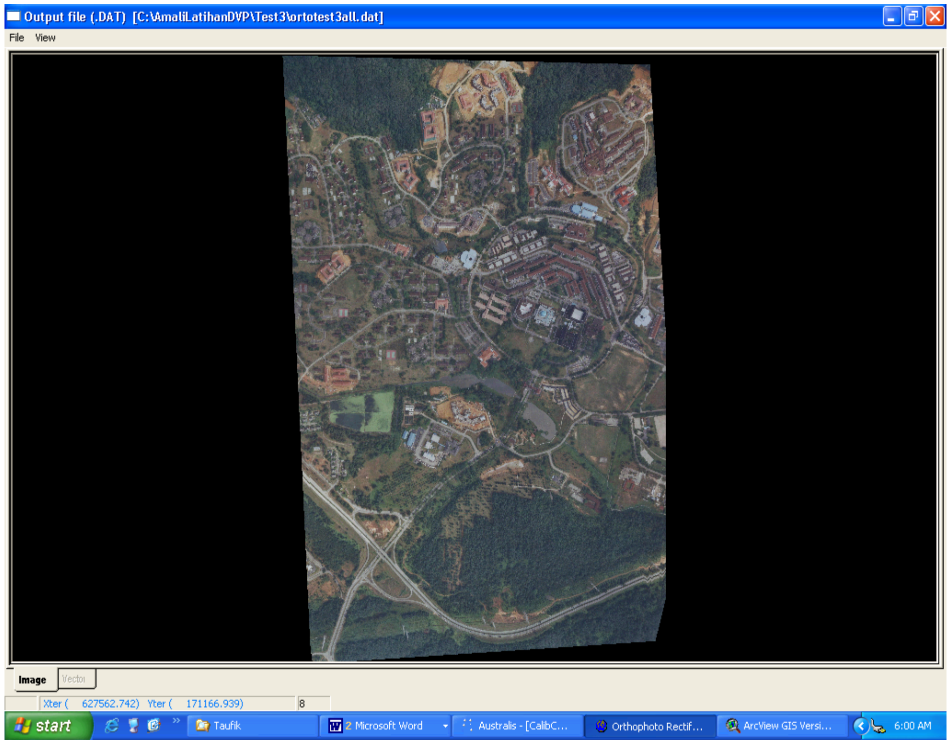

Figure 6 (a): Digital orthophoto of the large format metric camera

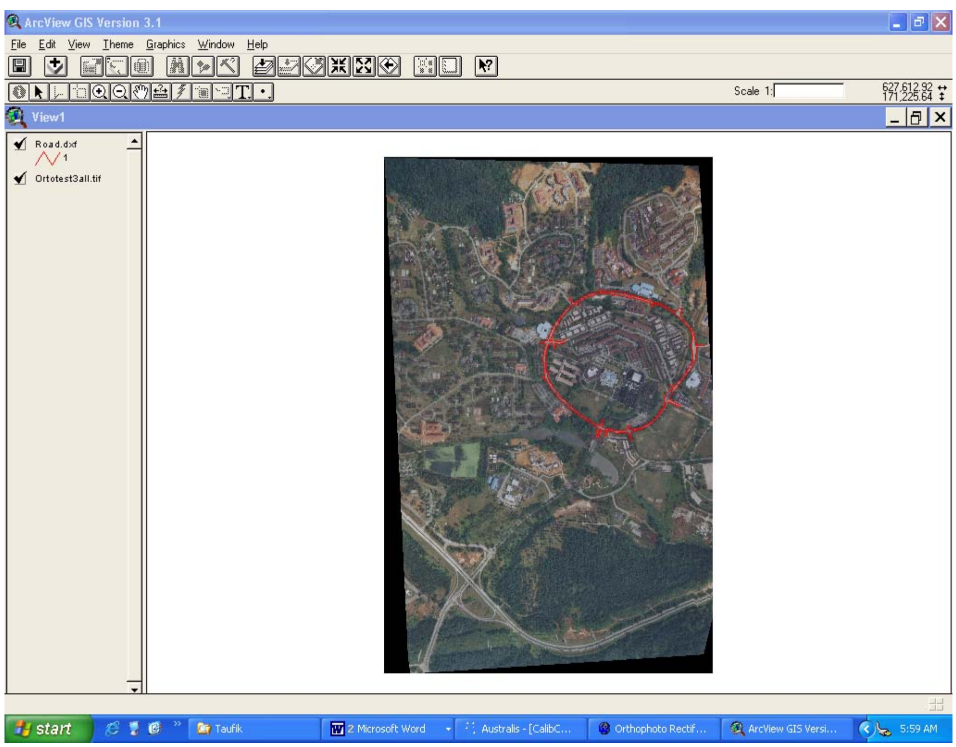

Figure 6(b): Digital orthophoto and vectors in ArcView

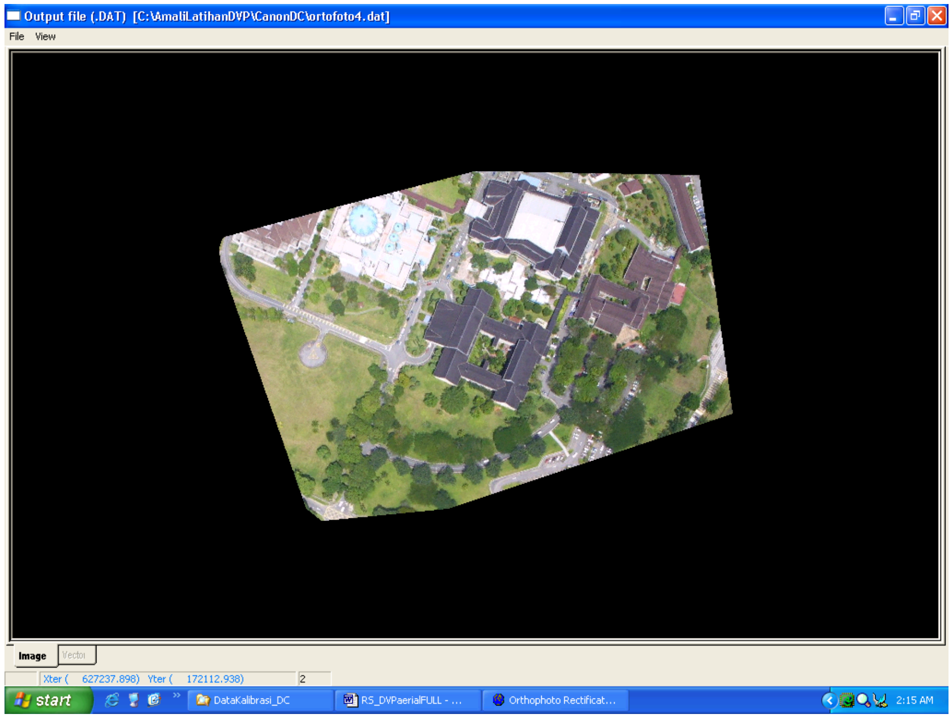

Figure 7 (a): Digital orthophoto of the digital camera

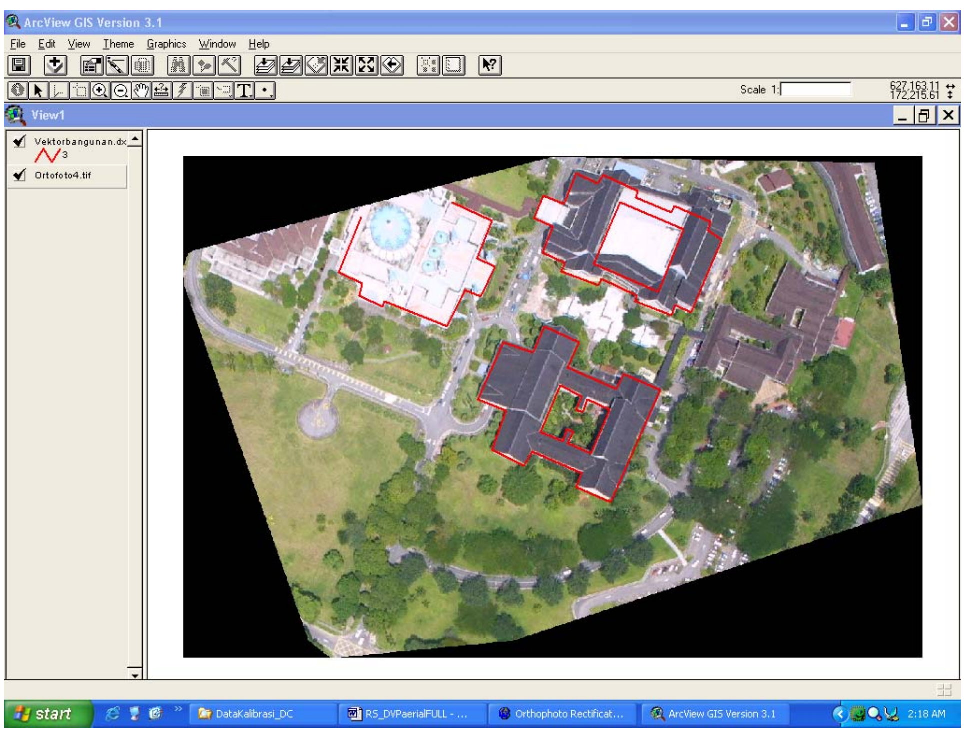

Figure 7(b): Digital orthophoto and vectors in ArcView

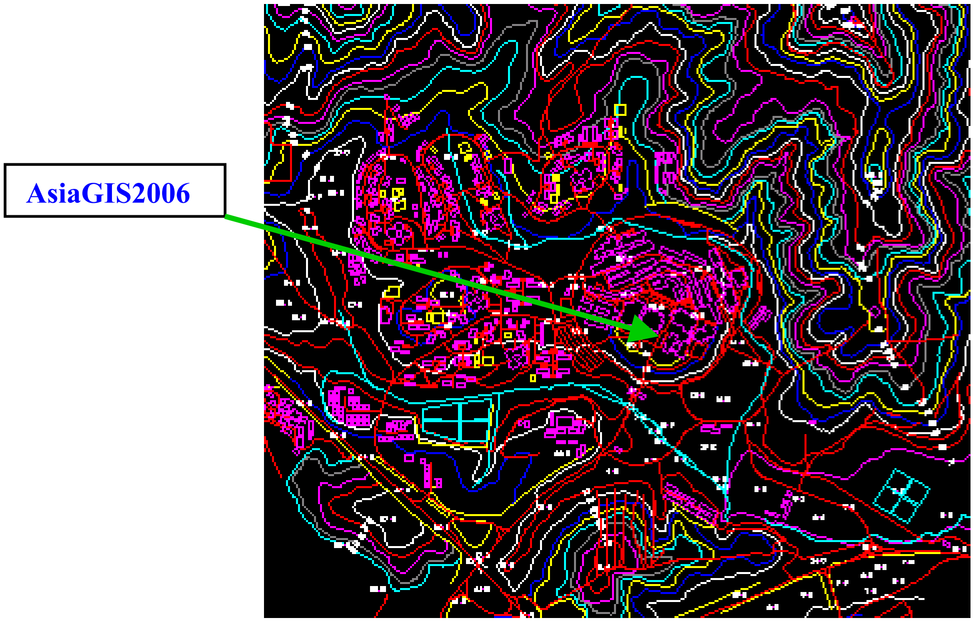

Figure 8: Vector format of UTM

6.0 CONCLUSION

From this study, it was found that the digital photogrammetric workstation DVP is capable of producing digital orthophoto and on screen digitizing of the aerial photographs using the large format metric camera. DVP also demonstrates that it is capable of producing the same output for the digital camera. However, the area covered by the digital camera is very small compared to the area covered by the large format metric camera. In this study, the digital orthophoto produced from the digital camera covers only a small area compared to the digital orthophoto produced from large format metric camera. In term of visualization, the digital images acquired using digital camera is much superior compared to the aerial photographs of the large format metric camera. In this study, no accuracy analysis is carried out, however, it can be anticipated that the metric camera should provides better accuracy compared to the digital camera. In this study, it is proved that digital camera can be used in aerial photogrammetry, however, the digital camera needs to be calibrated whether before or after aerial photography. The user should also aware that the digital camera could not produce high accuracy. For an application which does not require high accuracy and requires good visualization then the user can use digital camera. Finally, this study shows that digital camera has the potential to be used in aerial photogrammetry especially if the project area is small and budget is limited.

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