DIGITAL PHOTOGRAMMETRY: COMPARISON OF DIGITAL ORTHOPHOTO BASED ON DIFFERENT DATASET OF DIGITAL IMAGES OF AERIAL PHOTOGRAPH

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ABSTRACT

Data is an essential component in Geographic Information System (GIS), where it represents 70% of GIS. There are many techniques to acquire GIS data such as field work, photogrammetry, remote sensing, Global Positioning System (GPS) and source from existing data (primary data). Photogrammetry is one of the technique of data gathering and has become the earliest data source in topographic mapping. Photogrammetry has evolved from analogue to digital technique parallel with the development in digital camera technology. Orthophoto is one of the output of photogrammetry. Orthophoto can be produced from large format and small format aerial photo. This study is carried out to compare orthophoto between large and small format aerial photo. For large format aerial photo, two photographs are used. However, for small format aerial photo, about 20 photographs are used to cover the same area of the large format and the aerial triangulation procedure has to be carried out for the small format aerial photo. The processing of aerial photo processing was carried out using digital photogrammetry technique and ERDAS IMAGINE 8.6 software. The orthophoto were compared from the aspect of visualization, accuracy, time and cost to produce it. Results from this study showed that the orthophoto produced from large format aerial photograph (RMSE ±0.676m) is much better than orthophoto produced from small format aerial photograph (RMSE ±2.321m). In this study, it can also be concluded that the product from small format aerial photograph can be used for GIS application if the required accuracy is not so important and when large format aerial photography is not feasible to be executed.

Keywords: GIS, GPS, orthophoto, aerial photograph

1.0 Introduction

Photogrammetry is one of the technique that can be used for acquring data of the earth surface for the purpose of mapping, map revision and also be used as a source of GIS data. According to American Society of Photogrammetry and Remote Sensing, photogrammetry can be defined as art, science and technology in acquiring real information about the physical object and the environment through the process of recording, measuring and interpretation of photographic image, recording polar electromagnetic ray energy and other phenomena. Photographic images can be acquired either from air or ground. Aerial photograph is a photograph acquired from the air and widely used in aerial photogrammetry while terrestrial photograph is widely used in close range photogrammetry applications. This study focuses on the production of orthophoto based on aerial photograph. Aerial photograph can be acquired using large format or small format camera.

In aerial photogrammetry, the large format aerial camera is also known as metric camera. It was specially designed for the purpose of photogrammetry where accurate measurement can be obtained from the aerial photograph. This metric camera is stable, the interior orientation parameters are known, has fiducial mark, equipped with measuring device for exterior orientation and has format size of 23 cm x 23 cm. Apart from large format aerial camera, small format camera which has the size of less than 80 cm x 80 cm and uses light sensitive material can also be used in acquiring aerial photograph for the purpose of photogrammetry or mapping (Anuar Ahmad, 1992). This small format camera can be in the form of metric, semi-metric or non-metric. In photogrammetry, aerial photograph that is captured either using large or small format camera can be used together with digital photogrammetric system to produce photogrammetric products such as orthophoto, Digital Terrain Model (DTM), topographic map and others. All these output can be employed as a source of GIS data.

Photogrammetry is one of the data acquisition method used in GIS. This method is wiedly used until today and could provide accurate data in short period. The development of computer technology has shown the development of photogrammetry from analogue photogrammetry method to analytical photogrammetry and currently into digital photogrammetric method. Photogrammetric instrumentation such as aerial camera, analytical plotter and current digital photogrammetric system and software played an important role in the developement of photogrammetric technique.

Conventional method of recording aerial photograph is using metric aerial camera that is attached to the platform such as an aircraft. In general, not many organizations are capable of using this method since the cost of the large format aerial camera is very expensive, require large storage and the flight planning procedure is quite complicated. As an alternative, this problem can be solved by using small format camera attach to the aircraft, helicopter or balloon and the cost of acquiring the aerial photograph could be much cheaper. However, user must remember that the measurement accuracy of large format aerial camera is much superior than the small format camera. Hence, user should decide the type of camera used to fulfill their needs. Eventhough these two different types of camera format recorded the features of the earth, there exist differences in term of quality of the photogrammetric products such as orthophoto, DTM and others. The aim of this study is to compare the orthophoto produced from large format aerial camera with the orthophoto produced from small format camera. The orthophoto is compared in term of accuracy, visualisation, cost and time. The comparison involves the accuracy of XYZ coordinates and measured distances. For the comparison of cost and time, quantitative comparison is carried out.

2.0 Study area

The study area is located at main campus UTM Skudai, Johor Bahru, Malaysia. The large format aerial photograph was acquired by Department of Surveying and Mapping Malaysia (DSMM) in year 2001 using large format metric camera Wild RC30 and the scale of the photography is 1:10,000. For this study, the aerial photographs were purchased from DSMM . It covers partially the area of the campus. The physical topography of the study area is a mixed terrain. Figure 1 depicts the location of the study area. Most part of the area is covered by academic and administrative buildings with several student accommodation buildings occupied the rest of the area. For the small format aerial photograph, it was acquired using small format digital camera Canon EOS D30 (i.e 8 megapixels) and was acquired by a company in year 2003. Figure 2 depicts an example of small format aerial photograph.

In this study, digital photogrammetric software known as Erdas Imagine 8.6 was used to process both types of aerial photographs. For the large format aerial photograph, only two aerial photographs were used and scanned at 600dpi to convert it into digital form before process it using the software. For the small format aerial photograph, it can be utilised straight away since it is already in digital form. Due to the small format of the digital camera, 20 photographs were used to cover the same area of the overlapped area of the large format aerial photograph (Figure3). In this study, ArcGIS 9.2 is used for comparison of orthophoto and to prove the capabality of the software to display the orthophoto.

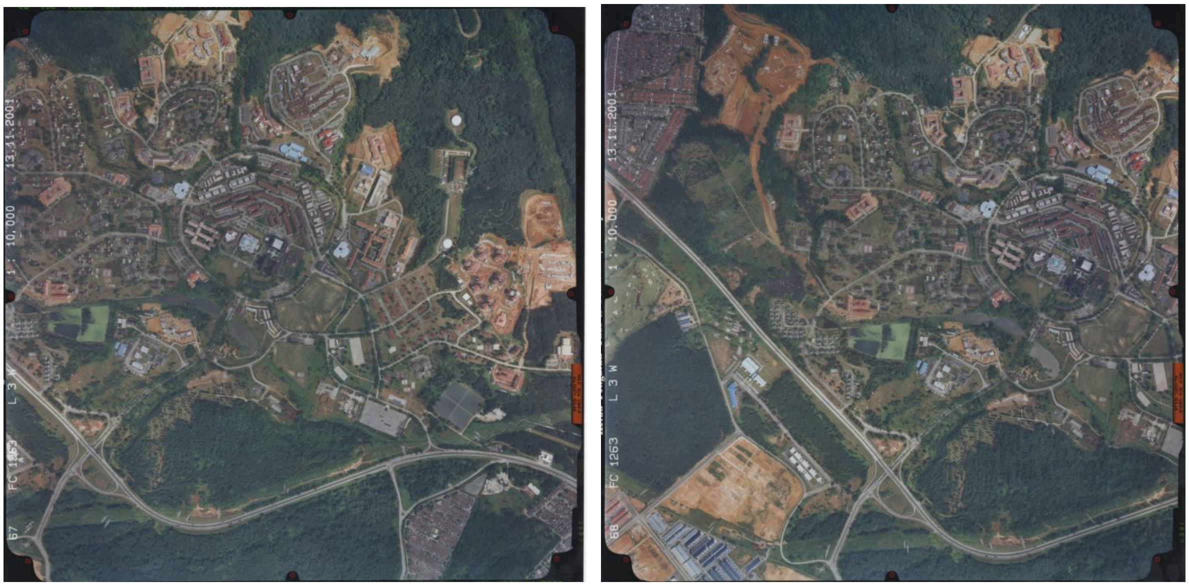

Figure 1: Large format aerial photograph of the study area

Figure 2: Small format aerial photograph of the study area

Figure 3: Mosaic of small format digital aerial photograph

3.0 Methodology

The study is carried out by conducting literature review for gathering information related to digital photogrammetry, large format aerial photograph, small format aerial photograph and previous study related to this study. The methodology of the study is divided into two different processes (i.e processing aerial photographs of large and small format). As mentioned in Section 2, the large format aerial photograph need to be scanned while the small format aerial photograph in digital is used straight away and form mosaiced for the selection of ground control point (GCP). Road junction, sharp edge of basket ball court and other clear features found on the aerial photograph are used as location of GCPs. Also in the process of selecting GCP, it was ensured that the location of the GCP is accessible. For the large format aerial photograph no mosaic is required since only two photogrphs are used. Nine GCPs and 17 GCPs were selected for the large format aerial photograph and small format aerial photograph respectively. After selecting GCPs for both type of aerial photographs, GPS survey using Leica SR530 was used. Rapid Static method was employed for the GPS survey and 15minutes was allocated for each GCP. Trimble Geomatic Office software was then used to process the GCPs.

After establishing the GCPs, both type of aerial photographs were processed using OrthoBASE module in Erdas Imagine 8.6 software which involved interior orienatation, exterior orientation, aerial triangulation (especially for small format aerial photograph), generating orthophoto and producing orthophoto. Then the comparison of orthophoto for the two different datasets was performed from the aspect of accuracy, visualisation, cost and time. Figure 4 depicts the research methodology employed in the study.

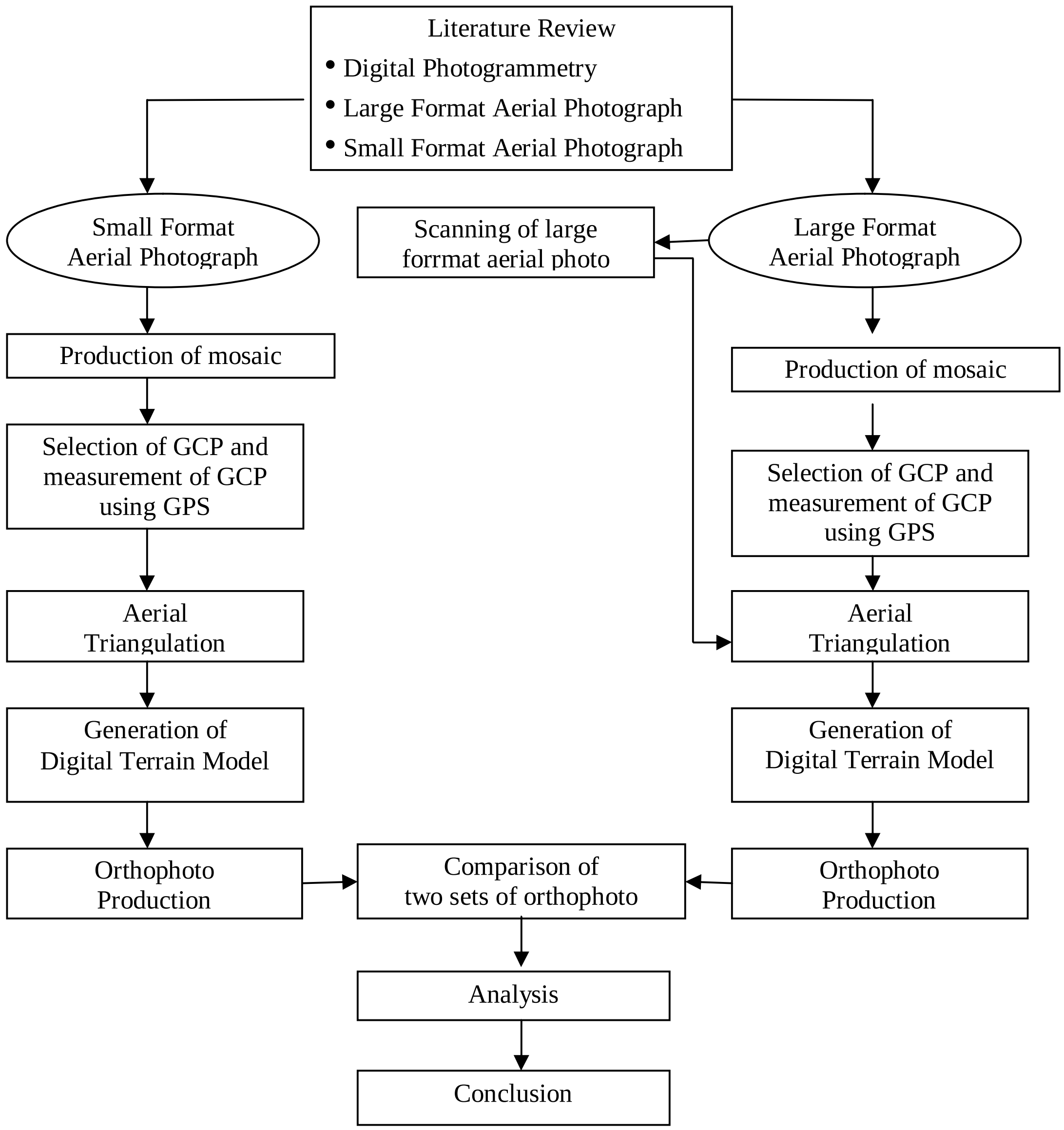

Figure 4: Flow chart of the research methodology

3.0 Results and Analysis

Orthophoto analysis is the most important phase in this study since it reflects the final product of the study. This phase is performed by comparing the two orthophotos produced by two different types of aerial photograph. This phase is divided into three stages which include qualitative, visualisation and accuracy analysis. Qualitative analysis is carried out by comparing the cost and time required to produce orthophoto for both type of camera format. The comparison is carried out qualitatively since accurate value is not known.

Visualisation comparison is performed by viewing the orthophoto with the physical eyes. Analytical comparison involves comparison between check point coordinates and the coordinates digitized in the stereomodel. The coordinates of check points were established using GPS for both large and small format camera.Then the RMSE (*Root Mean Square Error*) for both large and small format camera is computed.

Comparison between distances of check points and distances measured from orthophoto were also carried out and the RMSE is computed.

3.1 Orthophoto

Figure 5 depicts orthophoto produced from large format aerial camera and Figure 6 depicts orthophoto produced from small format digital camera

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Figure 5 : Ortophoto produced using large format aerial camera

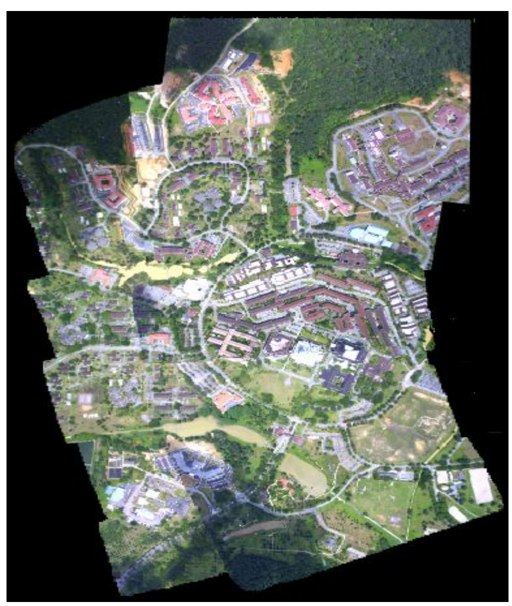

Figure6 : Ortophoto produced using small format digital camera

3.2 Analysis of Visualisation

From visual observation, it was found that the orthophoto of large format camera (Figure 5) is superior than the orthophoto of small format digital camera (Figure 6). It is also clearly seen that many small format digital images are required to form orthophoto of approximately the same size as the large format aerial photograph. However, the orthophoto of small format camera looks brighter than the orthophoto of large format. For the orthophoto of small format digital camera, it is less accurate since there is error between the edges of individual orthophoto that is mosaiced. In the orthophoto, some buildings are distorted or not joined perfectly if the error is viewed or examined closely (Figure 7) and certain part of the road also is not connected perfectly too (Figure 8).

Figure 7 : Error that causes the building distorted

Figure 8 : Error that causes the road not connected perfectly

3.3 Analysis of Point Measurement

In this study, 15 check points were established using GPS and used as a reference for determination of accuracy for point measurement. The check points were used to compare between them and the same coordinates of the similar points digitized from the stereoscopic model of the large format aerial camera and the small format digital camera. From Table 3.1, the RMSE is ±0.676m for the large format aerial camera while the RMSE is ±2.321m for the small format digital camera (Table 3.2). This indicates that the results of the large format aerial camera are much better than the small format digital camera, hence, better to use large format aerial camera for accurate results. However, if accuracy is not so important then small format digital camera can be used.

After the production of orthophoto for both type of datasets, the two orthophotos were successfully exported into ArcGIS. Then the location of the checks points in both orthophoto were digitized and compared with the surveyed checks points using GPS and the RMSE are computed. Table 3.3 and 3.4 showed the RMSE for the orthophotos for the large format aerial camera and small format digital camera respectively. The results (planimetry or 2D) showed that the orthophoto produced from the large format aerial camera is better than the orthophoto produced from the small format digital camera.

Table 3.1 : Comparison between the coordinates of check points and similar position digitized from stereoscopic model (3D) of large format aerial camera

Name of Point	**(Check Points) GPS**			**Stereoscopic model (3D)**			**Differences**		
	X (m)	**Y (m)**	**Z (m)**	**X (m)**	**Y (m)**	**Z (m)**	**ΔX (m)**	**ΔY (m)**	**ΔZ (m)**
TS1	626696.437	173406.710	49.348	626692.730	173407.770	49.988	3.707	1.060	0.640
TS2	626816.438	172794.195	20.447	626816.949	172795.162	21.086	0.511	0.967	0.639
TS3	626388.408	172444.235	25.699	626387.195	172447.702	27.661	1.213	3.467	1.962
TS4	626988.314	172176.790	20.922	626987.017	172180.501	20.453	1.297	3.711	0.469
TS5	626518.870	171997.045	21.226	626516.689	171996.832	23.294	2.181	0.213	2.068
TS6	627479.719	171897.278	16.630	627477.180	171897.238	17.076	2.539	0.040	0.446
TS7	627013.754	171881.719	11.762	627009.706	171882.029	11.736	4.048	0.310	0.026
TS8	626656.472	171948.529	22.729	626652.464	171949.889	23.389	4.008	1.360	0.660
TS9	627169.914	172034.227	13.349	627167.450	172035.132	13.674	2.464	0.905	0.325
TS10	626756.399	172321.929	20.699	626754.052	172322.386	22.570	2.347	0.457	1.871
TS11	626527.179	172434.610	24.728	626526.638	172437.139	26.389	0.541	2.529	1.661
TS12	626914.987	172370.057	34.808	626916.608	172372.983	35.659	1.621	2.926	0.851
TS13	626715.378	172652.787	26.364	626715.635	172654.581	27.729	0.257	1.794	1.365
TS14	626818.015	173014.990	30.819	626815.644	173015.097	30.997	3.938	0.107	0.178
TS15	626498.431	172866.338	31.646	626499.363	172871.764	32.767	0.932	5.426	1.121
						RMSE	±1.295	±1.548	±0.479
						Average RMSE	±0.676		

Table 3.2 : Comparison between the coordinates of check points and similar position digitized from stereoscopic model (3D) of small format digital camera

Name of Point	Check Points (GPS)			Stereoscopic model (3D)			Differences		
	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	ΔX (m)	ΔY (m)	ΔZ (m)
TS1	626696.437	173406.710	49.348	626693.960	173402.570	49.974	2.477	4.140	0.626
TS2	626816.438	172794.195	20.447	626814.510	172795.622	19.383	1.928	1.427	1.064
TS3	626388.408	172444.235	25.699	626389.832	172444.523	24.703	1.424	0.288	0.996
TS4	626988.314	172176.790	20.922	626980.908	172174.386	20.708	7.406	2.404	0.214
TS5	626518.870	171997.045	21.226	626521.253	172000.483	23.931	2.383	3.438	2.705
TS6	627479.719	171897.278	16.630	627480.144	171897.313	16.869	0.425	0.035	0.239
TS7	627013.754	171881.719	11.762	627012.936	171883.934	12.168	0.818	2.215	0.406
TS8	626656.472	171948.529	22.729	626656.534	171953.124	23.156	0.062	4.595	0.427
TS9	627169.914	172034.227	13.349	627162.647	172030.879	13.160	7.267	3.348	0.189
TS10	626756.399	172321.929	20.699	626754.126	172318.989	18.082	2.273	2.940	2.617
TS11	626527.179	172434.610	24.728	626524.595	172434.063	25.374	2.584	0.547	0.646
TS12	626914.987	172370.057	34.808	626912.750	172370.307	33.518	2.237	0.250	1.290
TS13	626715.378	172652.787	26.364	626713.614	172654.705	29.473	1.764	1.918	3.109
TS14	626818.015	173014.990	30.819	626810.754	173019.073	33.426	7.261	4.083	2.607
TS15	626498.431	172866.338	31.646	626501.920	172877.088	40.295	3.489	10.750	8.649
						RMSE	±2.353	±2.573	±2.037
						Average RMSE		±2.321	

Table 3.3 : Comparison between GPS survey dan orthophoto of large format in ArcGIS

Name of Point	Check Points (GPS)		ArcGIS (2D)		Differences	
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)
TS1	626696.437	173406.710	626694.496	173406.994	1.941	0.284
TS2	626816.438	172794.195	626815.981	172793.507	0.457	0.688
TS3	626388.408	172444.235	626387.691	172446.259	0.717	2.024
TS4	626988.314	172176.790	626985.914	172179.917	2.400	3.127
TS5	626518.870	171997.045	626518.288	171998.572	0.582	1.527
TS6	627479.719	171897.278	627477.726	171897.436	1.993	0.158
TS7	627013.754	171881.719	627011.276	171882.198	2.478	0.479
TS8	626656.472	171948.529	626651.268	171950.492	5.204	1.963
TS9	627169.914	172034.227	627168.843	172034.879	1.071	0.652
TS10	626756.399	172321.929	626755.194	172321.016	1.205	0.913
TS11	626527.179	172434.610	626526.554	172436.495	0.625	1.885
TS12	626914.987	172370.057	626911.443	172370.100	3.544	0.043
TS13	626715.378	172652.787	626712.839	172649.410	2.539	3.377
TS14	626818.015	173014.990	626816.059	173014.532	1.956	0.458
TS15	626498.431	172866.338	626497.870	172865.537	0.561	0.801
				RMSE	±1.274	±1.014
				Average RMSE	±1.144	

Table 3.4 : Comparison between GPS survey dan orthophoto of small format in ArcGIS

Name of Points	Check Points (GPS)		ArcGIS(2D)		Differences	
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)
TS1	626696.437	173406.710	626689.840	173408.946	6.597	2.236
TS2	626816.438	172794.195	626823.939	172792.709	7.501	1.486
TS3	626388.408	172444.235	626386.191	172444.133	2.217	0.102
TS4	626988.314	172176.790	626987.988	172180.091	0.326	3.301
TS5	626518.870	171997.045	626526.733	171999.789	7.863	2.744
TS6	627479.719	171897.278	627478.226	171898.695	1.493	1.417
TS7	627013.754	171881.719	627012.741	171882.768	1.013	1.049
TS8	626656.472	171948.529	626660.256	171950.935	3.784	2.406
TS9	627169.914	172034.227	627170.329	172034.372	0.415	0.145
TS10	626756.399	172321.929	626759.492	172319.878	3.093	2.051
TS11	626527.179	172434.610	626532.329	172443.201	5.150	8.591
TS12	626914.987	172370.057	626913.759	172369.627	1.228	0.430
TS13	626715.378	172652.787	626712.155	172652.653	3.223	0.134
TS14	626818.015	173014.990	626814.213	173010.517	3.802	4.473
TS15	626498.431	172866.338	626504.649	172868.604	6.218	2.266
				RMSE	±2.472	±2.099
				Average RMSE	±2.285	

3.4 Analysis of Distance Measurement

For this analysis, 10 distances were computed between the check points observed using GPS. These distances were used as a reference. Then 10 distances were measured between the same check points found on the orthophoto of the large format aerial camera and small format digital camera in ArcGIS software. Subsequently, the distances are compared and the RMSE is computed. Table 3.5 shows the results for large format aerial camera while Table 3.6 shows the results for the small format digital camera. From both tables, once again it is clearly shown that the orthophoto produced from large format aerial photograph (RMSE=±1.412) is better than the orthophoto produced from the small format digital camera (RMSE=±3.577).

Table 3.5 : Comparison of distances between GPS survey and orthphoto of large format in ArcGIS

No.	Check Point	Distance (m)			Differences (m)	
		GPS	Stereo	ArcGIS	ΔGPS & Stereo	ΔGPS & ArcGIS
1	TS1-TS2	624.159	625.075	625.399	0.916	1.240
2	TS3-TS4	656.821	656.645	654.835	0.176	1.986
3	TS5-TS6	966.014	965.641	964.754	0.373	1.260
4	TS7-TS8	363.475	636.630	366.428	0.155	2.953
5	TS9-TS10	503.753	503.401	502.972	0.352	0.781
6	TS11-TS12	393.144	395.212	390.574	2.068	2.570
7	TS13-TS14	376.464	374.130	379.431	2.334	2.967
8	TS14-TS15	352.465	347.243	351.346	5.221	1.119
9	TS1-TS10	841.119	841.134	840.846	0.015	0.273
10	TS2-TS11	855.325	852.009	851.723	3.316	3.602
				RMSE	±1.778	±1.046
				Average RMSE	±1.412	

Table 3.6 : Comparison of distance between GPS survey and orthphoto of small format in ArcGIS

No.	Check Point	Distance (m)			Differences (m)	
		GPS	Stereo	ArcGIS	ΔGPS & Stereo	ΔGPS & ArcGIS
1	TS1-TS2	624.159	618.804	630.659	5.355	6.500
2	TS3-TS4	656.821	649.881	657.174	6.940	0.353
3	TS5-TS6	966.014	964.848	956.848	1.166	9.166
4	TS7-TS8	363.475	363.056	359.016	0.419	4.459
5	TS9-TS10	503.753	499.897	500.301	3.856	3.452
6	TS11-TS12	393.144	393.356	388.461	0.212	4.683
7	TS13-TS14	376.464	377.094	372.132	0.630	4.332
8	TS14-TS15	352.465	339.909	340.542	12.556	11.923
9	TS1-TS10	841.119	838.164	841.247	2.955	0.128
10	TS2-TS11	855.325	861.655	848.413	6.329	6.912
				RMSE	±3.698	±3.455
				Average RMSE	±3.577	

3.5 Analysis of Digitizing

Analysis of digitizing accuracy is carried out by viewing the difference of digitizing line and polygon of the study area. Two features (i.e road and building) are digitized on the orthophoto using ArcGIS software for both large and small format cameras. Line is used to represent road while polygon is used to represent buildings. From the orthophoto, road and building layers were established. Then both layers were superimposed with road and building reference layers that were complied using photogrammetric technique in 2002. This data is then revised in 2007.

Figure 9 depicts the overlayed layer between the reference road and digitized road from orthophoto of large format aerial camera. The reference roads are shown in red colour and digitized road of orthophoto are shown in blue. This figure also shows only a portion of the study area and in general the digitized roads fit well with the refernce data.

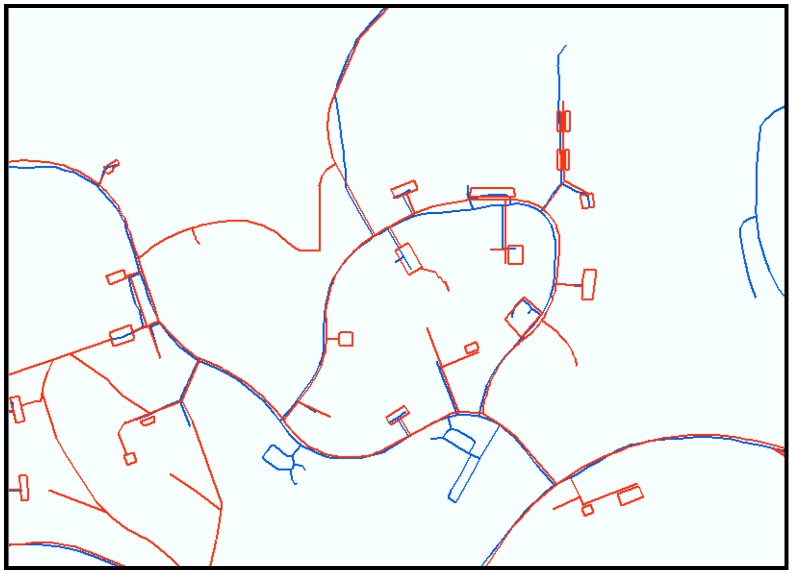

Figure 9: Seperimposition of road layer between reference data and orthophoto of large format aerial camera

Figure 10 depicts the overlayed layer between the reference road and digitized roads from orthophoto of small format aerial camera. The reference roads are shown in red colour and digitized roads of orthophoto are shown in green. This figure also shows only a portion of the study area and the digitized roads are coincide exactly with with reference data in many areas.

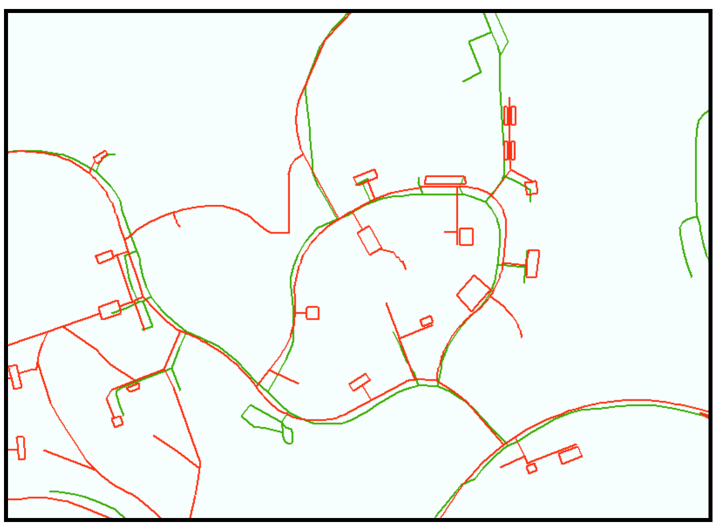

Figure 10: Seperimposition of road layer between reference data and orthophoto of small format digital camera

Figure 12 depicts overlayed layer between reference building and building digitized from orthophoto of large format aerial camera. Reference buildings are shown in red colour and digitized buildings from orthophoto are shown in blue. The digitized buildings include Faculty of Geoinformation Science and Engineering building and it's surrounding buildings. In general, the digitized buildings fit nicely with the reference data.

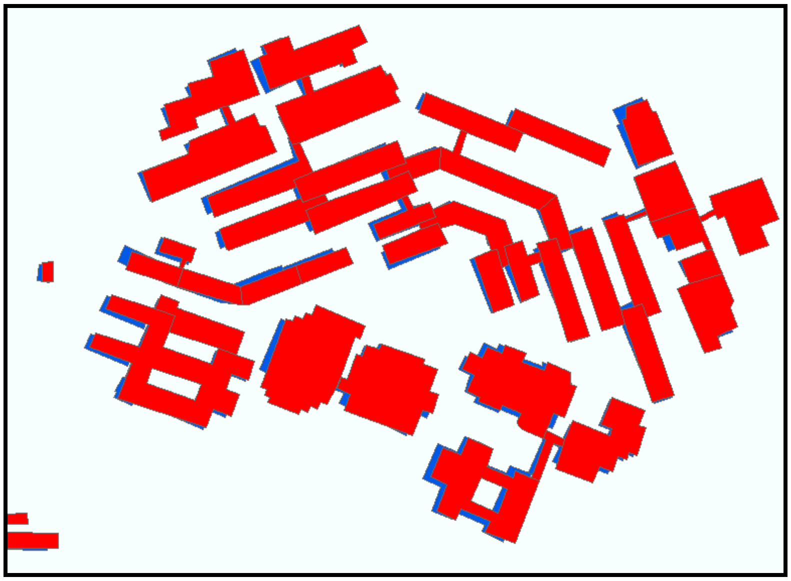

Figure 11 : Seperimposition of building layer between reference data and orthophoto of large format aerial camera

Figure 12 depicts overlayed layer between reference building and building digitized from orthophoto of small format digital camera. Reference buildings are shown in red colour and digitized building from orthophoto are shown in blue. The digitized buildings are the same as in Figure 11 but there are places where the digitized buildings are not fitted exactly with reference buildings.

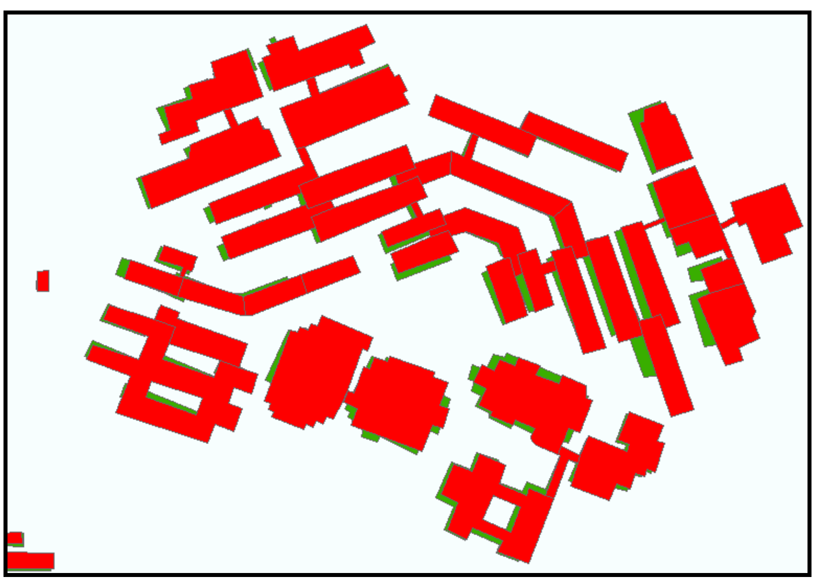

Figure 12 : Seperimposition of building layer between reference data and orthophoto of small format digital camera

3.3 Analysis of Cost and Time

Analyses of cost and time are carried out qualitatively where there is no specific value is produced as the accuracy analysis. This analysis include cost and time required to acquire and process the aerial photograph to produce orthophoto with the assumption that there are no constraints in acquiring and processing aerial photograph for both type of formats. After the processing of data acquisition including establishment of ground control and check points, it was found that the time to produce orthophoto of small format digital camera is much longer than the orthophoto produced from large format aerial camera. Hence, more time is required to established ground control points. This matter arised due to the issue that more ground control points are required to process small format aerial photograph to produce orthophoto. Apart from that, for the small format aerial photograph longer time is used to produce orthophoto since many photographs are required to cover approximately the same area of the large format aerial photograph.

In term of cost analysis, the cost of acquiring large format aerial photograph is dearer compared to the cost of acquiring small format aerial photograph. Also the cost of large format aerial camera or metric camera is very expensive compared to small format digital camera. Meanwhile the cost of establishing ground control points for small format digital camera is expensive since many points need to be established. In general, for large format aerial photograph it could provide accurate results but the cost is expensive for data acquisition. For small format aerial photograph, the accuracy still can be used if high accuracy is not required and the cost is less expensive.

4.0 Conclusions

This study shows that the accuracy of orthophoto of large format aerial camera is superior than the orthophoto of small format digital camera. This result has been anticipated, however, this study proves that orthophoto can still be produced using small format digital camera. Eventhough the accuracy of the orthphoto of small format digital camera cannot superceed the accuracy of large format aerial camera, it can still be used as a source of GIS data where high accuracy is not required. The orthophoto of the small format digital camera can also be used as base map and also be used in GIS application for small area.

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