Technical Evaluation of Khartoum State Mapping Project

Nagi Zomrawi[1] and Mohammed Fator[2]

[1]School of Surveying Engineering, Collage of Engineering, Sudan University of Science and Technology, Khartoum, Sudan

[2]School of Surveying Engineering, Collage of Engineering, Sudan University of Science and Technology, Khartoum, Sudan

[1]nagizomrawi@yahoo.com, [2]Fatorzaid@gmail.com

Abstract– **In order to develop the infrastructure and to improve service and utilities in Khartoum state, the government did a contract in 2010 to cover the state with large scale topographic maps. Digital aerial photography was the choice of producing these maps. Photogrammetric technical specifications were suggested by a high technical committee. Although there was no consultant, produced photographic coverage and maps were not checked. This research work aims to make a technical evaluation of the products concentrating on some parameters including camera specification, scale of photography and accuracy evaluation. Results proved that the used camera, photographic coverage and map products did not agree with specification.**

Keywords– **Aerial Triangulation, Global Positioning System (GPS) and Photogrammetry**

I. INTRODUCTION

Khartoum State was established as a capital of Sudan in 1821 by Turkish canalization. Since that time, it began to extend through different epochs and governments. It consists of three towns Khartoum, Omdurman and Khartoum north. Since eighteenth of the last century, desertification and wars make people to emigrate from different regions of the country to Khartoum. This irregular immigration leads to un-planned extensions of the state, quick growth of population, and declination of service.

In 2010 Khartoum state government think to produce a large scale topographic map upon which, strategic planning of infrastructure projects and future development can be planned.

The regular development of the state during the last two decades, on roads, bridges, banks, planning extension and residential services generally need a master plan outlining the shape and future of the state. So it needs to produce accurate updated maps to help in ideal services distribution and opportunities.

Since the local experience of the maps production using corresponding remote sensing techniques will not provide the accuracy requirements as well as the lack of accurate topographic data of the state. State government planned a project to produce up to date topographic maps utilizing modern digital photogrammetric techniques. Accordingly, the centre of the state covered with aerial photography of 1:5,000 scale. These photos should then be used to produce topographic maps at scale 1:1,000.

II. MAP PRODUCTION

Maps are a graphical representation of geospatial data, that is refer to the location or the attributes of object or phenomena location on earth. Maps help their users to better understand geospatial relationship. It give information of distance, direction and area. Size can be retrieved, patterns revealed, and relation understood and quantified.

Conventional land surveying techniques of map production, are very expensive, and time consuming, especially when covering large areas. So, photogrammetric methods of map production are practical alternative methods of land surveying. Here, measurements are taken indirectly from photograph rather than the field i.e., transforming the direct measurements from the nature, to indirect measurements from the photograph.

Maps can be sorted according to scale to small, medium and large scale maps. It can also be divided according to their contents and their components, such as; topographic maps and thematic maps.

III. DIGITAL PHOTOGRAMMETRY

The classical definition of photogrammetry (Phto- gamma-metron) is "the science of taking measurement from photograph". That means photogrammetry is surveying with photographs. Since other information can be extracted from photograph without measurement, this classical definition has no longer be valid.

Photogrammetry can be defined as the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena.

By the spread use of remote sensing, photogrammetry can be defined as "the art science and technology of extracting useful quantitive and qualitive information about physical and man-made objects by measurements and observations on photos and/or images of these objects.

Digital photogrammetry is photogrammetry as applied to digital images that are stored and processed on a computer.

Digital images can be scanned from photographs or can be directly captured by digital cameras. Many photogrammetric tasks can be highly automated in digital photogrammetry. The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media. With the development of digital photogrammetry, photogrammetric techniques are more closely integrated into remote sensing and GIS.

Although of availability of different surveying methods and techniques used for data collection to produce topographic maps, photogrammetry remains widely used. This is due to reducing the overall cost of projects, reducing the effort and manpower, and timesaving. In addition to these the development which had occurred in turning the conventional photogrammetric system to real time digital photogrammetric system that referred to the great development in computer science in general and related software in particular.

IV. STUDY AREA AND SPECIFICATION

Khartoum state is the grater and important state in Sudan. It is located approximately between longitude 31º 45´ 00" and 34º 30´ 00" in east west direction and latitude 15º 30´ 00" and 16º 30´ 00" in north south direction covering an area of about 22142 km^2 . Survey authority of the state planed a project to cover the center of the state with new topographic maps. These maps should be prepared from digital photographic images taken at scale 1:5000.

A committee of high technical specialist suggested number of specification. Table 1 below represents project specification.

Table 1: Part of project specification

Elements	Parameters	Requirements
Digital Camera	Lens	Focal length to suspend normal Angle for 1:5,000 scale
	Geometric Precision	≤ 2 µm
	Geometric Resolution(Physical Pixel Size)	≤ 15 µm
	Radiometric Resolution	≥ 12 bit
	Shutter Speed	1/500 or Faster
Aerial Triangulation	Tie points not Less Than 9 point on Each Image	Tie points not Less Than 9 point appearing in minimum 3 Photos
	A Control Diagram Should Be Prepared Showing The Location of all Types of Control Points by Different Symbols	
	RMSE of Residuals in E, N and h at control points	≤ 1/10,000 of the flying height above ground
	Average σ in Computed E, N, h	≤ 1/10,000 of the flying height above ground
	Max Residuals in any Control point & σ in E, N, h of Pass points	≤2.5RMSE of Control Points Residuals
	RMSE at any Mean Tie Point	≤1/ 20,000 of the flying height above ground
	Max Residuals in any Tie point	≤2.5RMSE of Tie Points Residuals
	Average Adjustment to Photo-coords. In Block	± 10 µm
	Max Adjustment to Photo-coords. Value	± 20 µm

V. MEASUREMENTS AND RESULTS

The research work depended on collecting the relevant documents of the project besides making some field observations and office investigations.

According to available data, the digital photographic coverage of the project was executed using UltraCamD, Serial Number UCD -1- 0043 Manufacture: Vexcel Imaging GmbH, A-8010 Graz, Austria.The following table is a part of calibration report of the camera.

Table 2: Part of calibration report of large format panchromatic output

Image Format	Long track	67.5mm	(7500 pixel)
	Cross track	103.5 mm	(11500 pixel)
Image Extent	(-33.75, -51.75) mm		(33.75, 51.75) mm
Pixel Size	9µm× 9µm		
Focal Length	105.200 mm± 0.002 mm		
Principal Point	X ppa	0.000 mm± 0.002 mm	
	Y ppa	0.000 mm± 0.002 mm	
Lens Distortion	Remaining Distortion less than ± 0.002 mm		

A sample area of the project was selected to cover 32 photographs. Four successive images from strip 38, 39, 40 and 41were chosen as illustrated in Fig. 1 below:

Fig. 1: Images of study area

Resultant IMU file of the selected photographs showing image numbers and camera orientation parameters was obtained as arranged in Table 3 hereunder.

Table 3: IMU file of the selected photographs

No.	Image ID	Camera Orientation Parameters					
		Easting(m)	Northing(m)	Height(m)	Omega°	Phi°	Kappa°
1	38-08281	448790.811	1725270.859	1602.606	0.18067	0.11479	90.66229
2	38-08282	448792.748	1724999.366	1600.537	0.16774	0.13713	90.67694
3	38-08283	448794.556	1724727.808	1599.753	0.18455	0.11108	90.64428
4	38-08284	448795.752	1724456.970	1600.585	0.15520	0.13028	90.25298
5	38-08285	448795.611	1724184.605	1602.610	0.16647	0.10943	89.87967
6	38-08286	448794.587	1723912.834	1605.266	0.16496	0.13458	89.85954
7	38-08287	448793.099	1723639.417	1607.355	0.16860	0.11611	89.74474
8	38-08288	448791.264	1723367.457	1607.448	0.15970	0.11127	89.71868
9	39-08021	449634.219	1723326.613	1602.461	-0.17043	-0.07834	-90.59829
10	39-08022	449636.343	1723598.519	1602.638	-0.17534	-0.10700	-90.14487
11	39-08022	449637.189	1723871.223	1604.625	-0.17953	-0.10763	-90.03777
12	39-08024	449637.618	1724143.356	1607.540	-0.17465	-0.09316	-89.93163
13	39-08025	449636.686	1724415.635	1608.616	-0.16362	-0.10281	-89.49022
14	39-08026	449634.260	1724686.588	1606.883	-0.17774	-0.10162	-89.37464
15	39-08027	449631.282	1724958.423	1603.242	-0.16730	-0.10592	-89.29397
16	39-08028	449628.453	1725229.401	1600.141	-0.16436	-0.09872	-89.37066
17	40-05370	450472.663	1723303.126	1595.371	-0.16798	-0.10185	-89.62783
18	40-05371	450472.333	1723574.764	1594.505	-0.16719	-0.10402	-89.45963
19	40-05372	450470.684	1723846.815	1594.069	-0.17341	-0.09312	-89.17806
20	40-05373	450467.735	1724119.637	1594.124	-0.18638	-0.08552	-89.12423
21	40-05374	450463.884	1724391.272	1594.650	-0.18672	-0.09574	-88.72759
22	40-05375	450459.669	1724662.770	1595.356	-0.17466	-0.09909	-88.73162
23	40-05376	450455.371	1724935.167	1596.016	-0.16677	-0.09528	-88.69266
24	40-05377	450451.185	1725207.356	1596.497	-0.15849	-0.09890	-88.81016
25	41-05030	451290.777	1724907.095	1607.832	0.17081	0.10269	89.84162
26	41-05031	451289.333	1724635.759	1605.810	0.14634	0.06526	89.92647
27	41-05032	451288.923	1724364.043	1603.945	0.15488	0.10390	90.20696
28	41-05033	451288.998	1724091.971	1602.738	0.17059	0.09677	90.12815
29	41-05034	451289.344	1723820.203	1602.174	0.15063	0.09287	90.14999
30	41-05035	451290.079	1723548.987	1602.265	0.15663	0.10381	90.39027
31	41-05036	451290.892	1723276.981	1603.046	0.17141	0.07918	90.26049
32	41-05037	451291.541	1723005.245	1604.316	0.16492	0.09857	90.19906

Referring to calibration report of the used camera, it can be noted that it was large format wide angle camera while normal angle was suggested to be used in project specification.

The average flying height is the average distance between the camera - at the time of exposure - and the average ground elevation. Analyzing data in Table 3 above, the average flying height can be computed as 1217.99 ≈ 1,220m.

Image scale can simply be computed as a ratio of the focal length to average flying height. Applying this ration to available data of photographic coverage, Image scale can be computed as 0.1052/1217.99 ≈ 1:12,000. Compared with suggested scale of photography this scale does not agree and approximately equals to 2.5 times the required.

Ground resolution distance is the smallest area of the earth's surface that can be clearly distinguished by the camera. This value can be obtained by multiplying the dimension of Charge Coupled Device (CCD) by the scale of photography.

Referring to used camera specification and the above computed scale, ground resolution distance will be 0.108m for panchromatic and 0.338m for multispectral. While, this value was suggested to be less than (5,000×15μ = 0.075m) in specification.

In order to evaluate the accuracy of the project, number of 7 well distributed points were selected to cover the study area. These points were then observed in the field using Deferential Global Positioning System (DGPS) model R8- GNN from Trimble Company. Static mode system are used every 45 minutes for observe each point. Unexpected amount accuracy was equal to 0.5 cm + 1ppm. Table 4 hereunder is a result of observed coordinates of the points.

Table 4: Actual coordinates of observed points

Point	X(m)	Y(m)	Z(m)
1*	449101.669	1725509.714	383.113
2*	448340.140	1725365.933	383.415
3*	448412.645	1724739.837	383.519
4	448367.877	1724260.062	381.851
5	448470.900	1723645.658	382.161
6*	448400.810	1723172.145	383.810
7*	449144.144	1724130.761	381.782
8	449152.327	1723066.223	384.543
9	450199.025	1725462.274	381.784
10*	450159.446	1724744.166	383.997
11*	450067.027	1724230.469	385.429
12	450198.86	1723497.647	385.493
13	450078.078	1722963.961	383.832
14	450921.739	1725231.631	386.380
15	450718.066	1724957.814	383.806
16	450877.109	1724054.616	383.764
17	450775.234	1723581.077	383.200
18	451003.688	1723088.568	385.259

*Control point used for map evaluation.

In order to evaluate accuracy of the photographic images of the project, the control points observed above were used to adjust the images. Leica Photogrammetry Suite (LPS) package was used to adjustment digital images. Number of 63 points were used as tie points.

When orientation procedures and aerial triangulation processes were completed, the ground coordinates of control and tie points were extracted. The total root mean square error (RMSE) for the total images are computed by the LPS software and was found to be 0.0625m.

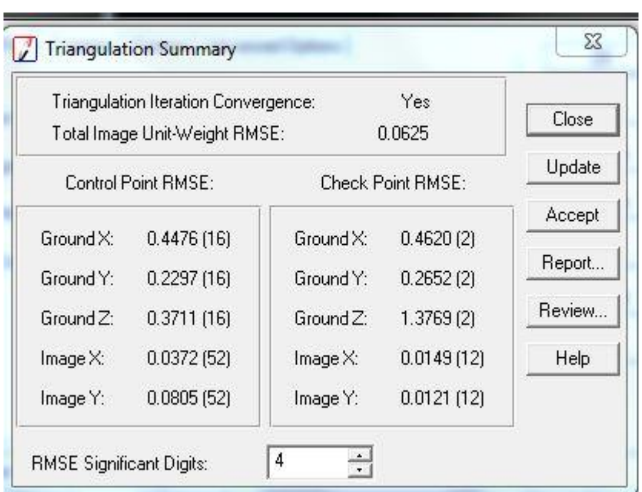

Fig. 2: Triangulation summary of study area

From the above triangulation summary result, planmetric accuracy can be computed to as:

$$\sqrt{(0.462)^2 + (0.265)^2} = 0.533 \text{ m}$$

On the other hand, linear accuracy of check points was found to be:

$$\sqrt{(0.462)^2 + (0.265)^2 + (1.377)^2} = 1.476\text{m}$$

Produced topographic map was also subject to accuracy evaluation. This was done by measuring map coordinates of seven control points then comparing results with their actual ground coordinates.

Table 5 below is a list of measured map coordinates of control points.

Table 5: Measured map coordinates

No.	X(m)	Y(m)
1	448340.175	1725366.322
2	448412.502	1724739.010
3	448368.047	1724260.351
4	449101.930	1725509.777
5	449144.572	1724131.203
6	450159.885	1724743.852
7	450067.143	1724230.490

Differences between actual ground coordinates of control point and map coordinate were found to be as shown in Table 6.

Table 6: Difference in coordinates

Point	ΔX(m)	ΔY(m)
1	-0.818	0.295
2	0.569	-0.461
3	0.776	0.070
4	1.149	-0.197
5	-0.087	0.237
6	0.430	0.040
7	0.247	-0.017
RMSE	**0.673**	**0.240**

From the above results, the Root Mean Square Error (RMSE) in X-coordinates can be calculated as 0.673m. While the RMSE of Y-coordinates was found to be 0.240m. Consequently, 0.715m is the planmetric accuracy of the produced map.

VI. CONCLUSIONS

The aim of this research work, is to make some sort of technical evaluation of Khartoum state mapping project that executed in 2010. Based on available data of the project and measurements carried out, conclusions can be summarized in the following points:

- The used camera was not normal angle as specified.
- Flying height did not satisfied specification.
- Scale of photography was about 2.5 times the required scale.
- Resolution of the used digital camera was lower than satisfied.
- The planmetric accuracy of photographic coverage was found to be 0.533m while linear accuracy was

found to be 1.476 m. This accuracy is suitable for producing topographic maps at scale 1:15,000

- Planmetric accuracy of produced maps was found to be 0.715m.

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