Application of High-Resolution Satellite Imagery for Large Scale Maps Updating

تطبيق صور الأقمار الصناعية عالية الدقة لتحديث الخرائط ذات مقاييس الرسم الكبيرة

By

Prof. Dr. Ahmed A. Shaker **Assoc. Prof. Dr. Ali A. El-Sagheer**

Dr. Ayman R. El-Shehaby **Eng. Mahmoud S. Mahmoud**

Departement of Surveying, Shoubra Faculty of Engineering, Zagazig University

ملخص البحث

ا رائط القد ة تسبب العديد من ا شاكل للمهندس وغ هم ن تاجون إ طيط أعما م على خرائط حديثة بقدر الإمكان. وللتغلب علي هذه ا شكلة فـ إن ذلك يتطلب مراجعة أرضية مكثفة للخرائط ا تاحة ا يتطلب الكث من الوقت وا هد والتكلفة كما أن استخدام الصور ا وية ذا الغرض تاج إ تكلفة عاليـة بالإضافة إ عدم توافرها كث من الأحيان.لذا يهدف البحث بشكل رئيسي إ وضع نظام لتحديث ا رائط ذات مقاييس الرسم الكب ة بالاستعانة بصور الأقمار الصناعية عالية الدقة مع الأخذ الاعتبار الإزاحة النا ة عن تضاريس سطح الأرض أو الـ DEM كذلك الإزاحة النا ة عن ارتفاعات ا بـا أو الـ ـ DBM. ولتنفيذ ذلك إجراء ربة وتقييم الدقة كل منهما أولا باستخدام نقاط كم أرضية مرصودة بنظام الـ G.P.S ، ثانيا باستخدام إحـداثيات لنقاط دليلية من ا ريطة نفسها. و كلتا ا الت استخدام العديد من النماذج الرياضية كما دراسة تأث وذج الأرض الرقمي وكذلك وذج ا با الرقمي.و سجلت نتائج هذه التجارب بالتفصيل با داول والرسومات ا رفقة و ليل النتائج ا أظهرت الأ ية القصوى لاعتبار تضاريس سطح الأرض أو الـ DEM و كذلك ارتفاعات ا با أو الـ DBM ومدى تأث ها على دقة الاحداثيات ا نتجة. أخ ا فقد وجد أن صور الأقمار الصناعية عالية الدقة ا قومة سوف تكون مناسبة لإنتاج و ديث ا رائط ذات مقاييس الرسم الكب ة.

Keywords (Ortorectification- High Resolution Satellite Imagery-DEM-DBM-Map Updating-)

Abstract

Obsolete maps creates so many problems to engineers, planners and other professionals who need to develop their work based on updated records. An extensive and time –consuming field revision would be required to update such obsolete maps. On the other hand the conventional methods of map revision with aerial photographs are so costly and highly time-consuming that base map revision cycle cannot be done as planned. In this research, an attempt is made to develop a workflow for map updating using satellite imagery of high resolution. The workflow comprises all necessary technical steps of dealing with satellite imagery until extracting desired image information. An experimental test utilizing a l-m resolution satellite image for updating an old map is investigated. Two experiments were conducted to evaluate the planimetric accuracy. The first one based on GPS Control Points and the second one based on MRP (Map Reference Points) Also the effects of both DEM (Digital Elevation Model) and DBM (Digital Building Model) on the rectification process were discussed. The used models are specified and the obtained results are tabulated and analyzed, which indicated that there is a significant effect of both DEM and DBM on the obtained results. Finally it has been found that, the rectified high-resolution satellite imagery will be of sufficient accuracy for large-scale maps updating.

1.Introduction

A so pressing problem that is common to many places in developing countries is that considerable amount of the population live in unplanned settlements. These settlements and their population grow so fast that unconventional mapping techniques are required to provide the decision-makers with continuously reliable picture. Space imagery promises to be will appropriate to produce and update maps. It would be an attractive solution to such countries whose mapping needs are difficult to satisfy using aerial photogrammetric methods [1].

Remote sensing from space is a rapidly growing field, with many nations and commercial companies developing and lunching new systems on a regular basis. The U.S. LANDSAT and French SPOT satellite systems were the first and most robust and global monitoring systems to acquire moderate resolution data on a systematic basis. In fact, many of their principles of operation apply to the other system available today and planned for the future. In addition to LANDSAT and SPOT, other moderate resolution land satellites have been developed and lunched by other countries. In 1985, Russia lunched the first of a series of RESURS-01 satellites. India began the Indian Remote Sensing (IRS) program with the lunch of IRS-1A in 1988. Japan lunched the Advanced Earth Observation Satellite (ADEOS) in 1996 [2].

Currently, too many countries have embarked on planning and developing moderate resolution satellite systems. Numerous systems have been lunched that reach much higher spatial resolution. With the successful lunch of the IKONOS-2, QuickBird and Orb View-3 satellites in late 1999, the surveying and photogrammetry communities entered the era of commercial high-resolution earth observation satellites. IKONOS-2 features a one-meter-resolution panchromatic sensor and a four-meter-resolution multispectral sensor. The impact of the one-meter-resolution satellite imagery on topographic mapping and map updating can be expected to be significant [3].

2.Study Area

The area of study is selected at Sakr-Korish area in Cairo City, covers approximately one and half-square Km. It is a largely urban area that contains buildings, a network of main roads as will as minor roads and some hilly areas. The following data sources are available for the study area:

a-A 1:5000 cadastral map (J-16) of same area of study last updated in 1978 from 1:15000 aerial photographs acquired in 1977. The map is published by the Egyptian Survey Authority (ESA), Figure(1.a).

b-A 1:5000 contour map over the same area last updated in 1978 from the same aerial photographs is used for generating the (DEM) digital elevation model required for the orthorectification process. The map is published by the Egyptian Survey Authority (ESA), Figure (1.b).

c-A one-meter spatial resolution and panchromatic image over the area of study were collected in April 17, 2000 by Space Imaging's IKONOS satellite and supplied in a TIFF digital format. This image has been radiometrically adjusted to improve the radiometric quality by the producer, Figure(1.c).

3-Methodology

Map updating of the study area was done using the above mentioned data and was implemented in several stages as follow:

- Scanning and Vectorization of the available hard copy maps.
- Map georeferencing.
- Generation of the digital elevation model
- Generation of the digital Building model
- Orthorectification of the satellite imagery.
- On screen digitizing and editing of satellite image features.
- Field revision and verification purposes.
- Production of the final updated map.

4.Map Scanning and Vectorization

Scanning is a very common procedure used for transforming hard copy maps into a digital format, where the output is a raster map [4]. Experience has shown that a resolution of 400 to 600 D.P.I (Dot Per Inch) gives the best scanning results. This resolution avoids line coalescence while still resolving very thin lines that might not be totally captured at lower resolutions, also this resolution will prevent most difficulties at the vectorization step [5]. Scanners come in three general types: line-following scanners, flatbed scanners and drum scanners [6]. In these research the 1/5000 hard-copy cadastral map has been scanned using Acer-A0 flatbed scanner at a resolution of 100 microns (250 dpi). That corresponds to a ground pixel size of 50.8 cm, which is consistent with the planimetric accuracy of the 1/5000 scale map and also with the spatial resolution of the used IKONOS image.

After that a process involves the conversion of data in analog form into a digital form that is directly readable by a computer, Vectorization, should be performed. This is normally achieved manually by a human operator using a digitizer, although methods of automated Vectorization and semi-automated Vectorization also exist. The result of digitizing is a digital map in vector form [7]. In these research and due to the limitation of automatic vectorization software on hand, the scanned map had been imported into the ERDAS IMAGINE-8.4 environment and vectorized using on screen digitizing approach.

5.Map Georeferencing

The process involved georeferencing of both scanned and vectorized maps to the Universal Transverse Mercator projection (UTM) by the map corners in the ERDAS IMAGINE-8.4 software. To evaluate the planimetric accuracy of the map nearly 25 GCPs evenly distributed through the area of study and well defined on both the map and ground were selected. GPS observations were carried out and compared against the corresponding MRP. All points were results in the UTM (Universal Transverse Mercator) system and the total RMSE were 1.825 m.

6. DEM Generation

To generate the DEM to be used for the orthorectification process the 1/5000 contour map mentioned before was digitized by a scanner, then georeferenced to the Universal Transverse Mercator projection (UTM) projection and a raster to vector conversion process (on-screen digitizing) was used (nearly 26342 point were digitized). The contour lines vector data were compiled by adding elevation attributes, and the DEM was built from the vector data by ERDAS IMAGINE 8.4 software (figure 2). Theoretical estimates and tests of the DEM against ordinary levelling data from bench mark 8144 of level 53.741m above men sea level, nearly 15 points evenly distributed across the area of interest, indicate that the standard elevation error of the produced DEM are 1.167 m.

7.Generation of the Digital Building Model

Since the processed image has already orthorectified using the digital terrain model. The remaining relief displacement comes from the buildings. So, a Digital Building Model (DBM) is necessary for true orthorectification. High quality and homogenous Digital Building Model (DBM) can be directly derived from ALS (Airborne Laser Scanner) data. Airborne laser scanner is an active technique to acquire 3D information describing the earth surface. A typical system can provide pixel data with 15cm vertical accuracy and 50cm horizontal accuracy, and the laser points are almost evenly distributed in the covered area [8]. Although the limitation of ALS (Airborne Laser Scanner) data on hand the Digital Building Model (DBM) had been generated manually, where the positions of buildings were digitized from the scanned map in the ERDAS EMAGINE 8.4 environment using on-screen digitizing technique each building as an area of interest .The elevation data were measured using the remote elevation program in the SOKKIA SET3000 Total Station and compiled by adding elevation attributes, where the building heights varied from 3m to 33m. After that all the areas in between had been masked to the datum level (figure 3).

8.Rectification of Satellite Imagery

To make the satellite imagery useful for mapping or map updating, the imagery must be adjusted to a geographic map projection. This process is often called georeferencing. It converts the image from an arbitrary coordinate system into that of the applied map [4]. Two main processes within rectification warrant further explanation.

8.1.Coordinate Transformation:

There are a variety of transformation models, but here we applied the most commonly used ones in image processing systems.

a) Polynomial Transformation

The transformation between the original and the rectified images is done by polynomials That is [6]:

$$\mathbf{x = x'^{T}\, A\, y' = fx\,(x', y')} \qquad \mathbf{(1)}$$

$$\mathbf{y = x'^{T}\, B\, y' = fy\,(x', y')} \qquad \mathbf{(2)}$$

where

x,y are coordinates of the original image,

x', y' are coordinates of the rectification

A, B are coefficient matrices of the polynomials.

$x'^{T} = (1, x', x'^{2}, x'^{3}, ...)$

$y'^{T} = (1, y', y'^{2}, y^{3}, ...)$

This method corrects the distortions of the image relative to a dense set of control points. Due to the polynomial transform, the original image is shifted, rotated, scaled, and squeezed so that it fits best to the given reference points. A first order (linear) transformation can change location, scale, skew and rotation. Second order transformations can correct nonlinear distortions. They can be used with data covering a large area to account for the Earth's curvature and with distorted data (for example, due to camera lens distortion). Third order transformations can be used with distorted aerial photographs and with radar imagery. Fourth order transformations are suitable for very distorted aerial photographs [9].

b) Rubber Sheeting Transformation

Rubber Sheeting transformations reconstruct the digital images in “patches” between ground control points (GCPs). These patches are typically triangles that form an irregular mesh covering most or the entire image. The transformation of the image is then executed on a triangle by triangle basis. A GCP exerts influence only on those triangles in which it is a vertex. While each triangle will have a different transformation function, adjacent triangles will share the same transformation function values at their common edge. This makes the piecewise transformation continuous across the image so that the transition from one triangle to another becomes seamless. Suppose a triangle has vertices P1, P2, P3 with corresponding image space coordinates of (u1,v1), (u2,v2), (u3,v3) and target space coordinates (x1,y1), (x2,y2), (x3,y3). For a point P within the triangle, with target space coordinate (x,y), the corresponding image space coordinate (u,v) is found by solving [4]:

$$\mathbf{x = Ar} \qquad \mathbf{(3)}$$

$$\mathbf{r = A^{-1}X} \qquad \mathbf{(4)}$$

$$\mathbf{u = Br} \qquad \mathbf{(5)}$$

where:

$$r = \begin{vmatrix} r1 \\ r2 \\ r3 \end{vmatrix} \qquad A = \begin{vmatrix} x1 & x2 & x3 \\ y1 & y2 & y3 \\ 1 & 1 & 1 \end{vmatrix} \qquad X = \begin{vmatrix} x \\ y \\ 1 \end{vmatrix} \qquad U = \begin{vmatrix} u \\ v \end{vmatrix} \qquad B = \begin{vmatrix} u1 & u2 & u3 \\ v1 & v2 & v3 \end{vmatrix}$$

Once the transformation equation has been solved an interpolation method is used to determine an output intensity value.b

c) Differential Transformation

A digital elevation model (DEM) is needed to correct for relief displacements in the image. The three dimensional coordinates (X, Y, Z) defined by a DEM pixel are transformed into the image by the collinearity equations (5,6). At the image position (x, y) the gray-value is interpolated by one of the resampling methods. The density is stored at the X, Y location of the digital orthophoto, which is equal to the position of the DEM point [6].

$$x = x_p - c\frac{r_{11}(X_o - X_o) + r_{21}(Y - Y_o) + r_{31}(Z - Z_0)}{r_{13}(X - X_o) + r_{23}(Y - Y_o) + r_{33}(Z - Z_o)} = fx(x`, y`) \quad \text{.......}(6)$$

$$y = y_p - c\frac{r_{11}(X - X_o) + r_{21}(Y - Y_o) + r_{33}(Z - Z_0)}{r_{13}(X - X_o) + r_{23}(Y - Y_o) + r_{33}(Z - Z_0)} = fx(x`, y`) \quad \text{.......}(7)$$

where x', y' are equivalent to the map coordinates X, Y.

To perform this transformation, the following parameters have to be available:

- The interior orientation of the camera: xp, yp, c.
- The exterior orientation of the camera: Xo, Yo, Zo – perspective center, R a rotation matrix composed of ω, φ, κ rotation angles,
- The pixel spacing of the digital image in camera units: px, Py (mm).
- The cell-size of the DEM pixels in ground units: gx, gy. (m).
- The reference coordinates of one DEM pixel in the given map projection (usually the left upper corner of the DEM file).

8.2.Resampling

The row and column coordinates from the transformation process are not integer values. Since the satellite image has digital numbers only for integral locations, a procedure is required to obtain the proper value from the satellite image. This procedure is commonly called resampling [9]. There are several techniques available for resampling of digital images, through three particulars ones are by the most prevalent. These three are known as Nearest Neighbor interpolation, Bilinear interpolation and Bicubic interpolation [10].

9.Overlaying and Change Detection

After image registration to the scanned map, they could be overlaid together. The new linear features could be detected by observing the image in the background covered by the vectorized map. The changes were screen digitized and generated in vector format. Then editing process such as closing of polygons and generating neat intersections could be done. Features that are not discernable enough in the image were kept for field revision. Aerial photographs, if available, can also provide a great help in the revision process [11].

10.Field Revision and Verification Purposes

All features that were located onto the maps in the office are then checked in the field. The purposes of field work were to verify and classify the detail of new features such as type of roads (hard or loose surfaces), road number and width, type of agricultural and names of features such as school, monastery, village, reservoir etc. Also, the ambiguous features from interpretation in the office could be identified after field verification. Some features could not a detected by satellite images like important official buildings then were covered with tree crowns. Such features could be mapped by field verification [12].

11.Production of the final updated maps

The physical production of final maps has evolved rapidly with the widespread availability of computer-based tools for map compilation, analysis, and publishing. Several options are available for the preparation and printing of high-quality hard-copy maps. Output devices include pen plotters, electrostatic plotters, direct raster plotters, and color printing systems using digitally rendered color separates as input. The choice of an output device is a function of the types of maps desired (color, black and white) and the media desired (stable-base media such as polyester, various paper media for thermal, electrostatic, or thermal wax printing, or film). These types of print processes are used primarily for small-volume printing. Large volume printing of maps is done by a letterpress or lithographic process just as mapping has been greatly affected by the use of computers, the traditional letterpress and lithographic print processes now can accept digital "plates." [13].

12.Results and Analysis

The technology based on high-resolution satellite imagery will be suitable cost and time effective for updating old maps at large and medium scales. The time and coast required to producing a 1/5000 cadastral map (2.5 X 3.5 Km) from 1m panchromatic IKONOS imagery may be reduced by 5.5 times than the traditional techniques. The resulting maps provide useful information that is necessary for planning and decision making at national and regional levels. Generally speaking, the use of IKONOS data for change detection of land cover and land use at scale of 1/5000 led to good results. However, their spatial resolution was always sufficient to interpret the individual classes clearly.

All the results in this study are evaluated by the Root Mean Square Error (RMSE) value that express the planimetric accuracy of the map. Two different results based on the source of GCPs were obtained. The first approach based on all the GCPs are GPS control points where available GPS and the Digital Elevation Model (DEM) with a grid size of 5m were sufficient for orthorectifying the IKONOS image with the accuracy of the 1:5,000 base map. The second approach are based on MRP (Map Reference Points), where available cadastral data (1:5,000 maps) and a Digital Elevation Model (DEM) with a grid size of 5m were sufficient for orthorectifying the IKONOS image with the accuracy of the 1:10,000 base map.

For GPS control points several mathematical models and control point configurations were applied and the results were recorded in Table (1) and graphically represented in Figure (4). Also for MRPs several mathematical models and control point configurations were applied and the results were recorded in Tables (4) and graphically represented by Figure (5).

The effect of DBM on the orthorectification process was tested and the results are recorded in Tables (2). Also the effect of the error in measuring building heights on the horizontal accuracy of the map were discussed and represented numerically in Table (3) and graphically in Figure (6).

13.Conclusion

In this research, an attempt is made to develop a workflow for map updating using satellite imagery of high resolution. The workflow comprises all necessary technical steps of dealing with satellite imagery until extracting desired image information. An experimental test utilizing a l-m resolution satellite image for updating an old map is investigated. Based on the test results, the following concluding remarks can be made:

- The technology based on high-resolution satellite imagery will be suitable cost and time effective for updating old maps at large and medium scales .
- Available cadastral data (1:5,000 maps) and a Digital Terrain Model (DTM) with a grid size of 5m were sufficient for orthorectifying the IKONOS image with the accuracy of the 1:10,000 base map.
- Available GPS and the same Digital Terrain Model (DTM) with a grid size of 5m were sufficient for orthorectifying the IKONOS image with the accuracy of the 1:5,000 base map.
- The generated orthoimage, by using DTM and by considering building effects may reach an accuracy of 1.838m when 10 MRP were employed.

- The generated orthoimage, by using DTM and by considering building effects may reach an accuracy of 0.838 when 10 GPS CPs were employed.
- The large RMSE of image registration using map GCPs may be due to some errors during the process of scanning and raster-to-vector conversion.
- In flat areas, geometric correction can be implemented by transformation of planimetric control points (simple rectification). While in hilly areas, relief displacement by terrain variation are significant and should be compensated so a 3-dimensional transformation should be used and (orthorectification) with DEM.
- The quality of the orthorectification process was examined on the screen by overlaying satellite images with the digitized vector map. The most accurate terrain features are the roads. They were coincoide within one or two meter since the image has already orthorectified using the digital terrain model. While the planimetric positions of buildings were still dislocalized by relief displacement comes from the buildings so, a Digital Building Model (DBM) is necessary.

References

[1] Shaker, A., Zahran, M., and EISagheer, A., : A PROPOSED APPROACH TO UPDATE LARGE-SCALE MAPS IN DEVELOPING COUNTRIES USING HIGH-RESOLUTION SATELLITE IMAGERY., CERM Vol.(24) No.(1) Jun. 2002. Page 344-362.

[2] Thomas, M., and Ralph, W., (2000): REMOTE SENSING AND IMAGE INTERPRETATION. fourth edition.

[3] Michael N., (1999): FUNDAMENTALS OF GEOGRAPHIC INFORMATION SYSTEMS second edition, New Mexico State University.

[4] Ochis, H., and Edward, C., (1996): " COMPARISON OF A PIECEWISE TRANSFORMATION TO POLYNOMIAL-BASED GEOMETRIC CORRECTION ALGORITHMS". Computer Terrain Mapping, Inc., Boulder, CO.

[5] Eileen, M., (1998): PLANNING A DIGITIZING PROJECT.THE NVGIA GIS CORE CURRICULUM FOR TECHNICAL PROGRAMS. October 5,1998.

[6] Novak, K.,(1992): "RECTIFICATION OF DIGITAL IMAGERY". Photogrammetric Engineering & Remote sensing, Vol. 58, No 3, March 1992, pp. 339-344.

[7] Warren, H., Lance, G., and Thomas N., (1997) : SEMI-AUTOMATED DATA CAPTURE FOR VECTORIZING GEOLOGIC QUADRANGLE MAPS IN KENTUCKY DIGITAL MAPPING TECHNIQUES '97 U.S. Geological Survey Open-File Report 97-269.

[8] Moik, J., 1980. Digital processing of Remotely Sensed images. NASA SP-431. Washington, D.C.: Government Printing office.

[9] Erdas, (1997): IMAGINE ESSENTIALS TRAINING REFERENCE MANUAL. Atlanta , Georgia USA.

[10] .Smith,S., .Dewitt, B., Gonzalez, E., and Hurt, G., " GEOREFERENCING OF SATELLITE IMAGERY FOR DIGITAL SOIL MAPPING" Surveying And Land Information System.VOL.55, NO.1, PP.13-20

[11] Robinson, A., et al. (1995): ELEMENTS OF CARTOGRAPHY. Sixth ed. Dent, D. Borden: Thematic Map Design.Jones, Christopher: Geographical Information Systems and Cartography August 2, 2000.Lecture Nine - Selected Topics in GIS and Cartography.

[12] Somkiat, A., (1990): BASE MAP REVISION USING HIGH RESOLUTION SATELLITE DATA, Royal Thai Survey Department, Thailand.

[13] James, M., and Edward, M.,(1998): SURVEYING THEORY AND PRACTICE, Seven edition.

Table (1): Statistics of the Differences among Measured (GPS) And Transformed Coordinates at Using Different Transformation Models, in meters

No. of control points	Statistics	Mathematical Model			
		POL. 1	POL. 2	R.S.	Diff.
5	Min.	0.126	0.485	0.218	0.565
	Max.	5.803	6.813	4.502	1.728
	Mean	2.378	2.583	1.465	1.089
	RMSE	2.843	3.182	1.914	1.2
10	Min.	0.508	0.252	0.218	0.565
	Max.	4.038	3.565	3.622	2.116
	Mean	1.893	1.457	1.347	1.121
	RMSE	2.219	1.787	1.064	0.816
15	Min.	0.092	0.273	0.218	0.565
	Max.	3.302	2.097	3.481	1.728
	Mean	1.52	1.002	1.313	1.007
	RMSE	1.75	1.146	0.908	0.812
20	Min.	0.022	0.057	0.123	0.637
	Max.	2.491	2.813	1.77	1.225
	Mean	1.24	1.113	0.859	0.972
	RMSE	1.425	1.417	1.03	0.753

POL.1: First Order Polynomial.
POL2: Second Order Polynomial.
R.S: Rubber Sheeting Transformation.
Diff: Differential Rectification

Table (2): Statistics of the Differences Among Measured (GPS) and Transformed Coordinates at Using DBM And Different GCPs Configurations, in meters.

No. of control points	Statistics	
5	Min.	0.247
	Max.	1.026
	Mean	0.79
	RMSE	0.838
10	Min.	0.33
	Max.	1.214
	Mean	0.708
	RMSE	0.7641
15	Min.	0.323
	Max.	1.125
	Mean	0.615
	RMSE	0.714
20	Min.	0.314
	Max.	1.093
	Mean	0.587
	RMSE	0.702

Table (3) :Effect of Error in Building Height Measurements on the Horizontal Map Accuracy (m)

Error (m)	Building Height (M)					
	3	12	15	18	24	33
±1	0.803	0.814	0.815	0.828	0.812	0.815
±2	0.79	0.806	0.809	0.837	0.809	0.812
±3	0.779	0.799	0.795	0.843	0.807	0.809
±6	0.825	0.834	0.832	0.854	0.822	0.823
±9	0.851	0.854	0.857	0.868	0.84	0.842

Table: (4) Statistics of the Differences among Measured (MRPs) and Transformed Coordinates at Using Different Transformation Models, in meters.

No. of control points	Statistics	Mathematical Model			
		POL. 1	POL. 2	R.S.	Diff.
5	Min.	0.793	0.443	0.63	0.242
	Max.	12.815	9.08	8.987	5.498
	Mean	4.985	4.772	3.593	2.369
	RMSE	5.863	5.405	4.297	2.594
10	Min.	0.515	1.018	0.13	0.432
	Max.	9.195	7.337	7.296	3.535
	Mean	3.724	3.801	2.678	2.035
	RMSE	4.621	4.376	3.177	2.156
15	Min.	0.265	0.142	0.409	0.479
	Max.	8.072	6.752	7.219	3.41
	Mean	3.587	3.172	2.194	1.856
	RMSE	4.442	3.71	2.873	2.024
20	Min.	1.093	0.375	0.309	1.315
	Max.	7.191	5.348	7.425	3.135
	Mean	3.837	3.177	1.932	2.006
	RMSE	4.173	3.473	2.52	2.1
25	Min.	0.46	1.956	0.375	1.288
	Max.	8.628	4.172	3.694	3.298
	Mean	2.674	3.059	1.605	1.857
	RMSE	3.743	3.164	1.973	1.998

Table (5): Accuracy of Orthorectification Process Using MRPs and DBM for Control Points

Pt.	X image (Pixel)	Y image (Pixel)	E map (Meter)	N map (Meter)	Z map (Meter)	ΔN Meter	ΔE Meter	.Resul (Meter)
GCP 1	87.625	-715.375	334456.2	3318986	18	0.2	0	0.2
GCP2	493	-1294	334870.1	3318357	24	0.3	-0.6	0.6
GCP 3	173	-1333	334548.4	3318314	18	2.3	0.4	2.3
GCP 4	186.875	-991.375	334558.4	3318685	18	0.4	-0.5	0.7
GCP 5	320.875	-527.625	334693.3	3319192	18	0.9	-0.8	1.2
GCP 6	899.375	-640.375	335282.2	3319076	15	2	-1.3	2.4
GCP 7	679.625	-902.875	335054.7	3318791	3	-1.9	1.1	2.2
GCP8	589.625	-687.875	334963.5	3319024	18	-1.8	2.1	2.7
GCP 9	528.625	-949.875	334902.7	3318734	24	-0.7	-0.3	0.8
GCP10	785	-1198	335162.3	3318465	33	-1.9	-0.1	1.9

Table (6): Accuracy of Orthorectification Process Using MRPs and DBM For Checkpoints

Pt.	X image (Pixel)	Y image (Pixel)	E map (Meter)	N map (Meter)	Z map (Meter)	ΔN Meter	ΔE Meter	.Resul (Meter)
GCP13	370.625	-706.625	334744.6	3318999	3	1.2	-1.4	1.9
GCP12	788.875	-700.125	335166.9	3319013	18	-0.5	2	2.1
GCP11	662.125	-560.375	335039.2	3319161	3	-0.6	-1.2	1.4
GCP15	381	-1198	334755.3	3318465	18	-0.3	2.1	2.2
GCP14	370	-943	334743.7	3318739	18	0.7	-1.7	1.8

The Root Mean Square (RMS) error from the satellite modelling were 0.738 m and 1.743 m in E and Y respectively and the total RMS error were 1.893m.

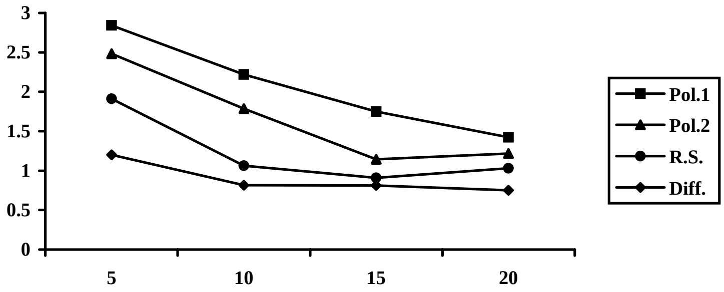


Figure (4): Graphic Summary of the RMSE of GPS Control Points Using the 1st Order, 2nd Order, Rubber Sheeting and Differential Transformations.

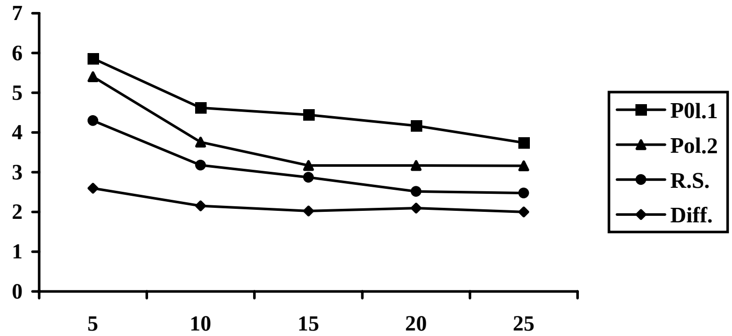


Figure (5): Graphic Summary of the RMSE of MRP Using the 1st Order, 2nd Order, Rubber Sheeting and Differential Transformations.

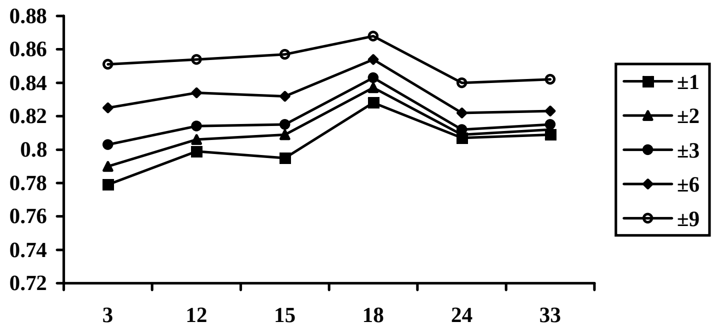
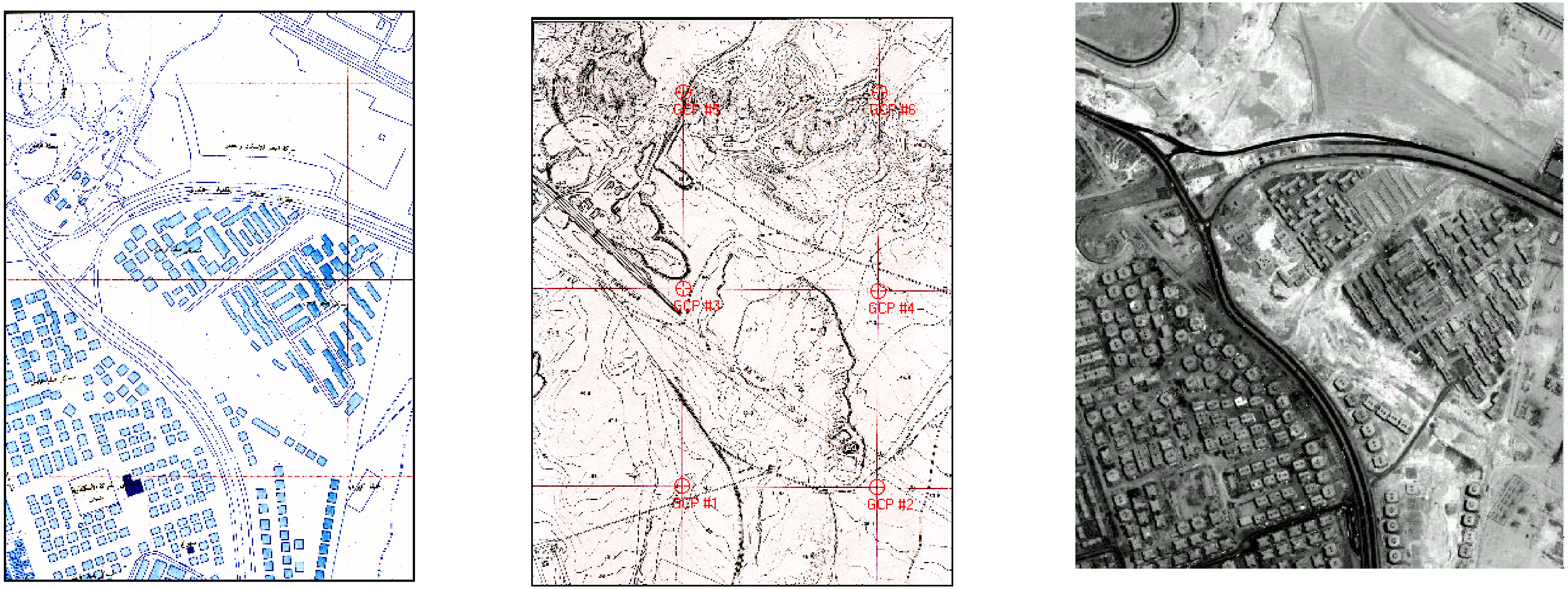


Fig (6) :Effect of Error in Building Height Measurement on the Horizontal Accuracy 0f the Map, in meter



(a) (b) (c)

Figure (1): Data Sources
(a) The 1/5000 test area original map last updated in 1978
(b) Scanned topographic map last updated in 1978
(c) An IKONOS image collected in April, 2000

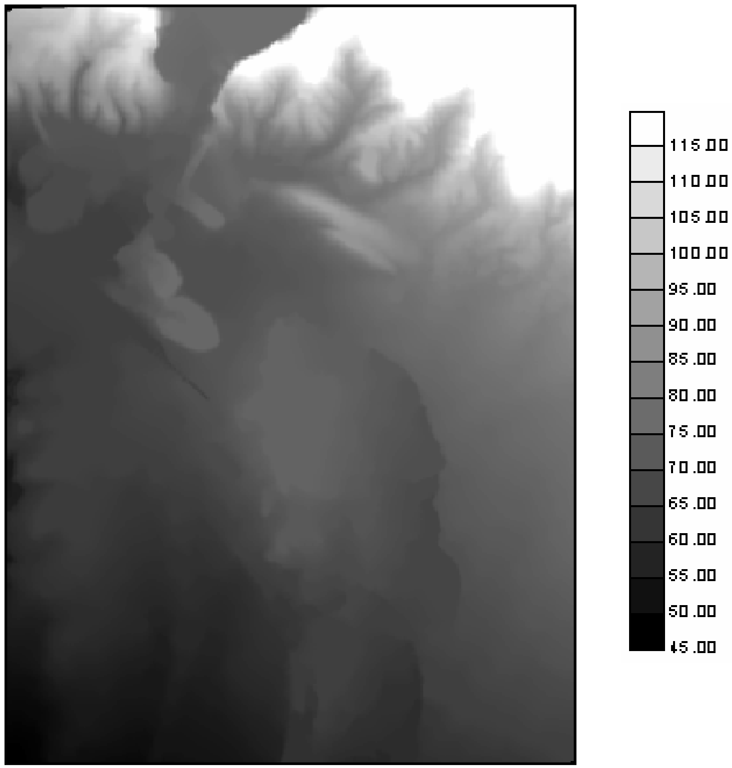


Figure (2): the generated Raster DEM of the area

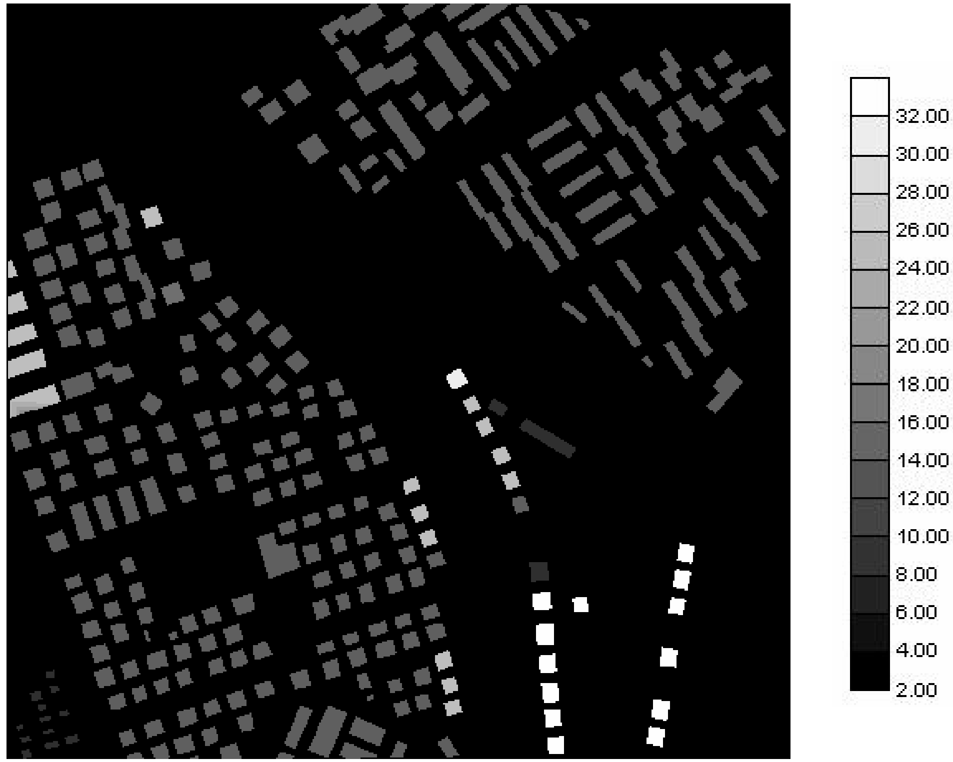


Figure (3): Digital building model of the area

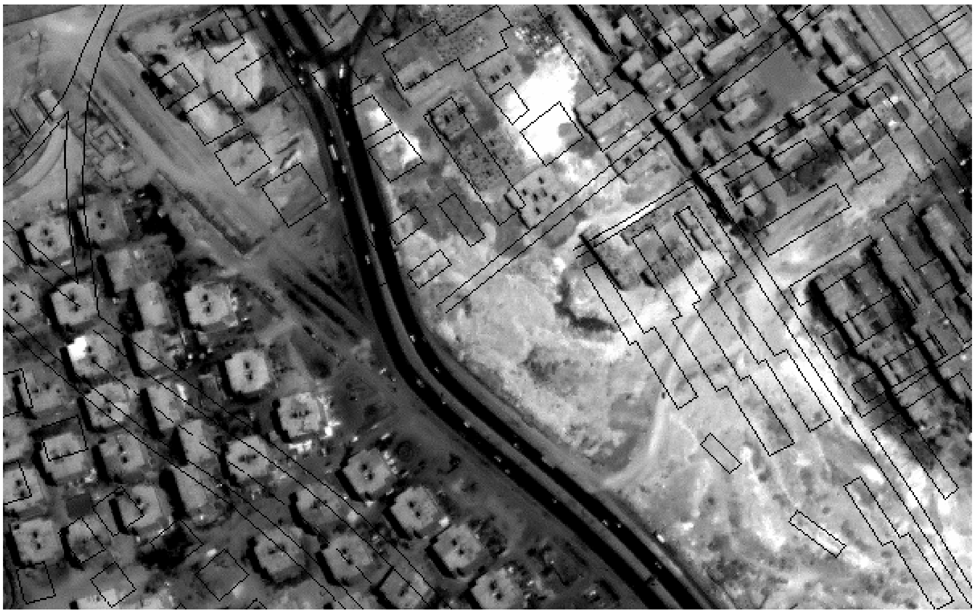


Figure (7): part of the Corrected image covering with the map before orthorectification

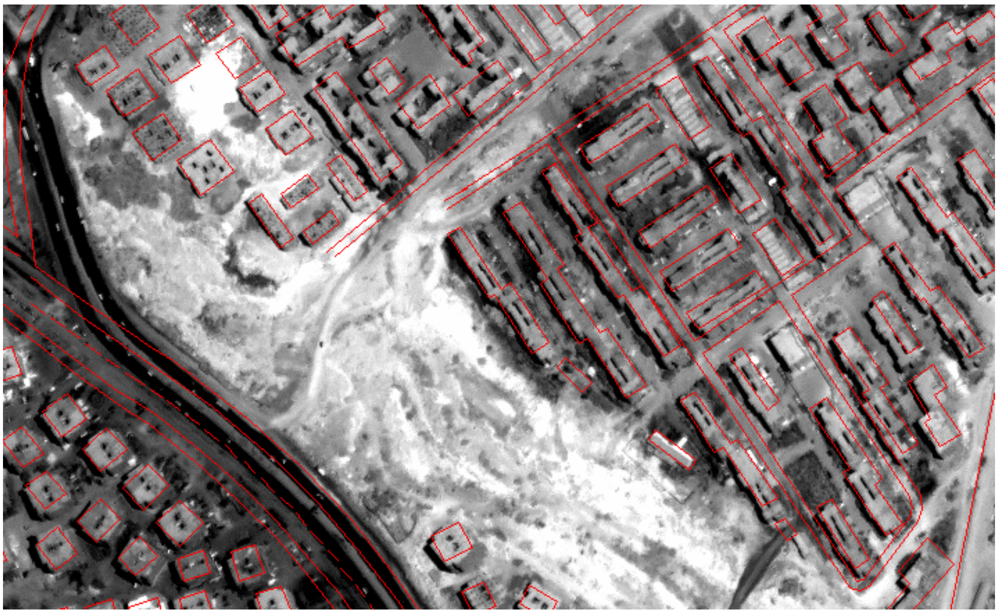


Figure (8): part of the Corrected image covering with the map after orthorectification

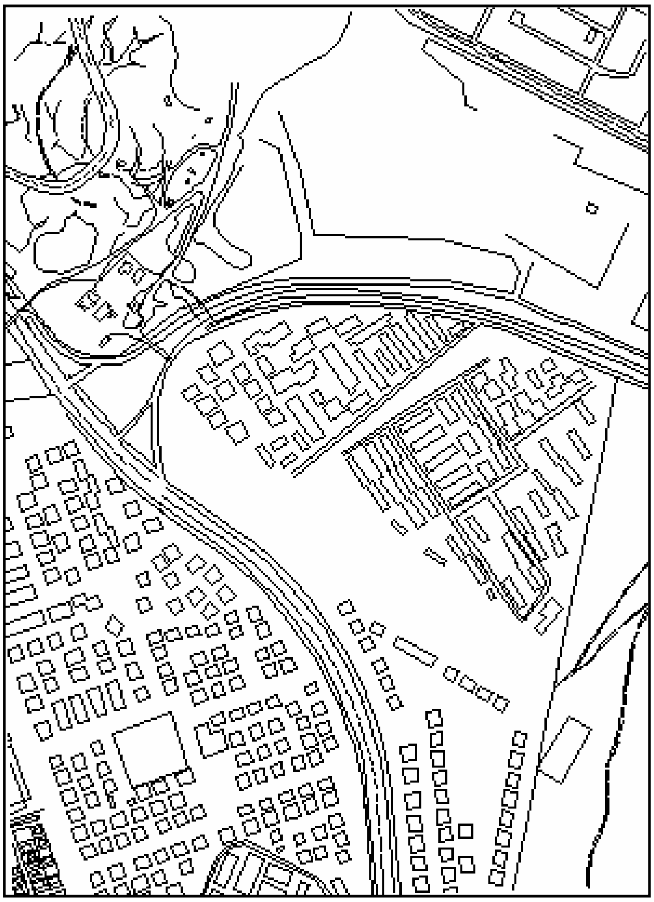


Fig. (5-3): Manual Vectorization of the test area original map