A Proposed Approach to Update Large-Scale Maps in Developing Countries Using High-Resolution Satellite Imagery

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الملخص العربي

تحديث الخرائط تمثل مشكلة جادة في معظم بلدان العالم النامي. في الواقع هناك توسع دائم في معظم مدن وقري الجمهورية نتيجة النمو السكاني المتزايد بمعدلات ملموسة . وللحصول علي معلومات دقيقة عن هذا الوضع الدائم التغير فانه يلزم عمل مراجعة أرضية مكثفة للخرائط المتاحة مما يتطلب جهد كبير و تكلفة عالية. لذلك من الضروري العمل علي تطوير أساليب غير تقليدية لتحديث الخرائط. يهدف البحث بشكل رئيسي إلى وضع نظام لتحديث الخرائط ذات مقاييس الرسم الكبيرة بالاستعانة بصور الأقمار الصناعية عالية الدقة. وقد تم تطبيقه علي منطقة سكنية تشتمل علي مبان وطرق فرعية ورئيسية وبعض المساحات الخضراء وتقع في الجزء الشرقي من مدينة القاهرة بالقرب من مطار القاهرة. والمنطقة تم اختيارها من صورة من صور الأقمار الصناعية أخذت في أغسطس ٢٠٠٠ وذات قدرة تحليلية ١ متر. وقد تم معالجة وتقويم الصورة قبل تسجيلها علي الخريطة المتاحة للمنطقة لتتبع ما أستحدث من معالم أرضية. و كذلك تم عمل مسح أرضي للمنطقة من أجل أعمال المراجعة و التحقيق. وقد أظهرت التجربة حاجة الخريطة إلى إضافة الكثير من المعالم المستحدثة فضلا عن تعديل بعض المعالم الموجودة بها. و قد تبين أن هذه هي الحالة التي عليها معظم خرائط المناطق الجديدة نسبيا بالجمهورية. أخيرا فقد وجد أن دقة تسجيل المعالم من الصورة أعلي من قدرتها التحليلية مما يناسب أعمال تحديث الخرائط ذات مقاييس الرسم الكبيرة.

Abstract

Updating maps seems to be a serious and costly task in most developing countries. As the population grows considerably fast, there is a periodical expansion in most cities, towns, and villages allover the country. An extensive and time-consuming field revision would be required to get reliable information from maps covering such expanding areas. Thus, it becomes crucial to develop unconventional strategies for map updating. The main objective of this research is setting up an operational workflow for updating large-scale maps utilizing high-resolution satellite imagery. The test area is located in the eastern part of the city of Cairo, close to Cairo airport. It is a largely urban area that comprise compounds, buildings, a network of main roads as well as minor roads, and some green areas. It is selected from an IKONOS panchromatic image acquired in August 2000, which has a ground resolution of one meter. Required image processing, rectification and registration operations have been carried out by using a software that is able to handle both vector as well as raster data. It has been found that the available map of the test area is considerably outdated with

respect to the satellite image, which is the case for most relatively recent settlements in the city of Cairo. Many new features were required to be added and some existed features were needed to be changed. A field survey for the test area has been accomplished to clarify image ambiguities and to verify feature dimensions. The digitization accuracy of all image features, acquired for updating the map, is found to be within the resolution of the satellite image. Therefore, high-resolution satellite imagery is greatly suitable and extremely useful for updating maps in developing countries.

1. Introduction

Most developing countries have great difficulties in systematic updating of their maps. In addition to the fact that large areas of such countries are not mapped, many of the existed maps are old and sometimes have an unsatisfactory scale. This situation creates so many problems to engineers, planners and other professionals who need to develop their work based on updated records. 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 well appropriate to produce and update maps [2,10,12]. It would be an attractive solution to such countries whose mapping needs are difficult to satisfy using aerial photogrammetric methods.

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 global monitoring systems to acquire moderate resolution data on a systematic basis. In fact, many of their principles of operation apply to the other systems available today and planned for the future. In addition to Landsat and SPOT, other moderate resolution land satellites have been developed and launched by other countries. In 1985, Russia launched the first of a series of RESURS-01 satellites. India began the Indian Remote Sensing (IRS) program with the launch of IRS-1A in 1988. Japan launched the Advanced Earth Observation Satellite (ADEOS) in 1996. Currently, too many countries have embarked on planning and developing moderate resolution satellite systems [8].

Numerous systems have been lunched that reach much higher spatial resolution. With the successful launch of the IKONOS-2, QuickBird and OrbView-3 satellites in late 1999, the surveying and photogrammetry communities entered the era of commercial high-resolution earth observation satellites. Each of the three satellites 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 [6].

According to the information provided by the Geographic Information System Sector, the Egyptian Cabinet Information and Decision Support Center [7], the country has a serious shortage of 1: 5,000 and 1: 10,000 scale maps. Currently, the Egyptian government is launching some plans for the production of 1:5,000 maps to cover many provinces in the country.

In addition to the problem of mapping the unmapped areas in the country, it seems that keeping systemically updated maps would be a very difficult task. As the population grows considerably fast, there is a periodical expansion in most cities, towns, and villages allover the country. In addition, new towns and communities are spreading out in many places. An extensive and time-consuming field revision would be required to get reliable information from maps covering such expanding areas. Aerial photographs can be used in map revision but they are not always available. Thus, it becomes crucial to develop unconventional strategies for map updating. The main objective of this research is setting up a workflow for updating large-scale maps utilizing high-resolution satellite imagery.

2. Test Area and Data Sources

The test area, roughly 1 km by 1 km, is located in the eastern part of Cairo city, close to Cairo airport. This area is largely urban, comprising compounds, buildings, a network of main roads as well as minor roads, and some green areas. It is selected from an IKONOS panchromatic image that is acquired in August, 2000 (see figure 1).

The image, supplied in digital form (TIFF format), has a ground resolution of one meter. It has been rectified using polynomial rectification based on GPS ground control points.

Figure 2 illustrates a 1:5,000 map available for the test area, after scanning (see section 4). It is compiled by the Egyptian Survey Authority (ESA) in 1987. The map compilation is based on 1:15,000 aerial photography in 1977 and ground control points that are connected to the Egyptian geodetic network. It is updated by the ESA in 1987. The adopted projection system for the map is the national mapping coordinate system; Egyptian Transverse Mercator (ETM).

In order to get updated ground information for verification purposes, the test area is also mapped by terrestrial surveying using Leica TC-1010 Total Station. The station has one-arc-second precision for angle measurements and 3mm+2ppm precision for distance measurements. Additional tape measurements are also taken to help deriving dimensions of required ground features.

3. Operational Updating Strategy

Given both the satellite image and the 1:5,000 map available for the test area, the proposed approach of map updating comprises the following procedures:

- Map scanning and Vectorization
- Image rectification
- Image georeferencing
- Image registration
- Overlaying and change detection
- Field Revision

Most of the processes required by the proposed approach can be carried out in the R2V (Raster to Vector conversion) software environment, developed by Able Software Company [1]. The software converts scanned maps or images to vector formats for mapping, geographic information system (GIS), CAD and scientific computing software. The main features of this software are:

- The software supports bit, gray scale and color images in TIFF, GeoTIFF and BMP formats
- The software imports and exports ArcView (shape file), Arc/Info Generate, DXF, Map Info (MIF/MID), Map Guide SDL, 3D grid, 3D USGS DEM, and 3D XYZ vector file formats.
- Three types of vectorization are available. First, manual on-screen heads-up digitizing, where lines are simply drawn with the images as the backdrop. Second, interactive lines tracing in which lines are traced by the after defining their end points. Third, fully automatic vectorization that is more suitable to scanned maps.
- Vector data can be edited, labeled and organized into layers. They can also be georeferenced using selected control points.
- For raster images, the software provides the essential tools for image editing and processing, georeferening, geometric correction, registration, and supervised as well as unsupervised classification.

Described in the following sections are the details of each of the procedures of the proposed approach.

4. Map Scanning and Vectorization

Hardcopy maps and photographs can be incorporated into the R2V environment through the use of scanning device to transfer them into a digital (raster) format. There are many commonly used scanners for image processing, GIS, and other desktop applications. Scanners come in three general types: line-following scanners, flatbed scanners, and drum scanners [4]. Both flatbed scanners and drum scanners can give monochromatic or color output. In order to convert the scanned object from raster to vector, a vectorization process has to be done. This process can be carried out manually or automatically. Automatic vectorization is very fast and yields good results with bit images and scanned maps. However, it does not work well with gray scale images.

To be converted into a digital format, the 1:5,000 paper map product used in this research has been scanned using Acer-A0 flatbed scanner. The used scanning resolution is 600 dpi. As the scale of the map is 1:5000, this resolution gives one pixel every 21 cm on the ground. The scanned map is then vectorized using automatic vectorization approach in the R2V software environment [1]. Figure 3 shows the vectorized map. It is worth mentioning that the software enables the user to detect all the lines from the raster image/map and display them for verification and editing.

5. Image Rectification

Raw, remotely sensed image data gathered by an aircraft or a satellite are representations of the irregular surface of the Earth. Even images of seemingly flat areas are distorted by both the topographic relief and the used sensor. Rectification aims at correcting the image geometrically so that it can be represented on a planar surface and have the integrity of a map [9]. In this process, the image data are transformed from one grid system to another using a geometric transformation that is based on ground control points. The most known rectification methods are polynomial transformation, triangle-based rectification, and orthorectificaion. A brief description for each of these methods is given in the following subsections.

5.1 Polynomial Rectification

In polynomial rectification, complex polynomial equations are used depending upon the distortion in the imagery, the number of used ground control points, and their locations relative to one another. However, first order or second order polynomials are usually used. 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. The polynomial equations for a n-order transformation can be expressed as follows [5]:

$$x' = \sum_{i=0}^{t} \sum_{j=0}^{i} a_k \, x^{i-j} \, y^j \qquad \text{.......(1)}$$

$$y' = \sum_{i=0}^{t} \sum_{j=0}^{i} b_k \, x^{i-j} \, y^j \qquad \text{.......(2)}$$

where t is the order of the polynomial and a_k and b_k are its coefficients.

5.2 Triangle-Based Rectification

In this process, the available ground control points are triangulated into many triangles. Each triangle has three control points as its vertices. The Delaunay triangulation is a widely used technique to triangulate the control points into a mesh of triangles [1]. A polynomial transformation is then used to define the mathematical relationship between input and output data inside each triangle. In this finite element analysis, the transformation exactly passes through each control point and is not in a uniform manner. Therefore, it is also called rubber sheeting. In order to assure smooth transitions between triangles, a non-linear polynomial transformation is recommended to be adopted for each generated triangle.

5.3 Orthorectification

This is a form of rectification that corrects for topographic relief by utilizing a DEM of the study area. Orthorectification process applies the DEM and the camera (or sensor) parameters, computed from collinearity condition equations and 3-D ground control points, on the raw digital imagery to create an orthorectified image. The collinearity condition equations can be written as [9]:

$$x = x_o - c\frac{m_{11}(X - X_L) + m_{12}(Y - Y_L) + m_{13}(Z - Z_L)}{m_{31}(X - X_L) + m_{32}(Y - Y_L) + m_{33}(Z - Z_L)} \quad (3)$$

$$y = y_o - c\frac{m_{21}(X - X_L) + m_{22}(Y - Y_L) + m_{23}(Z - Z_L)}{m_{31}(X - X_L) + m_{32}(Y - Y_L) + m_{33}(Z - Z_L)} \quad (4)$$

In equations 7 and 8, (x, y) are point coordinate in the photo coordinate system; (X, Y, Z) are point coordinates in the object coordinate system; (x_o, y_o, f) are perspective center coordinates in the photo coordinate system; (X_L, Y_L, Z_L) are perspective center coordinates in the object coordinate system; and (m_{11}, m_{12}, ..., m_{33}) are elements of the matrix of rotation from object coordinate system to photo coordinate system. Orthorectification is unnecessary when having relatively flat areas. On the other hand, this process is recommended at dealing with mountainous areas as well as building areas in order to get a high level of accuracy.

During rectification by any of the methods described above, the original data values of rectified pixels must be resampled to fit into a new grid of pixels. Resampling can be performed using nearest neighbor, bilinear interpolation or cubic convolution [5].

The quality of the rectification process depends on how well the rectification model represents the terrain and the configuration of the used ground control points.

Regarding the satellite image of the test area, a triangle-based rectification has been carried out utilizing the R2V software. The ground points necessary for the rectification process and a check analysis are selected in the image so that it has a good configuration in the test area. A GPS surveying is accomplished to derive the 3-D coordinates of the selected points. The observed GPS points are connected to the GPS network of the Egyptian Civil Aviation Authority, ECAA [3]. It is found that the estimated root mean square (RMS) values of the differences among check point coordinates before and after rectification are below the image resolution. These values reach 0.76 m for x-coordinate differences and 0.72 for y-coordinate differences.

6. Image Georeferencing

Map projections may be classified into three general categories: cylindrical, conical, and azimuthal or planar. Regardless of what type of projections used, it is unavoidable that some distortion occurs in transforming a spherical surface into a flat surface. A distortion-free map has four valuable properties: conformality (true shape), equivalence (equal area), equidistance and true direction. No map projection can carry on all these properties. Therefore, each projection is developed so that certain properties are preserved. Most often, a compromise among selected properties is made. Choice of projection used is influenced by many factors such as type of map, properties to be preserved, type of data to be mapped, map accuracy and map scale [11]. In mapping a relatively small area, theoretically any map projection is acceptable. The amount of distortion in a particular projection is barely noticeable. In mapping large areas, the choice of map projection becomes more critical.

Georeferencing refers to the process of assigning map coordinates to image data. Here only the map coordinate information of the image file is changed. The grid of the image does not change. Rectification, by definition involves georefemcing, since all map projection systems are associated with map coordinates. In the case that the map coordinate system of any georeferenced image is to be converted, it is recommended to rectify the original unrectified data to the desired map coordinate system.

In order to georefernce the rectified satellite image of the test area, the national mapping coordinate system (ETM) is adopted as a reference system. Here, as a first step, a seven-parameter transformation has been carried out from the GPS coordinate system (WGS84), used in rectifying the image, to the national geodetic coordinate system. The adopted transformation parameters for the Cairo-Airport area [3] are illustrated in Table 1. Second, a transformation from the national geodetic coordinate system to the national mapping coordinate system has been accomplished using the pertinent formulas. Finally, the rectified satellite image is georeferenced in the R2V software environment, using the transformation results, to the ETM coordinate system.

7. Image Registration

In many cases, images of one area that are collected from different sources must be used together. To be able to compare separate images pixel by pixel, the pixel grid of each image must conform to pixel grids of the other images [4]. Here, the dissimilar images have to be transformed to the same coordinate system. A map coordinate system is not necessarily involved. Registration is a process of making an image conform to another image. Regarding implementation, registration and rectification involve similar sets of procedures. As described in the image rectification, the original data values of registered pixels are to be resampled by any of the resampling methods to fit into a new grid of pixels.

After rectification and georeferencing the image of the test area, a registration (transformation) process is needed to register the image to the vectorized map using a set of reference, or common, points. This process enables overlaying the image and the map together for further processing. The R2V software is employed to accomplish the image registration based on triangle-based transformation using a number of well-distributed map points that appear in the image.

8. Overlaying and Change detection

After image registration to the scanned map, they are overlaid together in the R2V environment. The new linear features were detected by observing the image in the background covered by the vectorized map. The changes were screen digitized and generated in vector format. Then, these digitized changes are transformed into DXF format and exported to the AutoCAD Map Software. In AutoCAD Map environment, the editing process involved basically tasks that are necessary for further processing of digitized features such as closing of polygons and generating neat intersections. Finally, the digitized features were organized in layers; new buildings, new main roads, new minor roads, and new green areas. 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.

Two factors affect considerably the speed and accuracy of feature digitization process. First, how sharp the feature edges are. Second, how distinct the feature is from the neighboring features. Having distinct features with sharp edges leads to easy and accurate digitization. This is actually the case with most buildings and main roads. In the case of some small buildings, minor roads and green areas, a considerable effort is made to get reliable vectorization results. In building digitization, the building roofs are the features to be digitized. Thus, planimetric positions of digitized buildings are dislocalized by relief distortion. To reduce such a distortion, each digitized building is shifted to its base location. In most cases, at least one side of the building base would be discernable, which is sufficient to carry out the necessary shift. It is worth mentioning that shadows of buildings can be helpful in identifying building sides in the image and thus in the process of building digitization.

An automatic vectorization for the image is also carried out in the R2V environment. The image is first prepared for this automatic process by choosing the removing-image-background option, available by the software. Figure 4a illustrate the resulted image. Afterwards, a fully automatic vectorization is performed to yield the image exhibited in Figure 4b.

9. Field Revision

The screen digitization process that is carried out in the previous section depends mainly on the spectral as well as the geometrical differences among features. Different materials have different reflectance and different objects have different geometric properties. Having features with similar reflectance and geometry leads to recognition ambiguity that has to be resolved by field revision. Regarding the four types of digitized features: buildings, main roads, minor roads, and green areas, it is found that buildings need the least amount of field revision whereas the minor roads require careful revision.

As a matter of fact, most buildings of the test area have considerably distinct reflectance. This is also the case with main roads. The material of the surface of main roads gives clear and homogenous reflectance. On the other hand, many random spots of dust and fine sand cover minor roads, especially along their sides. The irregular-shaped spots create considerable reflectance variation along the minor roads. This variation leads to difficulties in identifying the borders and details of the roads. In regard to green areas, the situation is different from one area to another. In some cases, the reflectance given by green areas and their contiguous areas get mixed. However, having a sharp fence surrounding these areas assures good recognition and digitization. Figure 5 shows the final updated map based on the screen digitization of the image features and field revision.

10. Results and Analysis

Based on the map that are surveyed by terrestrial methods, the dimensions of the different types of digitized features are verified and tested against their corresponding ground values. The verification process is carried out using samples of digitized features. Table 2 shows the image measurements as well as ground measurements of a sample of buildings. Tables 3 and 4 show both measurements for two other samples of roads and green areas, respectively. The mean, maximum and the root mean square (RMS) values of the differences between the image measurements and ground measurements for different types of features are computed and listed in table 5.

In regard to buildings, the mean, maximum and RMS values are 0.42m, 0.76m and 0.47m for their lengths, and 0.40m, 0.74m and 0.45m for widths, respectively. In respect of roads, the corresponding statistical values are 0.31m, 0.52m and 0.33m for their widths, respectively. Concerning green areas, the corresponding numbers are 0.83m, 1.47m and 0.89m for lengths, and 0.76m, 1.33m and 0.82m for widths, receptively. In spite that the roads have the best accuracy number, the accuracy of all digitized features is within the resolution of the satellite image.

A quantitative evaluation is also made for the digitized features that were necessary for updating the original map. Table 6 shows the evaluation for each type of features before and after updating the map. The evaluation before updating considers only the original map features that are still unchanged. It has been found that there are many new features; 125 buildings, 3650m main roads, 1750m minor roads and 6 green areas. It has been realized also that the original map is notably outdated with respect to the feature content in the test area, as appear in the satellite image. The original map contains only a small number of buildings, and some roads that are modified after its compilation in 1987. In fact, this is the case for most relatively recent settlements in the city of Cairo and other mapped cities in the country, where the available maps are considerably outdated.

Finally, comparing the fully automatic vectorized image (see Figure 4b), with screen digitized image (see Figure 5), it can be concluded that the overall results of automatic vectorization are not satisfactory. Consequently, screen digitizing is still preferable for production and updating of vectorized maps.

11. Conclusions

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 1-m resolution satellite image for updating an old map is investigated. Based on the test results, the following concluding remarks can be made:

- High-resolution satellite imagery could play a key role in collecting spatial information and updating maps
- The accuracy of digitizing different types of features is within the image resolution. This would be enough for revision of 1:5,000 maps.
- Main roads and buildings are greatly identifiable in the imagery. On the other hand, the recognition of minor roads and green areas is problematic.
- Field verification can solve ambiguities during the updating process and has an important contribution to the final updated map.

- The geometry of some of the image features could be extracted automatically. However, more research is necessary to improve the quality of the automatic vectorization.

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Table (1): Transformation Parameters for Cairo Airport Area, ECAA, 1998.

DX, mrs	DY, mrs	DZ, mrs	Rx, secs	Ry, secs	Rz, secs	S, ppm
83.023	-142.191	209.398	3.557083	-5.370097	0.028862	-8.32848

Table (2): Ground and Image Measurements of a Sample of Buildings, in meters.

Buildg. No.	Gr. Length	Im. Length	Difference	Gr. Width	Im. Width	Difference
1	18.75	18.59	0.16	12.24	11.66	0.58
2	17.42	17.56	-0.14	9.58	9.64	-0.06
3	16.33	16.84	-0.51	10.45	10.12	0.33
4	17.82	17.86	-0.04	10.97	10.42	0.55
5	18.28	17.94	0.34	9.88	9.42	0.46
6	15.84	16.60	-0.76	9.28	8.93	0.35
7	17.51	16.94	0.57	9.43	9.40	0.03
8	19.13	18.66	0.47	13.49	12.75	0.74
9	18.90	19.55	-0.65	10.65	10.37	0.28
10	18.29	18.00	0.29	10.88	10.81	0.07
11	18.59	18.82	-0.23	10.97	10.57	0.40
12	17.59	18.24	-0.65	11.00	10.50	0.50
13	17.62	18.17	-0.55	11.42	10.84	0.58
14	21.70	21.52	0.18	19.51	19.00	0.51
15	22.27	22.39	-0.12	17.26	17.53	-0.27
16	24.88	24.47	0.41	17.69	18.10	-0.41
17	25.25	25.94	-0.69	18.90	18.39	0.51
18	17.05	16.48	0.57	16.95	17.14	-0.19
19	17.96	17.62	0.34	15.69	15.35	0.34
20	17.78	17.15	0.63	14.27	14.54	-0.27
21	19.09	18.42	0.67	13.15	13.80	-0.65
22	19.40	19.81	-0.41	12.25	12.86	-0.61
23	19.19	18.93	0.26	11.59	12.17	-0.58

Table (3): Ground and Image Measurements of a Sample of Roads, in meters.

Road No.	Gr. Width	Im. Width	Difference
1	10.90	10.77	0.13
2	11.10	11.33	-0.23
3	7.10	6.88	0.22
4	18.05	17.71	0.34
5	7.00	6.48	0.52
6	42.00	41.67	0.33
7	12.47	12.10	0.37
8	22.36	22.71	-0.35
9	25.22	25.56	-0.34

Table (4): Ground and Image Measurements of a Sample of Green Areas, in meters.

Area No.	Gr. Length	Im. Length	Difference	Gr. Width	Im. Width	Difference
1	64.65	65.42	-0.77	24.39	25.72	-1.33
2	64.15	65.62	-1.47	25.60	26 18	-0.58
3	45.16	45.91	-0.75	17.09	17.56	-0.47
4	115.44	116.12	-0.68	43.38	44.15	-0.77
5	183.79	183.32	0.47	52.32	51.67	0.65

Table (5): Statistics of Measurement Differences of the Samples, in meters.

Feature	Mean Diff.	Max. Diff	RMS
Building Lenghs	0.42	0.76	0.47
Building Widths	0.40	0.74	0.45
Road Widhs	0.31	0.52	0.33
Green Area Lenghs	0.83	1.47	0.89
Green Area widths	0.76	1.33	0.82

Table (6): Quantitive Evaluation of Features Before and After Updating

	Before Updating		After Updating	
Feature	Number	Length (m)	Number	Length (m)
Buildings	11		136	
Main Roads		500		4150
Minor Roads		300		2050
Green Areas	1		7	

Figure 1: The IKONOS Panchromatic Image for the Test Area.

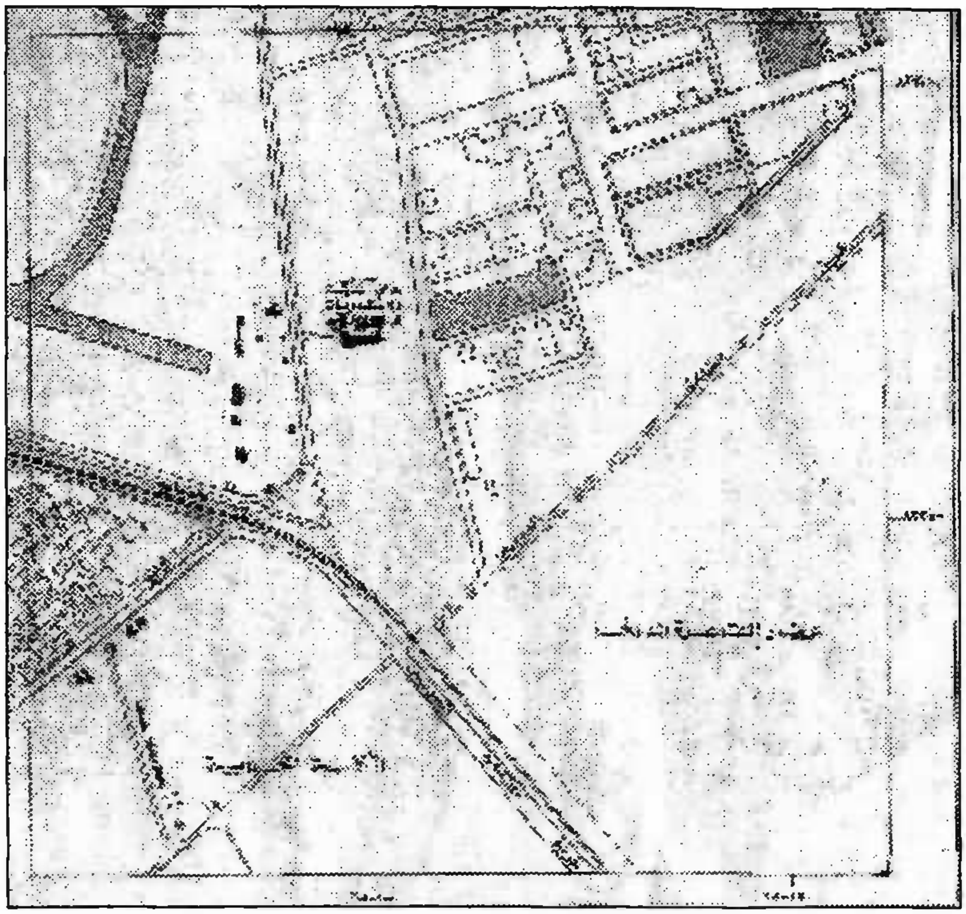

Figure 2: The Original Map for the Test Area.

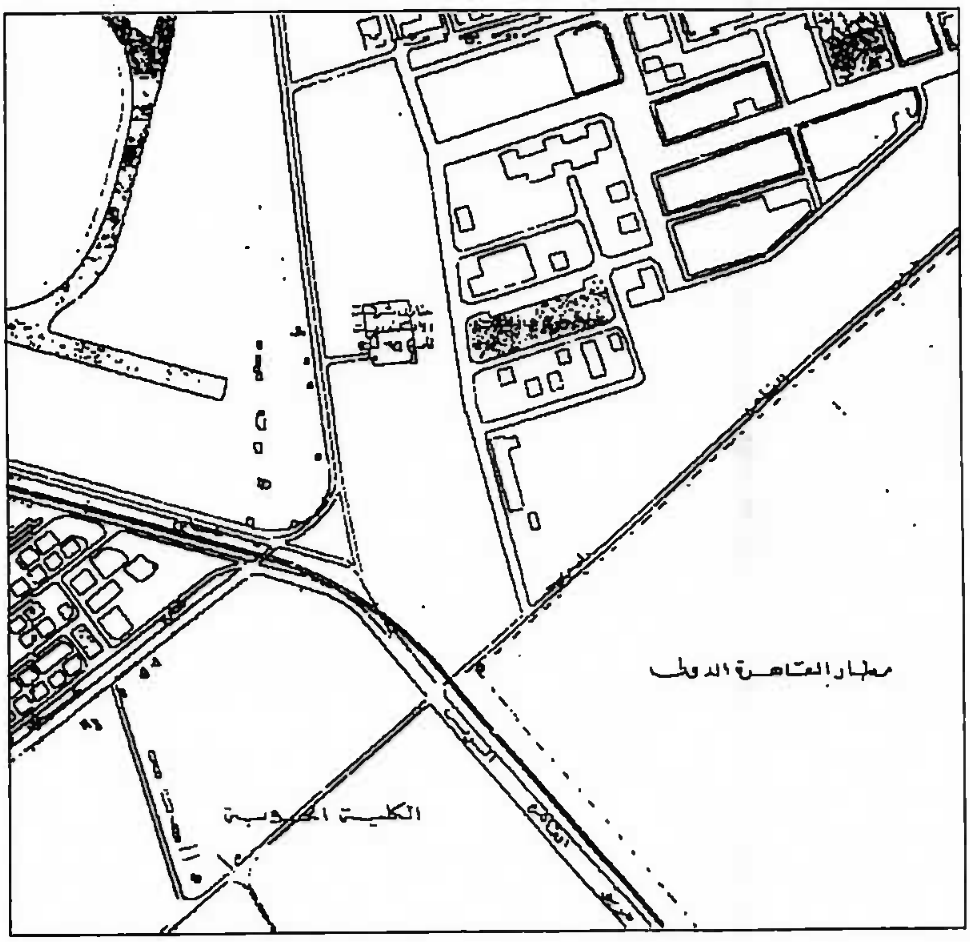

Figure 3: The Automatic Vectorization of the Original Map for the Test Area.

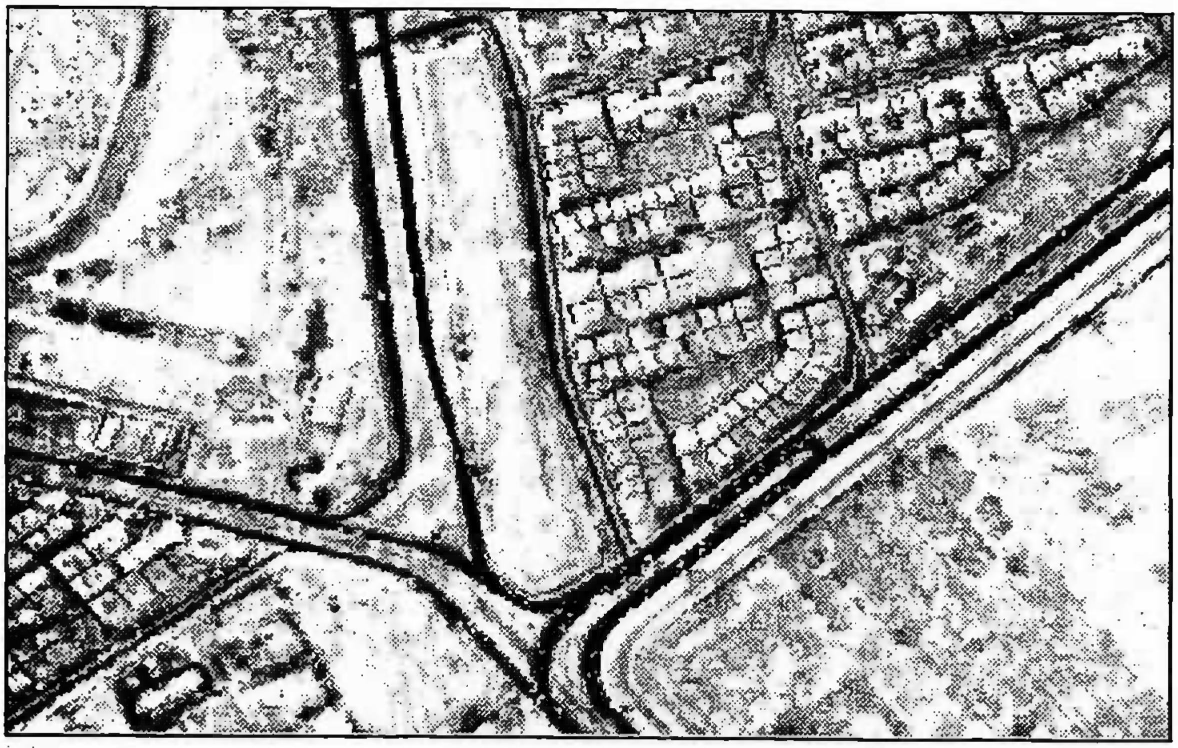

Figure 4-a: Prepared IKONOS Image for Automatic Vectorization

Figure 4-b: The Automatic Vectorization of the IKONOS Image for the Test Area.

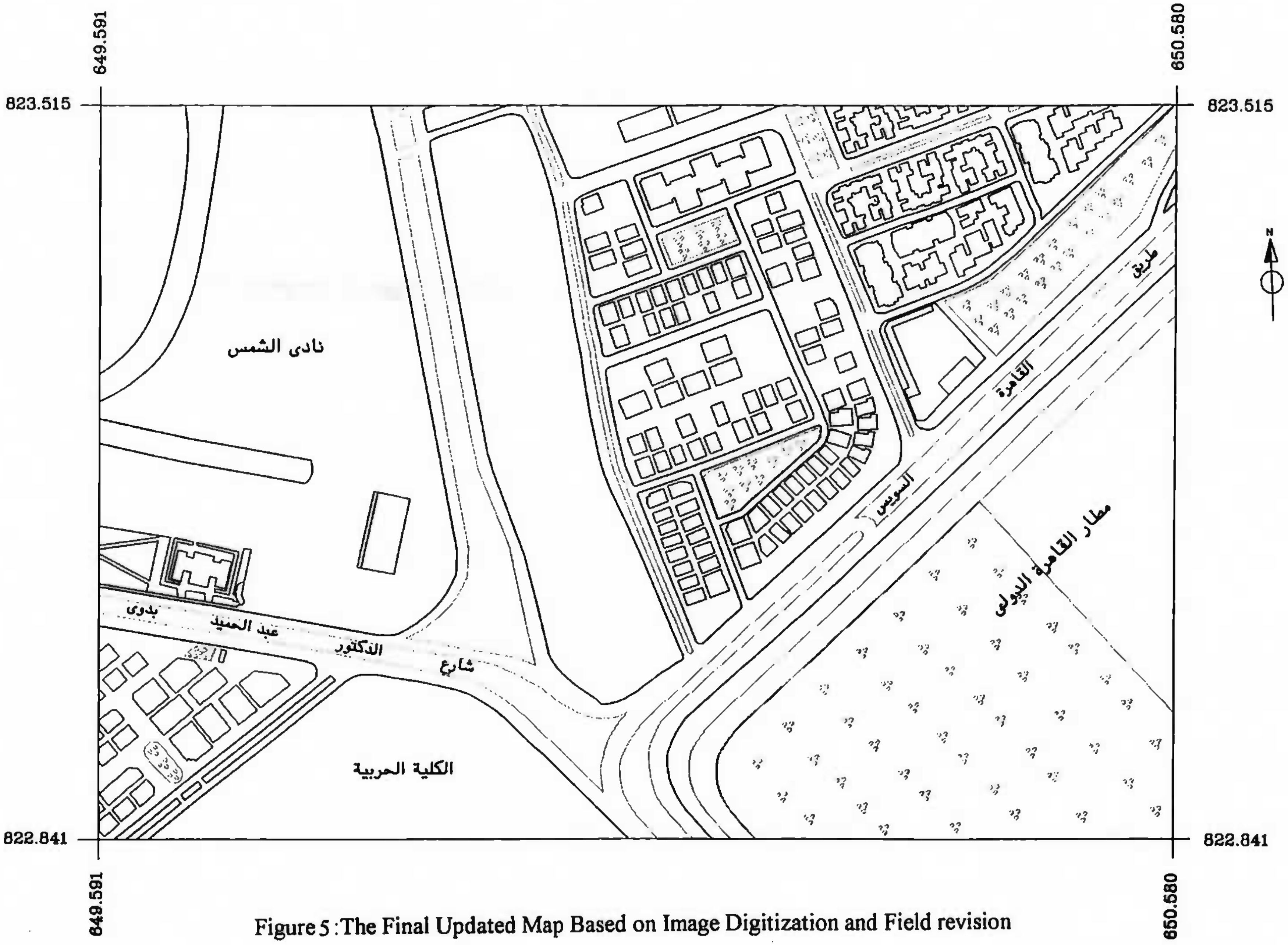

Figure 5 :The Final Updated Map Based on Image Digitization and Field revision