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USING OF HIGH RESOLUTION SATELLITE IMAGES FOR UPDATING LARGE SCALE MAPPING IN EGYPT

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ABSTRACT

High and accelerating rate of the urban changes and extensions, in developing countries such as Egypt, calls for an efficient and fast technique for mapping. The availability of the new generation commercial one-meter resolution satellite images has opened a new era for producing and updating large-scale digital maps. The main objective of this study is to evaluate the potential of VHR satellite images for large scale mapping in Egypt. Data used in this study are IKONOS-2 images (Panchromatic (1m) and Multispectral (4m)) acquired on 2006 and topographic map dated 2002 at scale 1:5000 of Assiut area.

In this paper, an investigation is carried out for the potential of the information content in pan-sharpened IKONOS image. Then, the classification process is carried out with object-based method. The classified image has been converted to vector format. After that, an investigation is carried out for these vectors through overlaid it to the available old map. The result showed that the information content of IKONOS images has the capability of updating of 1: 5000 maps for good planned area, while, that ability will be decreases with decreasing the degree of planning.

Keywords: Feature extraction, Information content, Map updating.

1. Introduction

Feature extraction for the purpose of mapping from space images became important in recent years to acquire accurate information on urban land use/land-covers and their change over time [1]. Large scale maps show more details than small scale maps, so a higher resolution is required for large scale mapping [2]. The availability of high-resolution satellite images, such as IKONOS has opened new possibilities for mapping by technological developments comparing past. The use of satellite images in updating maps depends mainly on the accuracy of the geometric correction for the image as well as for

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their information content. So it is important to evaluate the capabilities of any satellite images to fully understand its potential of application possibility [3].

Although several investigations have already begun on this subject [4, 5, 6, 7, 8, 9], still the subject demands more comprehensive tests for the determination of the suitability of such high-resolution images for the purpose of large-scale mapping. Recent work shows that the geometry of IKONOS images is accurate enough for mapping purpose up to scale of 1:5000 [10]. The aim of this research is to investigate the capability of IKONOS images to update large scale maps in Egyptian environment.

The remainder of this paper is organized as follows. Section 2&3 illustrate the methodology and data which are handled here, respectively. Data preprocessing is depicts in section 4. Information content of IKONOS image will be discussed in section 5. Map updating process is detailed in section 6. Results and discussion are demonstrated through section 7. Conclusions are given in Section 8.

2. Methodology

In order to achieve the objective of this study, the following steps have been performed and their results are evaluated:

1- The images are corrected geometrically and fitted to a known coordinate system (see section 4.1).

2- The produced corrected images are integrated together to obtain a high spatial and spectral quality satellite image which is known as Pan-Sharpened image.

3- Evaluating information content of the IKONOS image depending on visual inspection over four test areas with different degree of planning through study area.

4- Extraction of map features using object-based classification method.

5- Applying different refinement techniques for the classification results to improve the outlines or boundaries of the classes and to minimize the misclassification.

6- Transforming the obtained classification results into vector format.

7- These vectors are compared with the reference 1:5000 scale topographic vector map for editing and accuracy assessment of the results.

8- Updating the available map.

Figure (1) illustrates the methodology flow chart involves the above mentioned tasks.

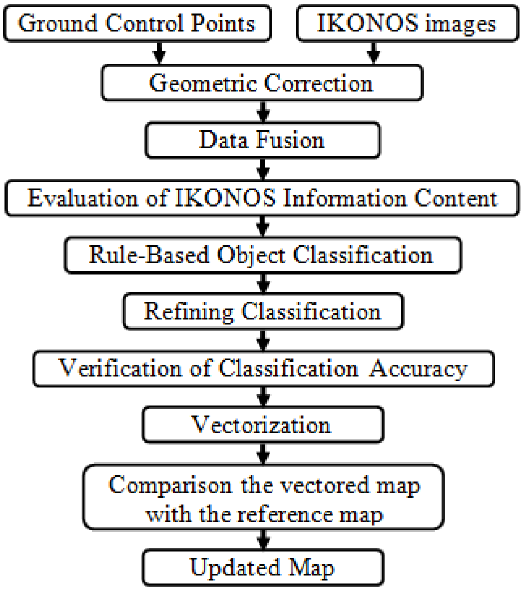

Fig. 1. Methodology flow chart.

3. Study area and data used

3.1. Study area

Assiut Governorate is one of the oldest governorates in Egypt and it is the capital of Upper Egypt. It lies between latitudes 26° 40` & 27° 30` North and longitudes 30° 41` & 31° 31` East. Its total area is about 25926 km². It is situated about 375km south of Cairo, the capital of Egypt. Assiut is one of the fastest growing urban areas in Egypt. The major land cover of the area consists of agricultural lands, urban, desert and the River Nile.

3.2. Data used

The used data at the present work are:

1. Satellite Images

IKONOS-2 Panchromatic (1m) and Multispectral (4m) images used for this research were acquired on 17th February 2006 at 08:59 (Figure 2).

2. Topographic map

Large scale (1:5000) topographic maps covering the study area (Figure 3) complied from aerial photographs in 2002. It was produced by Egyptian Survey Authority. It is used as a basis for comparison and assessment.

3. Ground data

Twenty five (25) Ground Control Points (GCPs) are taken as the source of supplementary data to be used in this respect for image geometric correction. The coordinates of the GCPs were determined from the field observations using the GPS receiver PROMARK3, Magellan, of ± (0.005m+1ppm) for horizontal accuracy.

Differential Global Positioning System (DGPS) was the applied technique. The configuration of these points in the study area is shown in Figure (2).

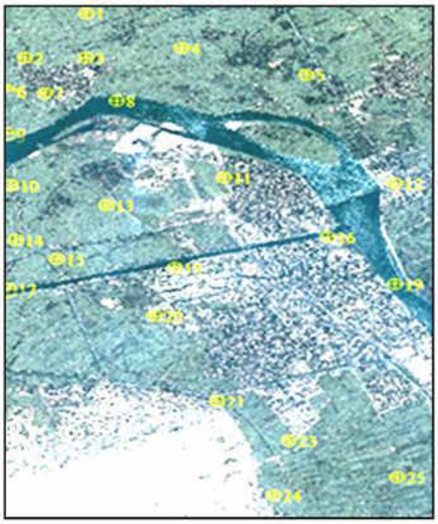

Fig. 2. The IKONOS image of 2006 for Assiut city and its surrounding

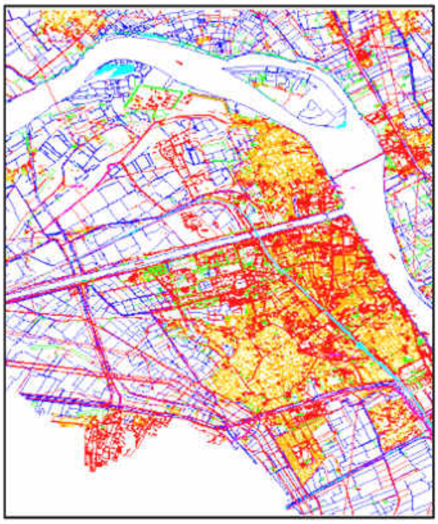

Fig. 3. The reference 1:5000 map of 2002 for Assiut city and its surrounding.

4. Data preprocessing

Data preprocessing includes the tasks required for presentation of the satellite images in a more suitable form that can leads to better interpretation and extracting the maximum information from these images. That stage has been carried out through the following steps:

4.1. Image geo-referencing

Satellite images were rectified to Egypt Transverse Mercator, Helmert, and Old Egypt 1907 coordinate system. A number of (13) control points as well as (12) check points were used. Third order polynomial transformation method was used to provide accuracy through Point Root Mean Square Errors (RMSE) in the check point of 1.1 m. The resampling process was carried out by using the nearest neighbor method. It is the simplest technique and it transfers original data values without averaging them as the other methods do; therefore, the extremes and subtleties of the data values are not lost [11]. Nearest Neighbor is best used for categorical data like land-use classification [12] Geo-referencing and resampling was implemented in Erdas Imagine software 9.1.

4.2. Data fusion

Pan-sharpened IKONOS image has been produced by fusion of high resolution PAN and MS images using Intensity-Hue-Saturation technique implemented in Erdas V9.2 software package. The nearest neighbor method is selected for resampling to keep the color content of the original multispectral image unchanged [13].

5. Information content

Any geoinformation acquisition system can be evaluated by the useful information content in the data collected by such a system [14]. In this respect, a reference 1:5000 scale map is used to investigate the information content in IKONOS image in order to evaluate its suitability for updating large scale maps by visual inspection. The features which exist in the study area and represented in 1:5000 map are considered and evaluated. The required information content for 1:5000 scale maps may be divided into four main categories; cultural feature, transportation, vegetation and hydrological (see Table 1). In Table (1) objects in IKONOS image are classified based on their level of detection and recognition. In this case, if object can be detected and recognized easily and sharply, then it is assigned as “Perfect”, if the level of detection and recognition is lowered, it is called as “Good”, if object only detected or only recognized, then it is put into the class of “Medium”, if the level was very low, then it is “Poor” and the object is not available in the image, it is categorized as “Not available” [15].

The Egypt environment contains different degrees of planning. These degrees of planning can be divided into four categories as; Good planned area, Semi-planned area, Un-planned area and Rural area. Accordingly, four different test areas were selected to discuss the possibility of features extraction from different degrees of planning in Egypt environment. These test areas (Figure 4) are:

5.1. Assiut university campus

This area is characterized as a good planned area (Figure 4-*A*). It includes large buildings with regular shape separated by green areas and the roads are wide. It is quite easy to detect and identify most features as isolated buildings, roads network and trees. Also, Table (1) show that there is no difficulty to detect or identify track, playground, fountain and swimming pool.

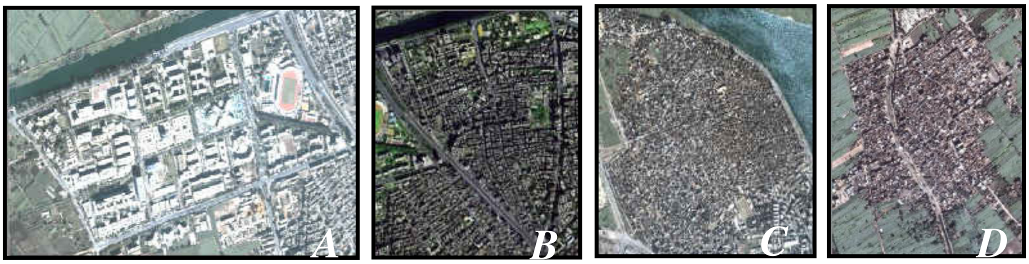

Fig. 4. Degrees of planning ***A.*** Good planned area. ***B.*** Semi-planned area. ***C.*** Un-planned area. ***D.*** Rural area.

5.2. El-Zahraa area

It is specified as semi-planned area (Figure 4-*B*). It contains small and straight streets. This area is high density area. The buildings in that area are residential buildings of up to 6 floors with small areas. The commercial areas cannot be differentiated from residential areas. Also, offices are located in buildings for residential purposes. All of the above mentioned specification of this study area limits the ability of feature extraction. Boundaries of individual buildings can be identified and delineated. North-South streets between buildings can be extracted easily. Streets between buildings without shadow can be identified and delineated. But the streets which are covered by shadows can't be extracted even if these streets are wider than the non-shaded ones. This shadow makes the object identification process to be hard.

5.3. El-Walidia area

This area is described as unplanned (Figure 4-*C*). This is high-density area containing small and randomly shaped buildings and narrow streets. The residential blocks are mainly constructed from concrete without any green areas separating different housing units. That area includes double or triple houses partly influenced by trees and bushes. Also, the buildings roofs in this area consist of different materials, so it is not possible to identify individual buildings. The buildings which have a roof area larger than 25m² can be extracted and digitized as isolated buildings. Other buildings which have smaller area or unclear roof cannot be extracted separately and should be grouped into building block. The boundaries of high residential area can be delineated. Also it is possible to extract major roads easier than minor roads which covered by shadow and it is difficult to extract secondary and unpaved roads.

5.4. Bani-mor area

It is a village which represents a sample for the Egyptian rural village (Figure 4-*D*). It contains small buildings with irregular shapes and distribution. The roads are unpaved and narrow, leading to a significant reduction in our ability to extract building and roads within the village. Most of the rural area is dominated by vegetation surrounding the village. Boundaries of vegetation area are often connected to features such as canals and drainages**.** The difference in contrast between agriculture and man-made features makes it easy to extract features surrounded by agriculture, also it makes defining the borders of the built up areas of the village more easily. Unpaved roads on the side of branch canals and drains are easy extracted. It is also possible to extract foot tracks wider than 1.0 m between farms. Small irrigation canals wider than 1.0 m can be identified within the surrounding green areas. General vegetation is easy to depict but the actual nature of the vegetation is not easy to identify.

Table 1.
Evaluation of IKONOS information content with 1:5000 map information content

Information content of the 1:5000 map			**Information content of pansharpend IKONOS image**									
			Detection					**Identification**				
			Perfect	**Good**	**Medium**	**Poor**	**Not Available**	**Perfect**	**Good**	**Medium**	**Poor**	**Not Available**
Cultural Feature	Buildings	Isolated building in good planned area	X					X				
		Isolated building in semi-planned area	X						X			
		Under construction	X								X	
		Boundaries of high density and rural area	X					X				
		Government building	X									X
		Mosque/Church/Jewish	X									X
		Hospital/School	X									X
	Recreational	Police station/	X									X
		Park/Garden	X						X			
		Play Ground	X					X				
		Swimming Pool	X					X				
		Stadium	X					X				
	Other	Cemetery mosllm/chrisian	X									X
		Electric power line			X					X		
		Telephone lines					X					X
		Pipe lines					X					X
		Wall/Fence	X					X				
		Electric pole				X						X
		Diesel Cisterns	X					X				
Transport	Road class	Main Paved Road	X					X				
		Secondary Paved Road	X					X				
		Unpaved Road	X					X				
		Track	X					X				
	Railway track	Railway double track		X						X		
		Railway single track		X						X		
	Transport Terminal	Railway Station	X							X		
		Airport *					X					X
	Others	Bridge	X					X				
		Tunnel			X					X		
Vegetation	Agriculture	Cultivated area	X					X				
	Tree/Palm	Single	X						X			
		Grove	X						X			
		Hedge	X						X			

Information content of the 1:5000 map			Information content of pansharpend IKONOS image									
			Detection					Identification				
			Perfect	Good	Medium	Poor	Not Available	Perfect	Good	Medium	Poor	Not Available
Hydrological	Water body	River	X					X				
		Stream	X						X			
		Lake*					X					X
		Water Tank		X					X			
		Drain	X						X			
		Canals	X						X			
		Ditch			X						X	
*Features not available in the study area												

6. Map updating

The extracted data in the good planned area (the campus of Assiut University) are compared with old map by using Erdas V9.1 and eCognition V8 software in order to distinguish the changes that happen in the real world. The results of comparison are summarized in Table (3).

6.1. Image classification

6.1.1. Object-based Classification

As a result of the increase in spatial resolution of the satellite images, the recently object-based approach becomes the most suitable technique for feature extraction [16]. Object-based image analysis comprises two steps; the first step is the image segmentation, in which, the image is divided into homogeneous, continuous and contiguous objects. Several parameters are used to affect the segmentation result. These parameters are scale, colour criterion, shape criterion, compactness and smoothness. At the present work, the segmentation criterion combinations uses are: scale factor 25, colour 0.9, shape 0.1, compactness 0.5 and smoothness 0.5. These values are taken as the best ones resulting from trial and error method which is performed by the author of the present work. The second step is object classification based on objects features in spectral and spatial domains.

6.1.2. Refinement classification results

Refinement classification results must be added to improve the outlines or boundaries of the class and to minimize the misclassifications. Many algorithms are used to refine classes such as Find enclosed by class, Remove Object, Merge Region and add objects are highly surrounded by certain class objects. Figure (5) shows the results of refinement process.

Fig. 5. Different refinement process implemented on the classification results ***A:*** fined enclosed by class. ***B:*** remove small area. ***C:*** merge region. ***D:*** add objects are highly surrounded by certain class objects.

6.1.3 Accuracy assessment

Table (2) shows the result of the accuracy assessment for object-based classification. From Table (2) it can be seen that the overall accuracy is 95.99% and overall kappa statistics is 0.9518.

Table 2.
The confusion matrix for object-based classification of the good planned area.

Classified Data	**Water**	**Vegetation**	**Shadow**	**Bare Soil**	**Road**	**Building**	**Total Row**	**Producers Accuracy**	**Users Accuracy**
Water	51	0	0	0	0	0	51	100.00%	100.00%
Vegetation	0	52	1	0	1	0	54	98.11%	96.30%
Shadow	0	0	47	0	2	0	49	94.00%	95.92%
Bare Soil	0	1	0	51	1	0	53	91.07%	96.23%
Road	0	0	2	4	54	0	60	93.10%	90.00%
Building	0	0	0	1	0	56	57	100.00%	98.25%
Total Column	51	53	50	56	58	56	324		
Overall accuracy 95.99% overall kappa statistics 0.9518									

6.2. Vectorization

Once the refining process of the classification results is finished, the obtained results are changed into vector format. This process was made through ERDAS 9.2 software. Figure (6) shows conversion from raster format to vector format for the extracted features of the good-planning area.

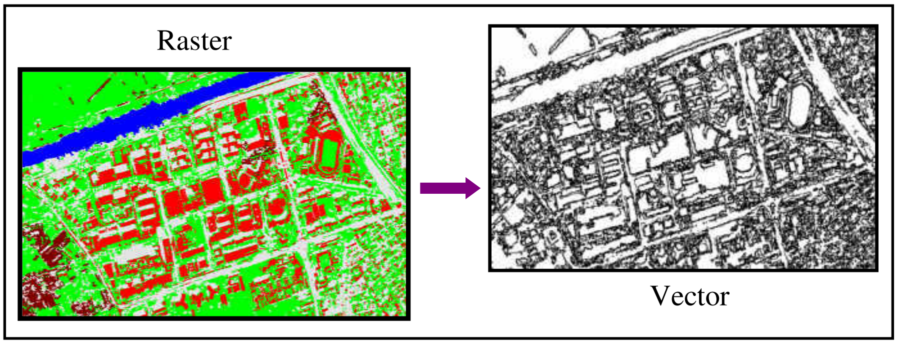

Fig. 6. Conversion of raster into vector for the extracted features

Much more effort has been paid to complete the vectorized polygon layer into a feasible condition. Many editing operations were performed on a vector layer to eliminate unnecessary vertices in the lines such as generalizing to remove steps from the line and reshaping to modify the shape of a single element after editing its nodes (Figure 7). In practice, conversion to practicable vector format and further completion by manual editing increase the smoothing of building boundaries and roads.

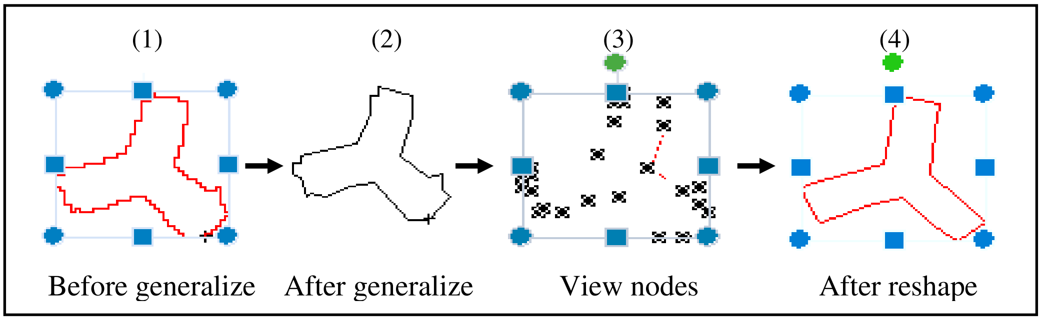

Fig. 7. Post-processing in vector layer

6.3 Evaluation of object-based feature extraction results

Feature extraction results on the good planned area were compared with reference vectors 1:5000 scale topographic map. In the following sub-sections, the most common quality measurements for extracted buildings and roads are explained and used. After there, the results are reported.

6.3.*1. Evaluating building extraction results*

Vector results of feature extraction of building were compared and superimposed with reference map as shown in Figure (8).

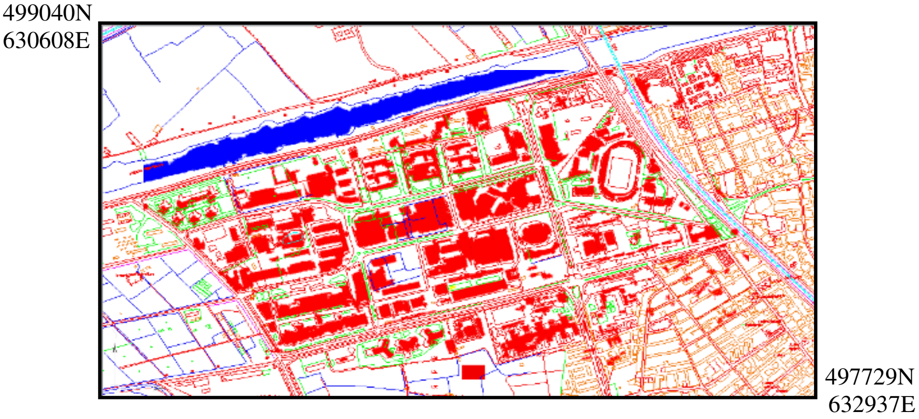

Fig. 8. The results after overlaying object-based building results on referance map

6.3.1.1. Building extraction rate (BER)

Building extraction rate is the number of building correctly extracted divided by the number of reference building polygons. Mathematically, extraction rate can be expressed as the below equation:

$$BER=\frac{BCE}{RBP}\times 100 \qquad \text{(Eq. 1)}$$

where: - BCE is the number of "Building Correctly Extracted".

- RBP is the number of "Reference Building Polygons".

By counting the extracted buildings in test area, considering the 25% coverage threshold, *BCE* is 76 building out of 89 *RBP* in the test area which correspond to 85.39% accuracy in extraction rate (*BER=76/89×100=85.39%*).

6.3.1.2. Roof area coverage (RAC)

In the roof area coverage metric, the intersected area between reference polygons and extracted buildings is computed in percentage.

$$RAC=\frac{EBA}{RPA}\times 100 \qquad \text{(Eq. 2)}$$

where: EBA is the total "Extracted Building Areas".

RPA is the total "Reference Polygon Areas".

Across the test area, *EBA* is estimated at 118505m² from *RPA* 132915m². The RAC equal to 89.16% *(RAC=118505/132915×100=89.16%).*

6.3.2. Evaluating roads extraction results

Figure (9) shows the extracted roads overlaying on the reference map. The quantitative assessment of the final extracted roads using two basic quality measures is performed against the reference data set.

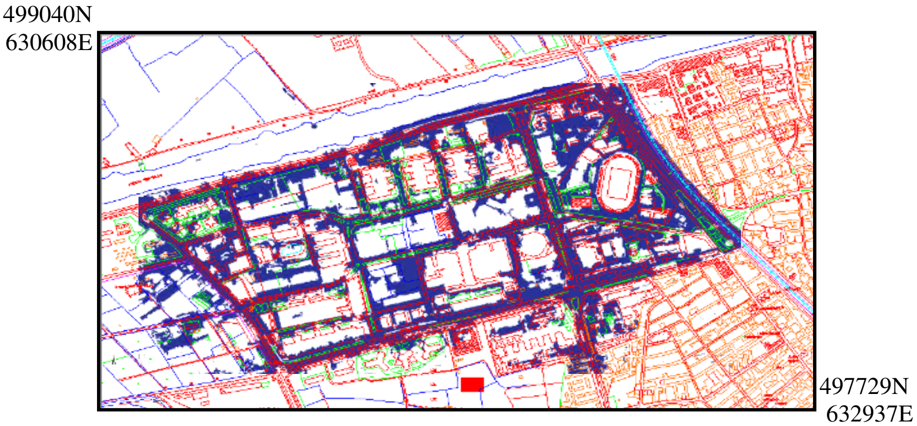

Fig. 9. The results after overlaying bject-based roads results on referance map

The metric derives a quality measure by comparing extracted centerlines to ground truth reference set. The quality measures which have been used are: Completeness and Correctness [17].

6.3.2.1. Completeness

The completeness is the ratio of the reference road data matched with the extracted road data to the total length of the reference road network (Eq.3). It indicates the ability of the road network extraction methods to extract the road network from an image [18].

$$\text{Completeness} = \frac{\text{Length of matched reference}}{\text{Length of reference}} \qquad \text{(Eq.3)}$$

By measuring the center lines of road network of reference vector and object-based results, it was found that the length of the extracted roads matched with the reference data is 9393m. The total length of the reference road network is 10237m. This indicates that, the ability of the entire road network extraction is 92% *(completeness=9393/10237=92%).* That means 8% of the roads are not extracted automatically.

6.3.2.2. Correctness

The correctness is the ratio of the extracted road data matched with the reference road data to the total length of the extracted road network (Eq.4) [19].

$$\frac{\text{Length of matched extraction}}{\text{Length of extraction}} \qquad \text{Correctness=} \qquad \text{(Eq.4)}$$

The measured length of the extracted roads matched with the reference data is 9393m and the total length of the extracted road is 10322m. This means that the percentage of correctly extracted roads is 91% (correctness=9393/10322×100=91%). In other word words, there are 9% increasing in the extracted road length.

6.4. Update reference map

The extracted data are compared with old map in order to distinguish the changes that happen in the real world. The results of comparison are summarized in Table (3).

Table 3.
Area and length of extracted features vs. that in reference map.

Feature	Reference map	Updated map
Building, m²	94,736	132,915
Roads, m	9,685	10,237

Table (3) shows that the resulting map added a large quantity of information to the original map. The comparison between areas of the buildings given in Table (3) shows a significant difference in the buildings area. The correct buildings area extracted from IKONOS image was 40.3% [(132915-94736/94736) ×100] more than that in the reference map. It is worth mentioning that, the satellite image is acquired in 2006 and the reference map had field revision in 2002. The increasing in buildings area is due to presence of new buildings after the reference map date. Also, there are a few roads has increased in the IKONOS image. It is about 552m in the North West part of the update map. It was 5.7% [(10237-9685/9685) ×100] more than that in the reference map. The increase in length of roads is due to the presence of new roads and changing from some unpaved to paved roads in secondary roads. Figure (10) shows the areas that have been updated.

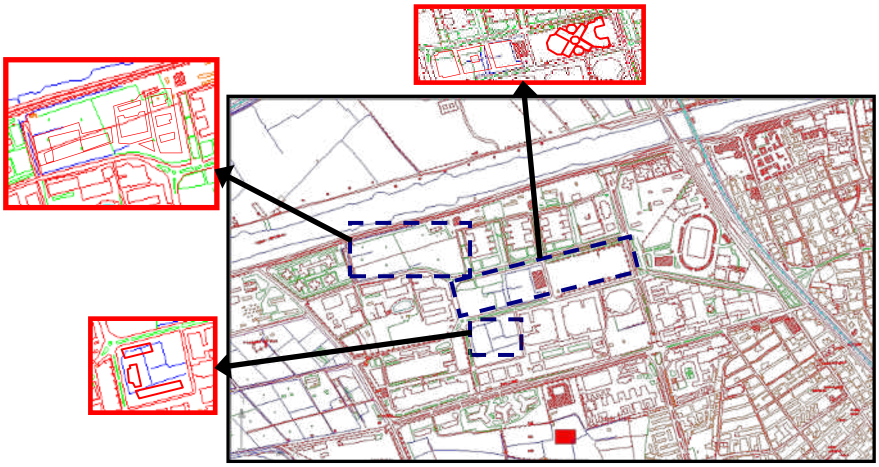

Fig. 10. The reference map showing the three updated areas

7. Results and Discussion

With regard to geometric accuracy, topographic line maps should have a geometric accuracy of approximately 0.3mm in the map scale according to the National Map Accuracy Standards (NMAS). For the reference 1:5000 scale map used in this research, the geometric accuracy of 1.5m (5000×0.3mm=1.5m) is required. That means with 1.1m geometric accuracy a map at scale 1: 5000 should be possible. This is a quite larger scale like justified by the information contents.

The evaluation of information content of IKONOS images for updating maps at 1:5000 scales showed that:

- There are features that can be clearly detected and identified. As shown in figure 2 the whole section of Nile River and main canals such as Ibrahimia canal can be mapped easily. It is easy to detect and identify linear features such as main roads, bridges and branch canals. There is no difficulty to detect and identify boundaries of area features (high residential area, villages, isolated buildings, boundaries of vegetation area, etc).
- There are features that can be detected but cannot be identified. Features such as the overhead power transmission lines cannot be detected. Where, the detected towers can be used as guide for the power lines. Also, features such as rails could not be seen and railway furniture (e.g. signals, points) was certainly not visible, but railway can be inferred by having elongated feature with constant alignment, no sudden curve and free of cars. It is difficult to distinguish the railroad single or double. In practice, a feature should not be captured solely from images unless there is some additional supporting information, which confirms the existence of the feature, and provides its attributes.
- There are features that can be neither detected nor identified such as the railway in desert area.
- A large quantity of information can be added to the original map. The building area extracted increased 40.3% and roads length increased 5.7% more than that in the reference map.

8. Conclusions

In correspondence with the results of the present work with respect to Egyptian environment, it can be concluded that:

- The geometric accuracy of IKONOS images meets the requirement of 1:5000 maps. It also provides a large amount of information that can be used for updating the most features of 1:5000 Egyptian maps.
- In good planned area all features can be detected with a high percentage. However, features are not extracted very well from areas which have low degree of planning with high density and rural area. In other word, the ability of extracting information content decreases with decreasing the degree of planning, not only because the size and shape of the features but also because of its density.
- Even thought there is some difficulty in the information content of IKONOS images to fully update 1:5000 maps, in all degree of planning, the acquired information content are good enough to be used for updating the main features of 1:5,000 Egyptian maps. The remaining features may be inferred from other mapping methods such as ground survey.

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استخدام مرئيات الأقمار الصناعية عالية الدقة في عمل خرائط ذات مقياس رسم كبير في مصر

الملخص العربي

إن النمو الذى تشهده معظم المدن والقرى المصرية فى مصر يجعل من الضرورى متابعة هذا النمو عن كثب. وفى سبيل تحقيق ذلك يتم دراسة إمكانية إستخدام مرئيات الأقمار الصناعية عالية الدقة بغرض الحصول على خرائط ذات مقياس رسم كبير. ولكن إستخدام مرئيات الأقمار الصناعية في تحديث الخرائط يعتمد بشكل أساسي على دقة التصحيح الهندسي للمرئية وكذلك على محتوى معلوماتها. الغرض من هذا البحث هو تقييم إمكانية استخدام مرئيات القمر الصناعى IKONOS عالية الدقة فى تحديث الخرائط ذات مقياس الرسم الكبير في البيئة المصرية. تم إختيار مدينة أسيوط كمنطقة دراسة لهذا البحث، وقد استخدمت خرائط طبوغرافية للمنطقة مقياس رسم 1 : 5000 لمقارنة النتائج. وفى سبيل تحقيق الهدف من هذا البحث تم إجراء عملية التصحيح الهندسى للمرئيات، ثم الدمج بين باندات المرئية الملونة ذات الدقة المكانية 4متر وباند المرئية الأبيض والأسود ذات الدقة المكانية 1متر للحصول على مرئية ملونة بدقة مكانية 1متر وذلك لتسهيل استخراج المعلومات منها. بعد ذلك تمت عملية استخراج المعلومات من المرئية بطريقة Object-based analysis ثم مقارنتها بما هو موجود على الخريطة وذلك بعد إجراء عمليات التدقيق والتحسين على نتائج إستخراج المعلومات وذلك للحصول على تحديث دقيق للخريطة القديمة. ومن ثم تم دراسة مدى ملائمة محتوى معلومات تلك المرئية لتحديث خرائط 1 :5000.

وقد أظهرت النتائج انه من حيث الدقة الهندسية فى المستوى الأفقي يمكن إستخدام مرئيات IKONOS بما يتناسب مع المواصفات القياسية لإنتاج وتحديث الخرائط ذات مقياس 1 :5000. كما أوضحت النتائج أيضا أن المرئية لديها القدرة العالية فى التعرف على الكثير من الأهداف الموجودة بخرائط 1 : 5000 للمناطق جيدة التخطيط مع تناقص هذة القدرة فى التعرف على الهداف كلما قلت درجة التخطيط. و باستخدام مرئية IKONOS لتحديث العينة الجيدة التخطيط من منطقة الدراسة والتى أعطت دقة عالية لتصنيف المعالم (95,99 ٪)، وجد أن مساحة المباني زادت بنسبة 40,3٪ كما زادت أطوال الطرق بنسبة 5,7٪. وقد خلص البحث ألي أن كمية البيانات التي يمكن استخلاصها من المرئيات عالية الدقة جيدة بما فيه الكفاية بحيث يمكن استخدامها في تحديث معظم معالم خرائط مقياس رسم 1 : 5000. ويمكن تحديث التفاصيل المتبقية من خلال المساحة الأرضية.