Assessment of Using Very High Resolution Google Earth Satellite Images for Producing Urban Mapping

By:

Prof. Ali A. El Sagheer
Professor of Surveying and Geodesy,
Head of Surveying Department,
Shoubra Faculty of Engineering.

Assoc. Prof. Maher M. Amen
Assoc. Prof. of Surveying,
Shoubra Faculty of Engineering.

Assoc. Prof. Khaled M. Zaky
Assoc. Prof. of Surveying,
Shoubra Faculty of Engineering.

Eng. Hassan Mohamed Hassan
M.sc. student, Department of Surveying,
Shoubra Faculty of Engineering.

ملخص البحث

نظراً للتطور الكبير فى تقنية الاستشعار عن بعد و خاصة صور الأقمار الصناعية التى أصبحت ذات قدرات تحليلية كبيرة يمكن من خلالها عمل خرائط ذات مقياس رسم كبير والتي يمكن استخدامها فى التخطيط للمشروعات الهندسية. أحد أسرع و أسهل الوسائل الحالية للحصول على صور الأقمار الصناعية هي من موقع جوجل إيرث Google Earth الذى يحتوى على صور أقمار صناعية ذات قدرات تحليلية عالية تصل الآن الى 50 سم (من القمر الصناعى GEO EYE. الهدف الأساسي لهذا البحث هو دراسة إمكانية استخدام هذه الصور كمصدر بديل لصور الاقمار الصناعية لعمل خرائط ذات مقياس رسم كبير بعد مقارنتها بالخرائط المنتجة من صور القمر الصناعى كويك بيرد QUICKBIRD . وتتم عملية انتاج الخرائط من صور الأقمار الصناعية عن طريق عملية التقويم الرأسى (Orthorectification) لكل من الصورتين لتصحيح خطأ فروق الارتفاعات عن طريق نقاط تحكم أرضية مرصودة باجهزة تحديد المواقع (GPS) ونموذج الارتفاع الرقمى (DEM) منتج من مساحة أرضية و ازاحة المبانى عن طريق نموذج المبانى الرقمى (DBM) ثم تحويل هذة الصور الى خرائط عن طريق عملية (Vectorization). دلت نتائج البحث على أن الـ RMS أو معدل الخطأ كان أفضل فى حالة الخرائط المنتجة من صورة جوجل إيرث و يساوى 0.76 متر من الخرائط المنتجة من صورة القمر الصناعى كويك بيرد الذى وصل الى 1.05 متر و كلتا النتائج تدل على أنه يمكن استخدام أي من هذة الصور لإنتاج خرائط بمقياس رسم 1 : 5000 طبقا لمقاييس الخطأ العالمية الثلاثة لتقييم دقة الخرائط وهي NMAS وASPRS وNSSDA . نفس النتائج اوضحت امكان إنتاج خرائط بمقياس رسم 1 : 2500 طبقا لاثنين فقط من هذة المقاييس وهما NMAS و NSSDA.

1. Abstract

Remote sensing has developed such as optics, sensor electronics, satellite platforms, transmission systems and computer data processing. Nowadays, a series of satellites were lunched as IKONOS, QUICKBIRD, WORLD-VIEW and GEO EYE providing high resolution images to the earth's surface up to 50 cm. The growing availability of high resolution Google-Earth satellite images led to evaluations of large scale maps that can be produced from these images which can be used in urban planning purposes. The main objective of this research was study of the possibility of using Google Earth satellite images

for producing large scale maps as an alternative source to other very high resolution satellite images through comparing these maps with their corresponding maps produced from QUICKBIRD satellite images. Maps can be created from these images by the Orthorectification process which is the process of geometrically correcting an image from elevation errors using GPS Ground Control Points (GCPs) and DEM. The relief displacement of buildings can be corrected using DBM, so that it can be represented on a planar surface, conform to other images or maps. The study shows that the RMS for maps were 1.05 m for QUICKBIRD and 0.76 m for Google Earth image. The RMS was within the required standard map accuracy for a map scale 1:5000 according to the three map accuracy standards (NMAS, ASPRS, NSSDA). The RMS was also within the required standard map accuracy for a map scale 1:2500 according to both the NMAS and NSSDA standards only.

2. Introduction

Maps with high resolution spatial content can be prepared from very high resolution remote sensing data **[8]**. This research presents a method of producing large scale urban map for small areas. Nowadays, high resolution remote sensing data can be used for many applications such as rural cadastral mapping, infrastructure and utility mapping for micro-level planning and development, road, rail and pipelines alignment plans and other applications.

The growing availability of high resolution Google-Earth satellite images led to investigate map scales which can be produced from these images. At this high resolution, details such as buildings and other infrastructure are easily visible. The imagery can be imported into remote sensing image processing software, as well as into GIS packages for analysis. The imagery can also be used as a backdrop for mapping applications, such as Google-Earth and Google Maps. Google Earth is a free, downloadable virtual globe program **[5].**

Google, which has its logo on the side of the rocket, has exclusive online mapping use of its data. While GeoEye-1 is capable of imagery with details size of 41 cm (16 in), that resolution is only available to the U.S. Government. Google have access to details of 50 cm (20 in) which is available commercially **[4].** Also there are many users and organizations using these satellite images for thematic maps production. These images are used in many applications such as planning and analysis without evaluating the thematic maps derived from it. Evaluating the use of these Google earth satellite images in thematic maps production with suitable scales for infra-structure planning purposes is the main objective of this research. The evaluation has been done by comparing the planimetric accuracy of Google-Earth maps and

QUICKBIRD maps with ground surveying maps, taking into consideration the effect of Digital Elevation Model (DEM) and Digital Building Model (DBM) on these maps, thus the main objectives of this research can be divided into:

- Evaluating the effect of DEM derived from land surveying and DBM on the orthorectification of the used images.
- Assessment of thematic maps produced from Google Earth satellite images using GCPs and comparing the planimetric accuracy of these maps with the maps produced from QUICKBIRD satellite images for the same area, which has approximately the same high resolution.

3. Previous Experience

Urban mapping using high resolution remote sensing data at a generalized level showing cluster of households/properties as single polygons bound by roads, was and is being carried out by several individuals and organizations both private and public. With multi-spectral and panchromatic merged data, urban transportortation network and rural cadastral mapping was attempted by some researches **[6 and 8]** and have performed with significant results urban mapping on 1:10000 scale using IKONOS panchromatic data (1m resolution).

Through very high resolution satellite data of the order of less than 1 m resolution has great possibility for micro-level mapping, automatic or semi-automatic methods do not help in extracting urban features and structures easily. The observation that visual interpretation of remotely sensed data or field surveying is still relevant**[2]**.

In this research, an attempt to produce accurate thematic maps at large scale of 1:5000 and 1:2500 from Google-Earth and QUICKBIRD satellite imagery is made.

4. Available Data and Methodology

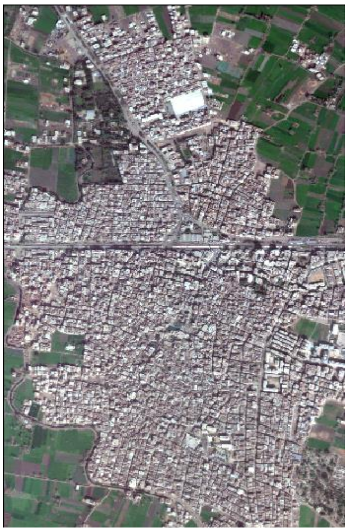
4.1. Available Data

A pan-sharpened image with 60 cm spatial resolution over an area has been selected for investigation study. The study area is selected at Qalyuob city in Qalyuobia governorate, covers about two square kilometers and located in zone 36 in UTM projection system. The selected area contains buildings and roads network which is suitable for the study requirements. This high resolution image was collected in May 31, 2005 by spacing imaging's QUICKBIRD satellite and supplied in a TIFF digital format. This image has been radiometrically corrected from radiometric distortions. The resulted image is now a rectified image produced by the producer before publishing (Figure 1b). A Google Earth satellite image of the same study area has been downloaded from Google Earth free program (Figure

1a). Fifteen Ground Control Points (GCPs) have been collected using Lieca GPS units on well defined places at sharp edges such as end of walls or corners of buildings. These points are evenly distributed over the area under investigation (Figure 2). Spot height points obtained from classical land surveying have been collected for the purpose of generating a DEM The Ground DEM was built from these points by ERDAS IMAGINE 9.2 software using nonlinear rubber sheeting interpolation method Figure (3.a). In order to distribute the slope change smoothly across triangles, the nonlinear transformation with polynomial order larger than one is used by considering the gradient information. The fifth order or quintic polynomial transformation is chosen here as the nonlinear rubber sheeting technique in this study. It is a smooth function. The transformation function and its first order partial derivative are continuous. It has the following equation:

$$\sum_{i=0}^{5}\sum_{j=0}^{5} a(i)k.Xi-j.Yj \tag{1}$$

Where a (i) are the coefficients which can be computed using the common 3522 points of the two systems and the subscript k = (i*i+j) / 2 + j required to perform the orthorectification process. The Digital Building Model has been also collected (Figure 3.b). There are many software packages which can be used for achieving the main aims of this research. These packages are ARCGIS version 9.3, ERDAS IMAGINE version 9.2, AutoCAD 2011 and GPS data processing program.

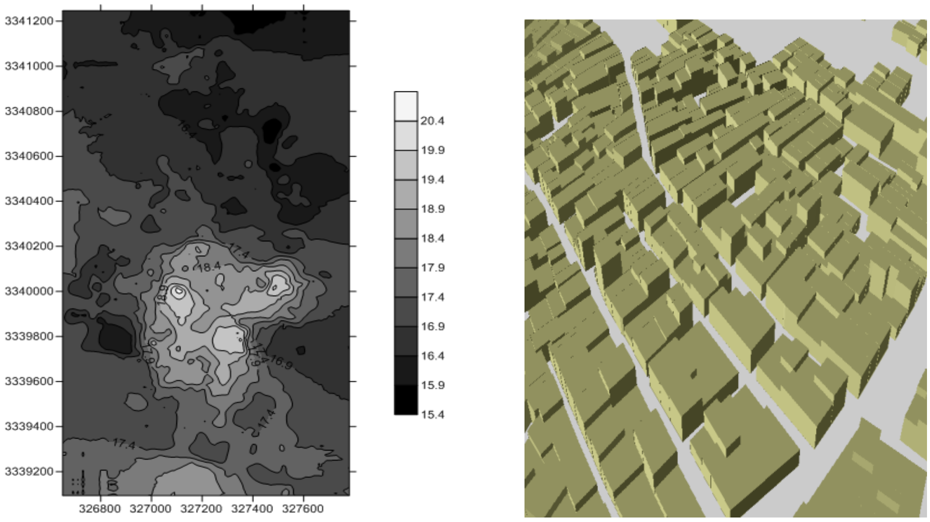


(a) ***(b)***

Figure (1): Satellite imagery sources.

(a) Google Earth satellite Image. ***(b) QUICKBIRD satellite Image.***

Figure (2): GCPs over the area under investigation.



(a) ***(b)***

Figure (3): (a) the Ground Digital Elevation Model (DEM) of the study area.
(b) 3-D Digital Building Model (DBM) of the study Area.

4.2. Methodology

To evaluate using Google Earth satellite images for the production of thematic maps for the study area the following steps should be followed:

1. Orthorectifying the Google Earth and QUICKBIRD satellite images.
2. On screen digitizing to produce thematic maps from both images.
3. Checking up the planimetric accuracy of the thematic maps produced from both images.

4.2.1. Orthorectification of Google Earth Image Using GPS Control Points, ground DEM and DBM

The process of orthorectification was carried out to rectify or geometrically correct the Google Earth satellite image using 10 GPS GCPs distributed over the study area. Practically, this process was performed with ERDAS Imagine software **[3]**.

Total Root Mean Square Error (RMS)

From the residuals, the following calculations are made to determine the total RMS error, the X RMS error, and the Y RMS error

$$Rx = \sqrt{\frac{1}{n}\sum_{i=1}^{n} XR_i^2}\ , Ry = \sqrt{\frac{1}{n}\sum_{i=1}^{n} YR_i^2}\ , Tot.RMSE = \sqrt{R_x^2 + R_y^2} \qquad (2)$$

Where:

Rx= X-RMS error, Ry= Y-RMS error, T= total RMS error, n= the number of GCPs, i= GCP number, XRi= the X-residual for GCPi and YRi= the Y residual for GCPi **[3].**

The results are given in table (1). Figure (3) show the difference in accuracy (RMS) in cases of using 5 GCPs only, 10 GCPs only and 10 GCPs with DBM.

Table (1): Accuracy of Orthorectification Process for 5 Check Points.

No. of GCPs	*X-RMS (m)*	*Y-RMS (m)*	*Total RMS (m)*
5 GCPs and DEM only	0.52	0.71	0.88
10 GCPs and DEM only	0.34	0.50	0.61
10 GCPs, DEM and DBM	0.25	0.48	0.55

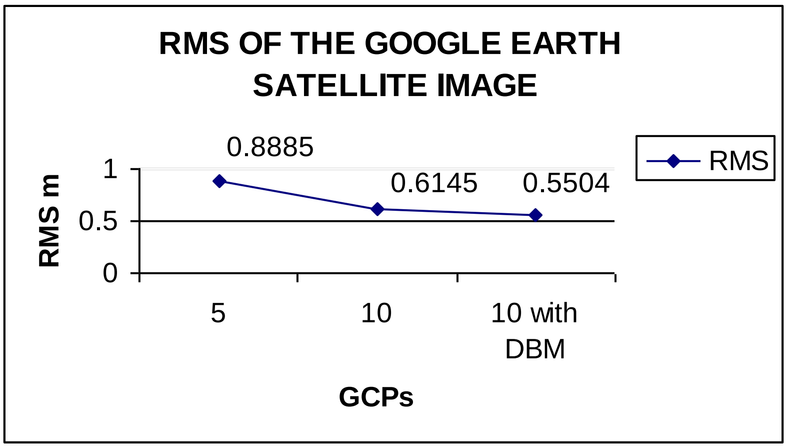


Figure (3): RMS of the Google Earth satellite image.

4.2.2. Orthorectification of QUICKBIRD Satellite Imagery Using GPS Control Points, ground DEM and DBM

This process was carried out to orthorectify QUICKBIRD Satellite image using 10 GCPs distributed over the study area derived from GPS measurements. The results are given in table (2).

Table (2): Accuracy of Orthorectification Process for 5 Check Points.

No. of GCPs	*X-RMS (m)*	*Y-RMS (m)*	*Total RMS (m)*
5 GCPs and DEM only	0.96	0.30	1.0
10 GCPs and DEM only	0.52	0.28	0.59
10 GCPs ,DEM and DBM	0.54	0.14	0.56

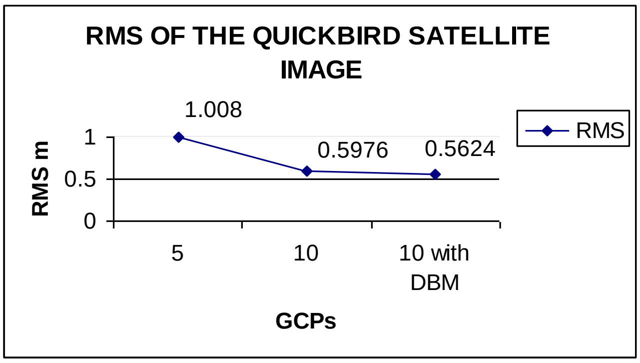


Figure (4): RMS of the QUICKBIRD satellite image

4.2.3. On Screen Digitizing for Thematic Map Production

The thematic maps can be created by on screen digitizing procedure using ARC-GIS 9.3 software for both images (for streets and buildings) as shown in the following figures.

Figure (5): On screen digitizing for GOOGLE-EARTH satellite image for streets.

Figure (6): On screen digitizing for GOOGLE-EARTH satellite image for buildings.

Figure (7): On screen digitizing for QUICKBIRD satellite image for streets.

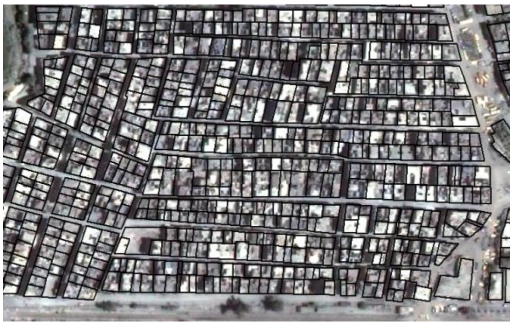


Figure (8): On screen digitizing for QUICKBIRD satellite image for buildings.

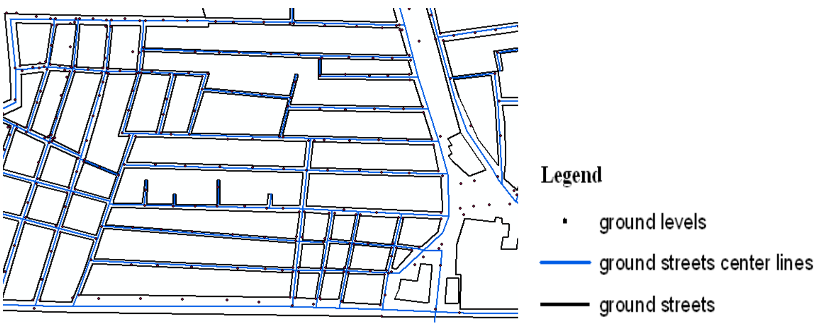


Figure (9): The final thematic map for both streets and buildings.

4.2.4. Checking up the Planimetric Accuracy of the Thematic Maps

The accuracy of the final thematic maps produced on both cases using Google Earth and QUICKBIRD satellite images will be evaluated according to the three major map accuracy standards. These standards use Root Mean Square Error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The First standard is the **National Map Accuracy Standards** (NMAS). For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch (0.8mm), measured on the publication scale. These limits of accuracy shall apply to positions of well-defined points that are easily plotted on the scale of the map within 1/100 inch (0.25mm) **[7].**. Also has been developed for medium-to-small scale maps (1:20000 and smaller) **[1].**

$$\text{NMAS}=0.03333 \times \text{map scale} \times 2.54 / 100 = \text{meters} \qquad (3)$$

For 1:2500 scale maps, NMAS = 0.03333 x 2500 x 2.54 / 100 = 2.12 meters.

The second standard is the **American Society for Photogrammetry and Remote Sensing** (ASPRS) **[ibid]**. It is the accuracy standards for Large-Scale Maps. For 1:2500 scale maps, ASPRS = (0.03333 x 2500 x 2.54 / 100)/3.333 = 0.64 meters.

The third standard is The **National Standard for Spatial Data Accuracy** (NSSDA) **[ibid]**. For 1:2500 scale maps, NSSDA = (0.03333 x 2500 x 2.54 / 100)/2 = 1.06 meters.

For checking the planimetric accuracy of the map produced from QUICKBIRD image, five check points (figure 10) have been used after the vectorization process to calculate the total RMSE of the final map. The results show that, the RMS for GCPs was 0.999 m in East direction and 0.352 m in North direction and the total RMS was 1.05 m.

For checking the planimetric accuracy of the map produced from Google Earth image, the same five check points have been used (Figure 10) after the vectorization to calculate the total RMSE of the final map. The results show that, the RMS for GCPs was 0.495 m in East direction and 0.574 m in North direction and the total RMS was 0.76 m.

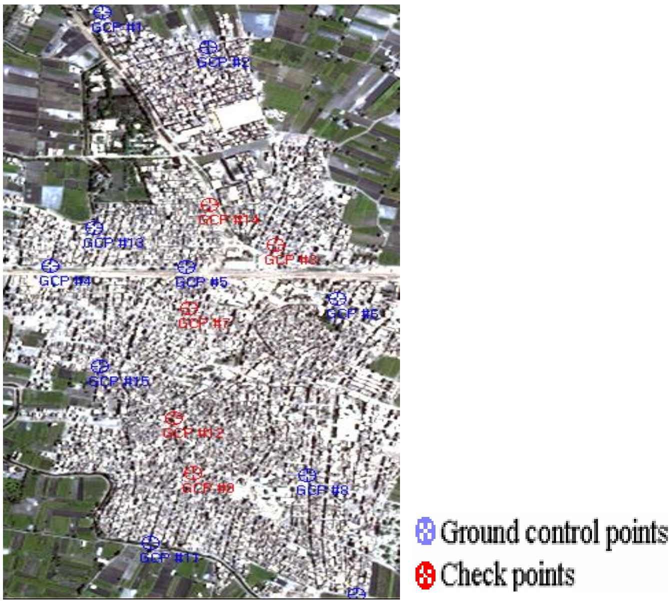


Figure (10): Distribution of GCPs and check points over the study area.

5. Conclusions

One of the main objectives of this research was assessment of thematic maps produced from Google Earth satellite images by comparing the planimetric accuracy of these maps with their corresponding maps produced from QUICKBIRD satellite images which have approximately the same high resolution. Also, evaluation of the effect of using DEM and DBM on the planimetric accuracy of these maps was one of the main research objectives. From the results of study, the following could be concluded:

- DEMs have the major effect on the orthorectification processes as it removes the effect of terrain relief.
- DBMs have less effect on the same process, but it should be applied because it removes the effect of relief displacement of buildings.
- The RMSs for both images were within the required standard map accuracy for a map scale 1:5000 according to the three map accuracy standards. Also these results were within the required map accuracy standard for a map scale 1:2500 according to both the NMAS and NSSDA standards.
- Google Earth satellite image can be used to produce large scale maps as an alternative source to satellite images.

References

1. **Anderson J., and Mikhail, E., (1998):** "Surveying Theory and Practice", Seven Edition, WCB/McGraw-Hill, Boston.
2. **Chuvieco, E., and Huete, A., (2010):**”Fundamentals of Satellite Remote Sensing”, First Edition. Taylor and Francis Group, LLC, United States of America.
3. **Erdas field guide Fifth Edition, (1999):**”Imagine Essentials Training Reference Manual”, Atlanta, Georgia, United States of America.
4. **http://en.wikipedia.org/wiki/GeoEye-1.**
5. **http://www.statemaster.com/encloypedia/Quickbird.**
6. **IZEIROSKI Subija; (2008)**: "Raster Based Integrated Remote Sensing GIG system for Managing of Real Estate", M.Sc. thesis, Faculty of technical sciences St. Kliment Ohridski”-Bitola University, Bitola.
7. **NMAS; (1947):** United States National Map Accuracy Standards. “National Mapping Program Maintained by the U.S. Department of Interior, U.S. Geological survey. Washington D.C. 1941 Revised 1947.
8. **IZEIROSKI Subija, Igor NEDELKOVSKI, Pece GORSEVSKI and Kujtim XHILA; (2010):** "Spatial Data Infrastructure For Real Estate Administration Based on Satellite Data", International Conference SDI 2010 – Skopje; 15-17-09-2010, pp 347-364.