

# GEOMETRIC ACCURACY OF HIGH-RESOLUTION DATA FOR URBAN PLANNING

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**KEY WORDS:** Ikonos, QuickBird, 2D Polynomial Transformations, Geometric Accuracy

## ABSTRACT:

The very high-resolution satellite data from IKONOS and QuickBird are in a competition to aerial images today. Although the IKONOS satellite has provided the world's first source of commercially available high-resolution satellite imagery, QuickBird is currently the satellite with the highest resolution for civilian uses. While the IKONOS and QuickBird panchromatic band images with 0.82 and 0.61 meter respectively, provide intelligence quality imagery both for military applications, such as monitoring and assessment, as well as for civilian applications such as urban planning and mapping. The multi-spectral bands of IKONOS and QuickBird multi-spectral images with 3.28 and 2.44 meter respectively provide spectral-radiometric measurements for the many applications in land-use mapping, environmental monitoring and resource development. The successful launch of these two high-resolution satellites has narrowed the gap between satellite images and aerial photos. In the near future, it could even replace aerial photos for some applications depending on the resolution and accuracy requirements. In this study, the geometric accuracy analysis has been done with both QuickBird-2003 and IKONOS-2002 images for Büyükçekmece region, Istanbul, Turkey. For the accuracy assessment, these two high-resolution images were rectified to UTM coordinate system using 1/5000-scaled orthophotos, GPS and hand GPS coordinates. The results obtained were tested at the known points and effectiveness of the use of high-resolution data was outlined.

## 1. INTRODUCTION

More than 70 percent of the populations of developed countries live in urbanized areas. In developing countries of the third and fourth world the migration to urban areas is continuing at an increasing rate and tends to rise to a peak of 85 %. Urban spaces are the areas developing most dynamically and are characterized by an enormous need of information as a basis for planning and decision making in order to take measures against the serious wide ranging problems arising out of rapid urbanization and mostly unplanned development (Krätzschar et al., 2004). Traditional land surveying methods, such as field surveys or using aerial photogrammetry, are costly and time consuming. In order to rapidly derive detail land use information in broad areas, it is necessary to use remote sensing techniques. With the successful launch of the satellites IKONOS in September of 1999 and QuickBird in October of 2001 new sources of digital imagery are available to decision makers in Provincial, State, and Local governments. This improvement in the resolution of satellite images has broadened the applications for satellite images to areas such as urban planning, data fusion with aerial photos and digital terrain models (DTMs), and the integration of cartographic features with GIS data. However, these high-resolution satellites, such as 1-m resolution IKONOS and 0.6m QuickBird, still could not replace the use of aerial photos, which have resolution as high as 0.2 to 0.3m. But, these high-resolution sensors have narrowed the gap between satellite images and aerial photos, permitting the easy updating of urban information. Such data the panchromatic resolution from 1-metre to 70-centimetre and multi-spectral from 4-metre to 2.80-metre resolution are likely to stimulate the development of

urban remote sensing (Fritz, 1999). However, these Very High Resolution (VHR) images can not be used directly with map base products into a Geographic Information System (GIS) because of some distortions. Consequently, multi source data integration (vector and raster) for mapping applications requires geometric and radiometric correction models. These distortions of VHR images are due to radiometric distortions, internal sensor geometry, some optical and sensor deficiencies and viewing geometry and terrain relief. In addition to these, some distortions occur based on the map projection type used. It was found that the exact geometric correction of VHR images required complex mathematical functions and models, which based on principles related to orbitography, photogrammetry, geodesy, and cartography (Toutin et al., 2002). For geometric correction of VHR images, either 2D/3D non-parametric models or rigorous 3D parametric models are being used. Although 2D non-parametric models do not take into account sources of distortion due to the image formation and terrain relief, they have a simple mathematical formation and require fewer numbers of GCPs than 3D models.

In this paper, we investigate a geometric correction procedure based on 2D polynomial non-parametric models for Ikonos and QuickBird images. We aimed to show the effectiveness of 2D polynomial models for VHR images in terms of GCPs obtained from different sources. The GCPs were collected by geodesic GPS campaign, measuring from photogrammetrically produced orthofoto and the hand-GPS.

## 1.1 Study Area And Data Used

Büyükçekmece (41° 03' latitude, 28° 45' longitude) is one of the 32 administrative districts, which comprise the city of Istanbul. It is surrounded by the Marmara Sea on the south, the east by Avcılar and Küçükçekmece, the north by Çatalca, and the west by Silivri districts (Figure 1). It has 9 administrative sub districts: Büyükçekmece Centrum, Kavaklı, Yakuplu, Kıraç, Gürpınar, Esenyurt, Mimarşinan, Kumburgaz and Tepecik and also has 5 villages (Türkoba, Hoşdere, Çakmaklı, Karaağaç and Ahmediye). The population in the district is generally higher in coastal sub districts due to high rates of migration, and in summer this rate is maximized because of the summer residences.

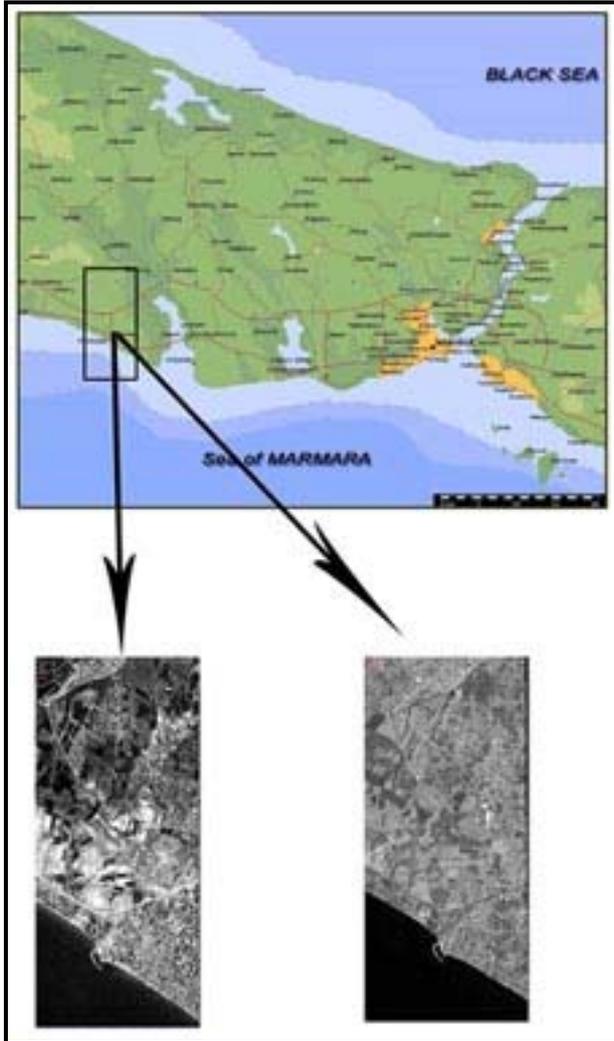


Figure 1. The map and satellite images of the study area. (a) Ikonos image dated 13/ 02/2002 (b) QuickBird image dated 03/05/2003.

In this study, very high-resolution images of Ikonos and QuickBird-2 dated 2002 and 2003 in panchromatic band were used as remotely sensed data. Besides, the digitized 1/5000-scaled orthophotos dated 1996; Leica System 300 GPS receiver and Garmin eTrex summit pocket GPS data were used to evaluate the geometric accuracy of the images. The specifications of the remotely sensed data used are given in Table 1.

Satellite	Date	Spectral Res.( $\mu\text{m}$ )	Spatial Res.(m)
Ikonos	2002	0.45-0.52 (Visible) 0.52-0.60 (Visible) 0.63-0.69 (Visible) 0.76-0.90 (NIR) Pan 0.45-0.90	1 m Pan 4 m MS
QuickBird2	2003	0.45-0.52 (Visible) 0.52-0.60 (Visible) 0.63- 0.69 (Visible) 0.76-0.90 (NIR) Pan 0.52-0.90	0.61-0.72 m Pan 2.44-2.88 m MS

Table 1.Specifications of the data used.

## 1.2 Methodology

In this study, the analysis of the geometric accuracies of these two very high resolution images were conducted by the geometric rectification using with rapid-static GPS survey, pocket survey and digitized 1/5000 scaled orthophotos.

As a first step, the panchromatic band of Ikonos and QuickBird were enhanced using different digital enhancement techniques for better visual analysis, such as contrast modification and filtering.

Rapid static GPS survey was the base information source for this study. While two stable GPS receiver were collecting data on the known stations, which one of them is IGS-ISTA permanent station in the Istanbul Technical University and the other is a triangulation point determined in the study area; one rover GPS receiver was used to measure the coordinates of the GCPs selected. Measures of X, Y and Z coordinates were recorded at 5 sec intervals for about 5 minutes with at least four satellites availability for each point. Most of the observed points are wharves, buildings and parcels corners. Then, these collected GPS data were transferred to computer and their UTM coordinates were calculated. UTM coordinates of GCPs were calculated about cm accuracy by using Ski-Pro GPS data processing software. The second field survey was conducted with pocket GPS and UTM coordinates of the selected GCP's were gathered and recorded automatically. As a third data collection method, the same GCPs were selected from the digitized 1/5000-scaled orthophotos. All the coordinates obtained from different techniques calculated in UTM projection system in ED50 (European Datum 1950).

## 2. APPLICATION AND RESULTS

When considering 2D transformation models, many models can be checked such as polynomials, similarity, affine and projective models. In this research, 1<sup>st</sup> and 2<sup>nd</sup> degree polynomials model was used due to its simplicity and availability within most of remote sensing software packages. Two orders of polynomials were utilized to check the metric integrity of images. The two transformation models adopted for testing were as follows (Shaker et al., 2002). 1<sup>st</sup> and 2<sup>nd</sup> order polynomials;

$$X_0 = b_1 + b_2 X + b_3 Y \quad (1)$$

$$Y_0 = a_1 + a_2 X + a_3 Y \quad (2)$$

$$X_0 = b_1 + b_2 X + b_3 Y + b_4 XY + b_5 X^2 + b_6 Y^2 \quad (3)$$

$$Y_0 = a_1 + a_2 X + a_3 Y + a_4 XY + a_5 X^2 + a_6 Y^2 \quad (4)$$

Where  $X_0$ ,  $Y_0$  image coordinates and  $X$ ,  $Y$  ground coordinates. One of the main goals of this study is to evaluate the accuracy of very high-resolution data using 2D image transformation method. For this aim, Ikonos and QuickBird image were firstly assessed using 1st and 2nd order polynomials with 10 and 20 GCPs respectively. Table 2 shows the results of Root Mean Square (RMS) errors of the ground control points, which were formed using GPS measurement results. Although 45 well defined and distributed ground control points were observed by means of the rapid static GPS measurement, the GCPs which had the best distribution and minimum error factor among all were chosen for geometric transformation (Figure 2 and 3). As can be seen in tables, the RMS errors are being decreased with an increase of the order of transformation.

	# of GCP	1st degree RMS(m)	2nd degree RMS(m)
<b>Ikonos</b>	9	1.66	
	18	2.65	1.35
<b>QuickBird</b>	9	0.91	
	18	2.83	2.57

Table 2. RMS errors calculated by using with GPS

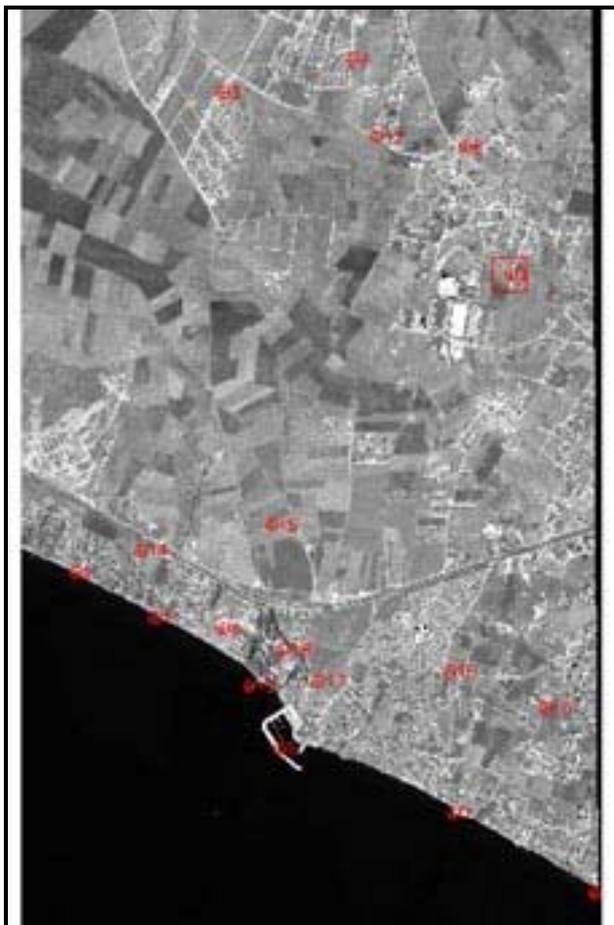


Figure 2. GCPs observed by GPS measurements in QuickBird image.



Figure 3. GCPs observed by GPS measurements in Ikonos image

As a next phase of this study, the GCPs were collected by using hand GPS measurement technique for the same goals. In the next field measurements because of the bad weather conditions, the same GCPs which were collected by GPS before were not reached. Only the 18 same GCPs were used in this evaluation phase. It was again seen that the higher order of transformation the better RMS errors obtained (Table 3).

	# of GCP	1st degree RMS(m)	2nd degree RMS(m)
<b>Ikonos</b>	9	7.48	
	18	8.94	6.57
<b>QuickBird</b>	9	10.48	
	18	14.36	11.40

Table 3. RMS errors calculated by hand GPS

In the last phase of the analysis, the digitized 1/5000 scale orthophotos were used to collect GCPs. Only 6 GCPs from GPS were able to be determined over the orthophotos because of the date factor. 24 GCPs were selected from the 8 digitized orthophotos which cover the study area. The transformation was evaluated using with 10 and 24 GCPs respectively. Table 4 shows the RMS errors calculated from the 1st and 2nd order transformations.

	# of GCP	1st degree RMS(m)	2nd degree RMS(m)
Ikonos	10	8.69	
	24	8.16	4.28
QuickBird	10	7.65	
	24	7.41	5.18

Table 4. RMS errors calculated by orthophotos

After the rectification process, geometric accuracy of images was tested with ground truth measurements as areal extent and length. Manually digitized area and length measurements in two images were compared with the ones measured in field. As a length, a refuge in the middle of the road was selected; as an areal extent, a triangle established in the map of Tepekent residence site and its areal extent was calculated by AutoCAD software (Figure 4). The actual values of length and areal extent are 502.49 m and 932.343 m<sup>2</sup>.

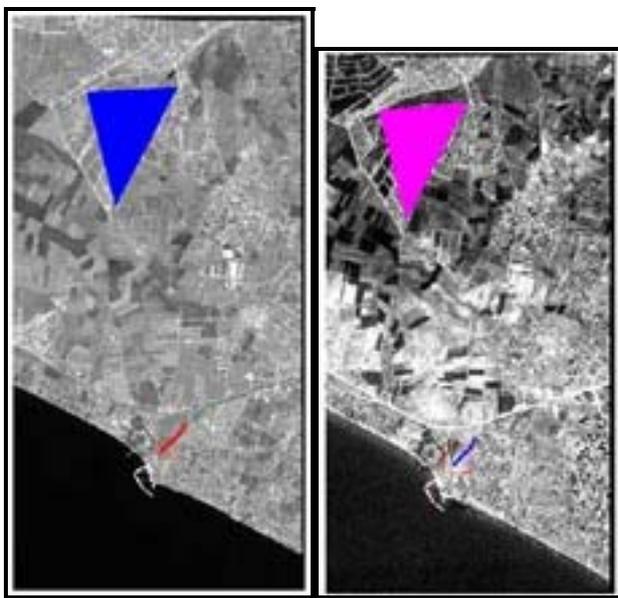


Figure 4. Selected test areas in QuickBird image (left side) and Ikonos image (right side).

The comparison was carried out according to the number of GCPs and order of transformation and outlined in Table 5, 6.

	# of GCP	QuickBird		Ikonos	
		1 <sup>st</sup> degree trans.	2 <sup>nd</sup> degree trans.	1 <sup>st</sup> degree trans.	2 <sup>nd</sup> degree trans.
GPS	9	0.51	-	-6.26	-
	18	1.35	-0.48	-6.58	-4.08
Hand-GPS	9	-6.73	-	-4.71	-
	18	0.47	0.10	-5.29	2.66
Orthophoto	10	1.19	-	-2.00	-
	24	2.71	-1.78	-4.82	-0.94

Table 5. The errors (meter) from the measured lengths in the images rectified using GPS, Orthophoto and Hand-GPS.

	# of GCP	QuickBird		Ikonos	
		1 <sup>st</sup> degree trans.	2 <sup>nd</sup> degree trans.	1 <sup>st</sup> degree trans.	2 <sup>nd</sup> degree trans.
GPS	9	13.04	-	17.603	-
	18	13.778	14.137	16.216	7.682
Hand-GPS	9	11.114	-	16.685	-
	18	11.873	29.744	20.597	2.128
Orthophoto	10	18.002	-	20.288	-
	24	21.531	64.460	27.291	32.119

Table 6. The errors (square meter) from the measured areas in the images rectified using GPS, Orthophoto and Hand-GPS.

In the results of investigations, it was clearly seen in tables, the most correct result of length measurements was determined in the QuickBird image, which was rectified using 1/5000 scaled orthophotos with 24 GCPs and 2<sup>nd</sup> transformation degree. In the comparisons of areal extent, the most correct result was found from the Ikonos image, which was rectified using orthophotos with 24 GCPs and 2<sup>nd</sup> transformation degree. From the results obtained that best accuracy was found applying 2<sup>nd</sup> degree transformation to these high-resolution images.

### 3. CONCLUSION

In recent years Remote Sensing of Urban areas is getting more realistic and promising application field driven by the emergence of VHR images for general use (Ulubay et.al, 2003). The accuracy and interpretability of VHR data such as Ikonos and QuickBird image make it ideal data for planning and management efforts and help city managers in planning new development and developing urban growth studies (Maktav et.al, 2002).

In this study, the geometric accuracy of VHR images has been tested with 2D transformation by using GCPs collected in different ways and comparisons between ground truth data and the measured length and areal extent in the rectified images were performed. From the comparison results, it was seen that the 2D polynomial nonparametric models gave reasonable results and the geometric accuracy of high-resolution satellite images is very satisfactory and this leads to conclusion that they can be used in land use mapping efficiently. It also shows that VHR images continue to provide more valuable and cost-effective spatial information that could help planning development in urban areas.

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#### **ACKNOWLEDGEMENTS**

We would like to thank to Mr. Greg Knoblauch and Melanie Rowe from Digital Globe Company for QB data supply, support and help