GEOMETRIC ACCURACY AND FEATURE COMPILATION ASSESSMENT OF HIGH RESOLUTION SATELLITE IMAGES

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ABSTRACT:

High resolution satellite images have reached to a high quality and have proved to be a useful data source for the creation of orthophoto images and different mapping products.

A study was carried out in Gölbaşı near Ankara for geometric accuracy and feature compilation assessment of high resolution satellite images. Twelve ground control points (GCP's) were established and marked before recording of images. Stereo-pair Ikonos, mono Quickbird and 1:16.000 scaled aerial images were provided free of charge by Inta Inc. (Turkey), Eurimage (Italy) and General Command of Mapping (Turkey).

Using photogrammetric, cartographic or Ikonos DEM, various orthophotos have been produced with different combinations of ground control points. Well-recognized 27 checkpoints (CP's) such as junction of roads and field corners have been defined and measured with GPS. Planimetric coordinates of the checkpoints were also measured on all orthophotos and compared with GPS coordinates. Three regions of different characteristics have been selected in the study area for feature compilation analyses. Three different experienced operators compiled features on these regions for 1:5.000 scaled map productions. Map productions from different sources (Ikonos, Quickbird and aerial images) have been compared within each other. And finally the compiled features have been controlled in field.

The geometric accuracy results show that the high resolution satellite images can be used in middle to large scale (1:6.000 to 1:10.000) mapping productions. Moreover feature compilation assessment results reveal that these images are still insufficient with respect to aerial images in terms of determining and identifying of small features.

1. INTRODUCTION

The high quality that high resolution satellite images have reached in the last years has proved that these images could be a useful data source for the production of orthophoto images and for different mapping products as well. Specifically, it is very important in areas where aerial photogrammetry is not possible or feasible due to political reasons/restrictions and mapping frequency constrained by the limits of flight planning (Li et al., 2000).

There are two important criteria for quality assessment of the images; geometric accuracy and object definition. When we take the mapping processes into consideration, these criteria are basically dependent on the relation between pixel size and the map scale, contrast information (spectral range and colour), atmosphere and the sun elevation, the printing technology and the resolution of the human eye (Topan et al., 2004).

Research activities about high resolution satellite images have been mainly focusing on the geometric accuracy aspects in ortho-image generation and digital elevation model (DEM) extraction (e.g. Grodecki and Dial, 2001; Toutin, 2004).

In addition to this activities, some researches are increasingly concentrating on feature detection, recognition and reconstruction studies like automated mapping of roads (e.g.

Baltsavias et al., 2004), extraction of 3D buildings (e.g. Fraser et al., 2002) and cadastral mapping (e.g. Alexandrov et al., 2004).

Actually there is nearly a consensus among photogrammetry and remote sensing society that some mapping applications from high resolution space imagery can be realized in 1:6.000-1:10.000 scale (Holland and Marshall, 2004; Volpe, 2003). Accordingly, in the world literature it is very seldom to see compilation assessments in big scale mapping (e.g. 1:5.000) in which both high resolution satellite images are used and all feature types have been detected. Therefore nowadays, the discussions about usage of high resolution space imagery in big scale map productions are still going on.

2. STUDY AREA AND DATA SETS

2.1 Study Area

The study was carried out in Gölbaşı near Ankara, which has 10 km X 10 km area and a height difference about 440 m. This area has been used in many photogrammetric and geodetic applications of General Command of Mapping. The region has open rural areas with different land cover, different road types, water features, communication and electricity transmission lines and small towns (Figure 1).
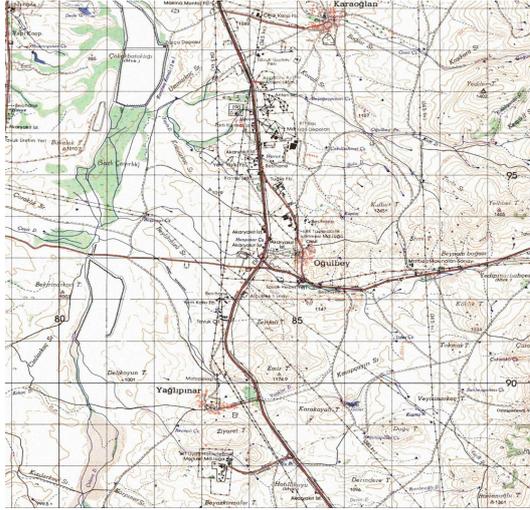
Figure 1. Gölbaşı test area

2.2 Ground Control Points (GCP's)

Geometric accuracy depends on the number and distribution of GCP's. However it is not necessary, to collect a very large number of GCP's, since the accuracy doesn't vary in an appreciable way when considering more than 10-15 GCP's (Volpe, 2003). Besides, a well spread distribution of even a few GCP's is more beneficial to accuracy improvement than a dense but poorly spread distribution (Li et al., 2000).

In this study, 12 GCP's were established and marked in May 2002 before the recording of images. The coordinates of GCP's have been measured with Global Positioning System (GPS).

2.3 Images

Stereo-pair IKONOS (dated August 4th, 2002), mono Quickbird (dated May 26th, 2002) and 1:16.000 scaled aerial images (dated August 29th, 2002) were provided by Inta Inc. (Turkey), Eurimage (Italy) and General Command of Mapping (Turkey) free of charge. The information about stereo-pair IKONOS and Quickbird images are given in Table 1.

	Nominal Collection Azimuth	Nominal Collection Elevation	Sun Angle Azimuth	Sun Angle Elevation
IKONOS-1	343.397 °	79.1812 °	145.587 °	64.083 °
IKONOS-2	206.640 °	65.7324 °	146.031 °	64.182 °
Quickbird	239.034 °	83.0699 °	139.486 °	67.278 °

Table 1. Azimuth and elevation angles of satellite images

1:16.000 scaled aerial images have been taken by B-200 Beechcraft airplane and with Zeiss RMK Top 15 camera. 40 photographs in 5 strips were taken during the flight. The overlaps between the images and the strips were % 60 and % 30.

2.4 Digital Elevation Models (DEM's)

Photogrammetric, cartographic and Ikonos DEM's are used for different orthophoto productions.

The photogrammetric DEM was produced by manually collecting data in 20 m intervals (İşcan et al., 2004). Surfer Tool module in the Softplotter 3.0 software was employed in the derivation of DEM's. It is considered that the accuracy of photogrammetric DEM is approximately ± 1 m.

The cartographic DEM has been already produced by General Command of Mapping using printed sheets. In this production, the printed sheets have been scanned first and then the contour lines have been digitized through semi automatic methods. It can be considered that the accuracy of cartographic DEM is approximately ± 5 m.

The last DEM has been produced form IKONOS stereo images using PCI Ortho Engine module. 8 GCP's and 34 tie points were used in this process and a correlation success percent of % 97.2919 was obtained after production. It can be accepted that the accuracy of IKONOS-DEM is approximately ± 2 m (Erdoğan, 2006).

3. GEOMETRIC ACCURACY ASSESSMENT

For geometric accuracy assessment, orthophotos from satellite images and mosaic images from aerial photographs have been produced first. Then, check points (CP's) have been selected from both orthophotos and mosaic images and finally, ground and image coordinates were measured and compared.

Producing of orthophotos/mosaic images and measuring of image coordinates were realized using Erdas Imagine 8.6 software.

3.1 Orthophoto and Mosaic Production

Using photogrammetric, cartographic or Ikonos DEM, various ortho and mosaic images have been produced with different GCP's distributions. Furthermore, a stereo IKONOS image (using 7 GCP's and 91 tie points) and orthophotos (using direct sensor orientation without GCP's) were also produced.

Aerial triangulation processes have been applied after taking aerial photographs using kinematic GPS technique. 11 GCP's and 986 photogrammetric tie points have been measured and used for adjustment phase.

After adjustment, orthophotos have been produced from every image using both cartographic and photogrammetric DEM. Lastly, a joined mosaic image was formed from all orthophotos.

In addition, in orthophoto productions from satellite images, the rational polynomial coefficients (RPC's) approach has been applied with a polynomial third order refinement.

3.2 Check Points (CP's)

Easily-recognizable and well-distributed 35 CP's such as road junctions and field corners were selected from orthophotos and mosaic images.

However, because of travel restrictions to the points, only 27 CP's coordinates could be measured with GPS. And the field applications have been fulfilled in March 2003 using two reference points.
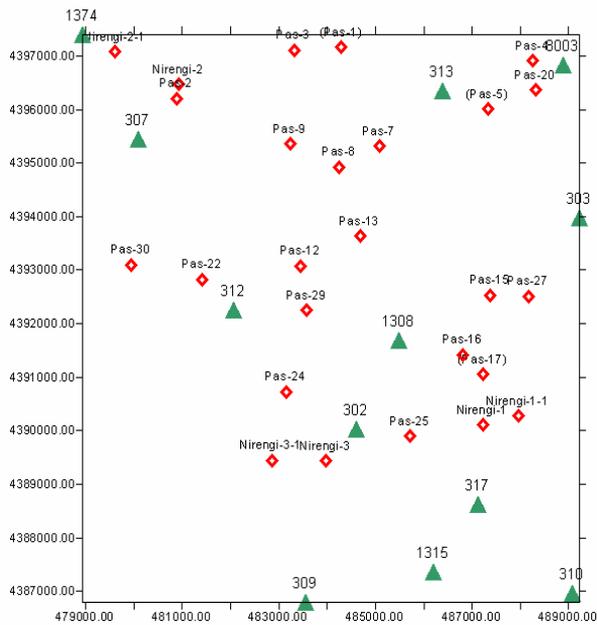
Figure 2. Distribution of GCP's (▲) and CP's (◇)

3.3 Coordinate Measurements

Planimetric coordinates of the CP's have been measured on all orthophotos/mosaic images and stereo IKONOS images. These coordinates have been compared with GPS coordinates.

Of course, because of big time difference between images and measurements, some difficulties have been encountered in detection of features on images and in finding the selected CP's in field. Therefore it has been tried to find the pixels which have the same gray scale values and represent the same features. In this process, it was very beneficial to use the brightness or darkness of adjacent pixels.

If the coordinates differences were bigger than 3σ, they were identified as gross errors and re-measured or eliminated.

Image	No. Of GCP's	DEM	No. Of CP's	RMSE (m)		
				x	y	x y
Aerial Photo	11	Photog. DEM	23	0.94	0.95	1.33
Aerial Photo	11	Cartog. DEM	22	1.20	0.98	1.55

Table 2. Differences on aerial photographs

Image	No. Of GCP's	No. Of CP's	RMSE (m)			
			x	y	x y	z
IKONOS	7	24	0.77	0.89	1.17	0.94

Table 3. Differences on stereo IKONOS images

Image	No. Of GCP's	DEM	No. Of Check Points	RMSE (m)		
				x	y	x y
IKONOS	4	Photog. DEM	25	2.25	1.54	2.73
IKONOS	4	Ikonos DEM	25	2.25	1.43	2.67
IKONOS	5	Photog. DEM	25	2.16	1.49	2.62
IKONOS	7	Photog. DEM	26	1.28	1.55	2.01
IKONOS	7	Ikonos DEM	26	1.28	1.54	2.00
IKONOS	7	Cartog. DEM	26	1.37	2.19	2.58
IKONOS	Orient. Para.	Ikonos DEM	27	11.97	11.84	16.84
IKONOS	Orient. Para.	Cartog. DEM	26	11.58	10.66	15.74

Table 4. Differences on IKONOS images

Image	No. Of GCP's	DEM	No. Of Check Points	RMSE (m)		
				x	y	x y
Quickbird	4	Photog. DEM	25	1.05	0.85	1.35
Quickbird	5	Photog. DEM	25	1.04	0.84	1.33
Quickbird	9	Photog. DEM	26	1.29	1.01	1.63
Quickbird	9	Cartog. DEM	26	1.56	1.02	1.86
Quickbird	Orient. Para.	Cartog. DEM	27	38.97	14.89	41.72

Table 5. Differences on Quickbird images

3.4 Results

The geometric accuracy results show generally that the high resolution satellite images can be used in mid/large scale (1:6.000 to 1:10.000) mapping processes.

And we can say that;

- Quickbird ortho-images having 9 GCP's have better accuracy than IKONOS ortho-images having 7 GCP's. In fact, Quickbird ortho-images having 4/5 GCP's have an accuracy that is very close to aerial photographs.

  Moreover it has been detected that the accuracy is getting worse in IKONOS ortho-images if the number of GCP's decreases but in the same situation the accuracy is getting better in Quickbird ortho-images. The reason of this is the GCP's quality.

- When using direct sensor orientation parameters given by the companies (in the year 2002), IKONOS ortho-images have better accuracy than Quickbird ortho-images. But today, it is possible to reach better accuracy with new sensor orientation parameters.

In addition, systematic errors have been observed in the easting/north easting (across track) direction. In most studies it has been noted that the RMS geopositioning accuracy is just below ¼ pixel in the cross-track direction and close to ½ pixel in both the along-track direction and in height (Hanley and Fraser, 2004). And a significant portion of the easting errors may have been due to variations in satellite elevation, especially when the IKONOS satellite imaged at low elevation angles (Helder et al., 2003; Yamakawa and Fraser, 2004).

- The results obtained from orthophotos using IKONOS-DEM and photogrammetric DEM are very close. Therefore it can be said that IKONOS-DEM can be used instead of photogrammetric DEM.

- After evaluating of the positions of gross errors, it is determined that they are mostly (25 of 27 - % 92.6) located on the edge / outside of the GCP's network.

- Finally, the results show that the stereo IKONOS image has the best accuracy and stereo IKONOS image allows mapping processes up to 1:6.000 scale. On the other hand, it is possible to realize mapping processes up to 1:7.000 - 1:7.500 scale from mono satellite ortho-images.

4. FEATURE COMPILATION ASSESSMENT

4.1 Mapping Areas

Three regions which have different characteristics have been selected in the study area for feature compilation analyses. Some criteria were taken into consideration in selection of compilation areas;

- The areas have to be inside of the GCP's/CP's network,

- The areas should have different feature types,

- The areas should have a significant height difference and

- The areas should be reachable with vehicles for control operations in field.

1:5.000 scale was selected for compilation processes because of on-going discussions about usage of high resolution space imagery in big scale (especially in 1:5.000 or greater scale) map productions.

The selected 3 regions have height differences about 110 m, 250 m and 220 m respectively.

4.2 Map Production

Three different experienced operators compiled all features on these regions (roads, buildings, water features, forests, hedges, communication and electricity transmission lines etc.) using mono satellite and stereo aerial images for 1:5.000 scaled map productions.

The operators have used Autometric Softplotter, MicroStation V8 and VirtuoZo software for compilation. In compilation processes, the operators have followed all the standard procedures applied in General Command of Mapping for producing a big scale map.

4.3 Comparison of Compilations

The map productions from different sources (Ikonos, Quickbird and aerial images) have been compared within each other and the compiled features have been controlled in field.

The comparison studies have been applied by means of MicroStation V8, Arcview 3.3 and MaverickPro software. Firstly, the numbers of features in text, line, polygon and point layers have been detected, controlled and compared by using these software. In this stage, aerial photographs have been selected as reference data because the numbers of features compiled in aerial photographs were more than satellite images (Table 6).

		Line	%	Polygon	%	Point	%	Total	%
1. Sheet	Aerial Photo	1894	100	541	100	2242	100	4677	100
	Ikonos	776	41.0	338	62.5	1189	53.0	2303	49.2
	Quickbird	891	47.0	348	64.3	1068	47.6	2307	49.3
2. Sheet	Aerial Photo	529	100	53	100	242	100	824	100
	Ikonos	295	55.8	26	49.1	186	76.9	507	61.5
	Quickbird	285	53.9	18	34.0	111	45.9	414	50.2
3. Sheet	Aerial Photo	746	100	84	100	384	100	1214	100
	Ikonos	397	53.2	77	91.7	471	122.7	945	77.8
	Quickbird	424	56.8	61	72.6	475	123.7	960	79.1
Total	Aerial Photo	3169	100	678	100	2868	100	6715	100
	Ikonos	1468	46.3	441	65.0	1846	64.4	3755	55.9
	Quickbird	1600	50.5	427	63.0	1654	57.7	3681	54.8

Table 6. The number of details compiled on images

Secondly, the features compiled from different sources have been located one on the top of the other and detected the differences between operators (Figure 3).
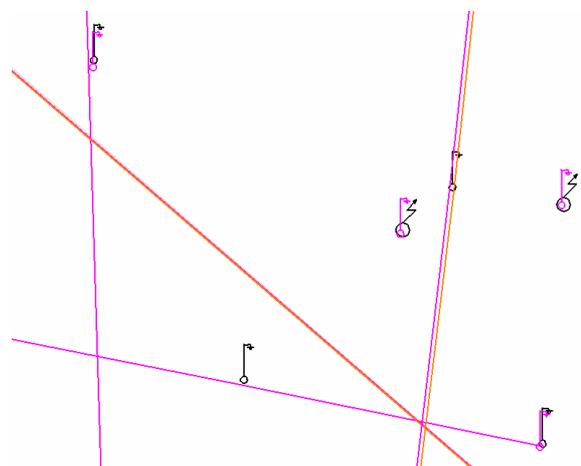

Figure 3. Features located one on the top of the other

And lastly, the feature layers have been evaluated in detail. Also in compilation processes, the symbol files in which 437 features have been classified in 62 layers have been used. So, every feature layer in every sheet has been compared aerial photographs (Table 7).

Layer No	Feature Names in Layer	Aerial Photo	IKONOS	
		Number of Features	Number of Features	%
5	Rocks and stony place	22	-	0.0
31	Water depot	1	-	0.0
42	Telephone/Radio line/station	2	-	0.0
43	Sporting facilities	6	-	0.0
44	Single grave or graveyard	2	-	0.0
49	Pipe line and sewerage	3	-	0.0
51	Ditch, set and tumulus	43	-	0.0
27	Lean-to roof	397	13	3.3
48	Telephone/Electric pole, lamp	321	32	10.0
20	Pavement	183	30	16.4
50	Slope and natural split	183	31	16.9
12	Water well and canal	9	2	22.2
45	Electric line and transformer	53	18	34.0
38	Hedge, wire fence, railing	245	95	38.8
14	Water tower, small lake, winch	10	4	40.0
16	Ownership border	235	99	42.1
11	Stream, spring, marsh	20	9	45.0
26	Building under construction	19	9	47.4
39	Bushes, orchard, tree	1758	1015	57.7
21	Country road, footpath	543	375	69.1
13	Fountain and pool	14	12	85.7
25	Private building	249	225	90.4
36	Factory, chimney, factory hut	41	48	117.1
17	Disapproval ownership border	94	120	127.7
46	Patrol station and pump	6	8	133.3
15	Tunnel, bridge, stop	67	108	161.2
40	Tree, forest area, green house	18	51	283.3
41	Park and garden	-	1	+ 1
22	Under- and top-passage	-	2	+ 2

Table 7. Comparison of feature layers compiled on IKONOS satellite images in 1. sheet

4.4 Control of Compilations in Field

When small objects or boundaries are unclear and can not be identified properly, some other sources of information like cadastral information or field survey are used (Alexandrov et al., 2004). Therefore, this study has been carried out as control and completion applications in field in October 2005 by two personnel. But because of season conditions and vehicle capabilities, it was not possible to pass over some roads. For field control applications, some materials have been taken by the personnel. These materials are;

- Feature attribute lists which were prepared before,

- Compilation result tables,

- Regulation book of big scaled mapping applications,

- A laptop in which the digital compiled data exist and

- 1:25.000 scaled printed sheet of Gölbaşı area.

In field control application, in turn in order;

- The control of outputs of compilations belong to aerial photographs has been carried out firstly because most of the data have been compiled on aerial photographs.

- While determining an error during the controls, brief notes have been taken on the outputs about the errors and then these errors have been controlled on the outputs of compilations belong to high resolution satellite images.

- The attributes of features controlled and the errors determined have been investigated on laptop and lastly,

- Taking all these data into consideration, it has been tried to evaluate the compilations.

Because of long time interval between images and field controls, some difficulties have been encountered in finding and detection of features on Gölbaşı region which is growing very quickly.

4.5 Results

Feature compilation assessment results show that high resolution satellite images couldn't reach to the level of aerial photographs in determining/identifying of small features yet. As a result, concerning compilation applications, we can say that;

- The number of features compiled from Quickbird and IKONOS ortho-images was approximately equal. And when we made an interpretation, we determined that the nearest values to the aerial photographs was obtained firstly in polygon layer (% 63-65), secondly in point layer (% 57-64) and lastly in line layer (% 46-50).

- Quickbird orthophotos showed better performance in line layer and IKONOS orthophotos have shown better performance in point layer.

- The features which were almost not compiled at all in high resolution satellite images (% 0-10) and acquired in aerial photographs are; borders, rocks, stony and sandy places, lean-to roofs and pavements.

- The features compiled in minimum number (% 10-% 40) compared aerial photographs are; slopes, natural splits, telephone and electric poles, water wells, canals, transformers, trees and forest area.

- The features compiled in number of % 40-% 70 compared aerial photographs are; streams, springs, hedges, railings and walls, tunnels, bridges, fountains and bushes.

- The features compiled in best number (% 70-% 100) compared aerial photographs are; country roads, footpaths and single buildings.

As an overall assessment for field control applications, we can say that the operators have had some difficulties in determining and identifying of some features existing in high resolution satellite images. These features are; water wells and transformers taking place in every private country house, communication and electricity transmission lines in dense

residence areas, electric/illumination poles, wire hedges, small huts and lean-to roofs.

5. CONCLUSION

In summary, it can be said that;

- IKONOS-DEM can be used instead of photogrammetric DEM and the quality of GCP's is as important as the number of GCP's.

- When using direct sensor orientation parameters, IKONOS images have better accuracy than Quickbird images. In addition, systematic errors have been observed in the easting/north easting (across track) direction.

- The compilation performance of features in Quickbird and IKONOS ortho-images were approximately the same. And the nearest values to the aerial photographs were obtained in polygon layer.

- Quickbird orthophotos have shown better performance in line layer and IKONOS orthophotos exhibit better performance in point layer.

- In compilation of high resolution satellite images, the operators faced difficulties in determining and identifying of some small and complex features available.

Also the geometric accuracy and feature compilation assessment results show that the high resolution satellite images can be used in mid/large scale (1:6.000 to 1:10.000) mapping processes and these images couldn't reach to the level of aerial images in determining and identifying of small features yet.

Lastly, in next researches, it can be recommended to establish a system of artificially marked points that augment the few existing photo-identifiable man-made features. These panel markers provided clearly identifiable points for which to compare the image pixel locations to the GPS coordinates (Helder et al., 2003).

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