POTENTIAL OF MANUAL AND AUTOMATIC FEATURE EXTRACTION FROM HIGH RESOLUTION SPACE IMAGES IN MOUNTAINOUS URBAN AREAS

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ABSTRACT:

Recent developments of optical space sensors enable us to use high resolution space images for topographic mapping. Geometric and radiometric resolution are the major factors for identification of objects in space images. Panchromatic and pan-sharpened images of IKONOS and QuickBird, and panchromatic OrbView-3 image are investigated in this study. The feature extraction is performed by manual and automatic methods, supported by eCognition. The results are verified against the 1:5000 topographic map. The test site is located in Zonguldak city centre, a mountainous urban area in Western Black Sea region of Turkey. The completeness of manual extraction reaches up to ~70% for buildings, ~100% for roads and ~80% for the coast line. The success of automatic extraction is limited compared to the manual extraction. Only the information content of a 1:10000 topographic map could be derived from these images. The geometric-, radiometric- and spectral-resolution, effective GSD, object contrast, atmospheric condition, imaging time, sun elevation and topographic condition of imaged area are the important parameters for the object identification.

1. INTRODUCTION

Feature extraction for the purpose of topographic mapping from space images became important in recent years. Available high resolution optical space images (HRSI), in visible and near infrared (VNIR) spectrum and with up to sub-meter geometric- and 11 bit radiometric-resolution, enables large scale mapping. Limiting factors for mapping are the information content and the geometric accuracy. Topographic maps should have a geometric accuracy of 0.2 mm up to 0.3 mm in the published map scale, corresponding to 1.0 m up to 1.5 m for the map scale 1:5000 and 2.0 m up to 3.0 m for the scale 1:10000. Such accuracy can be reached without problems based on the mentioned space images. The limiting factor for topographic mapping is the information content, i.e. the performance of feature extraction from the images. Information content carried out by the image depends also on the characteristics of images, such as effective GSD and used methods for data acquisition - manual and automatic feature extraction.

2. IMAGING GEOMETRY AND EFFECTIVE GSD

Projected pixel size on the ground and Ground Sampling Distance (GSD) are two important terms of geometric resolution. The pixel size on the ground is the physical size of the projected pixel. Neighboured pixels may be over-sampled, or under-sampled, i.e. there is a gap between neighboured pixels. GSD means the distance of the centres of neighboured pixels projected on the ground. Between GSD and projected pixel size there may be a large discrepancy as for SPOT-5 Supermode and OrbView-3 panchromatic images. For instance, SPOT-5 has 5 m pixel size on the ground which is partially overlapping 50% in order to generate 2.5 m GSD Supermode images (Topan et al., 2009).
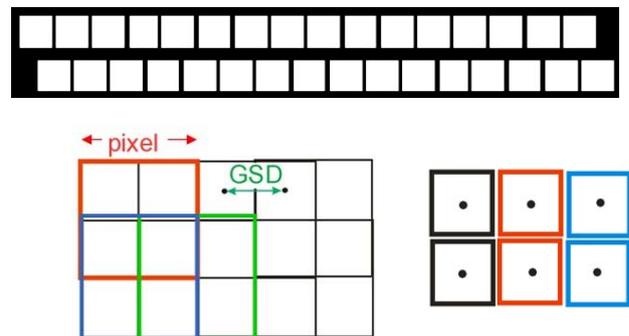

Figure 1. (above) Staggered CCD-lines, (below-left) over-sampled and (below-right) under-sampled pixels

The optical space sensors are located in a flying altitude corresponding to approximately 7km/sec footprint speed, so just 1.4msec exposure time is available for acquisition of 1m GSD. 1.4msec is not a sufficient integration time for the generation of an acceptable image quality. By this reason, some of the very high resolution sensors are equipped with time delay and integration (TDI) sensors (Jacobsen et al., 2005). Like IKONOS and QuickBird TDI sensors are not just CCD-lines, they are a CCD-array with a small number of pixels in the flight direction. During imaging the charge is generated in the CCD-elements and shifted to the neighboured CCD-line corresponding to the speed of the image motion (Jacobsen, 2002). OrbView-3 is not equipped with TDI sensor. OrbView-3 has a projected pixel size of 2 m, but it has staggered CCD-lines causing an over-sampling of 50%, leading to 1 m GSD. In addition it is slowing down the image motion by asynchronous imaging with a permanent change of the view direction (Jacobsen, 2008). The

limitation of the sampling rate to 2500 lines/sec requires at least a slow down factor of 1.4 for the footprint speed of 7.1 km/sec. It should be noticed that OrbView-3 could not generate panchromatic and colour images at the same time, not allowing a direct pan-sharpening (GEOEYE, 2006).

Not in any case the nominal GSD corresponds to the image quality, so the effective GSD should be determined. A sudden change of the object brightness is causing an unsharp edge in the image. A differentiation of the grey value profile leads to the point spread function (PSF) including the information of the effective GSD (Figure 2). PSF is a total result of optical, electronic, detector and image motion PSFs (Schowengerdt, 1997).
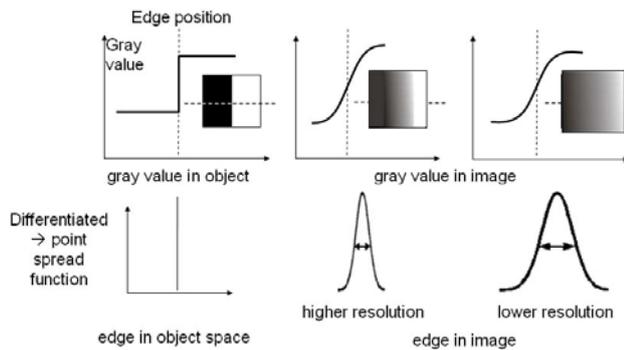

Figure 2. Point spread function of an edge imaged in different quality.

The analysis for effective GSD on analogue and digital space images shows a non-negligible loss of radiometric image quality for some sensors. TK-350 and KVR-1000 in Table 1 are scanned analogue space photographs. IKONOS and QuickBird have no difference between effective and nominal GSD while OrbView-3 has a loss of 20% caused by the staggered arrays.

Table 1. Nominal and effective GSD of space images used in Zonguldak test field (Topan et al. 2009)

Sensor	Nominal (m)	Effective (m)	Difference (%)
TK-350	10.0	13.0	30
KVR-1000	1.6	2.2	37.5
ASTER VNIR	15.0	15.0	0
Kompsat-1 pan	6.6	6.6	0
IRS-1C pan	5.0	5.8	16
SPOT-5 pan	5.0	5.0	0
IKONOS pan	1.0	1.0	0
Orbview-3 pan	1.0	1.2	20
QuickBird pan	0.6	0.6	0

3. MANUAL AND AUTOMATIC FEATURE EXTRACTION

When HRSIs are introduced into geographic information system (GIS) based applications, it may be also presented in raster form. However the vector features carried by the image, such as building lines, roads etc., have to be represented in various layers. This purpose needs a proper feature extraction process. Manual and automatic feature extractions in this study are the methods depending on different methodology.

Manual extraction is performed by on-screen vectorization of images. The operator has to perform the vectorization process considering the line properties of features, such as border of roofs or side or centre line of roads. The relation between the geometric resolution of HRSIs and the published map scale, as mentioned before, has to be considered as the limiting factor in this process. Experience of operator, performance of operation, and used time is an important limiting factor.

Automatic feature extraction, or object-oriented classification, is based on the segmentation of images. This method takes the form, texture and spectral information into account. Its classification phase starts with the crucial and initial step of grouping neighbouring pixels into meaningful areas, which can be handled in the later step of classification. Such segmentation and topology generation must be set according to the resolution and the scale of the expected objects. By this method, not single pixels are classified but homogenous image objects are extracted during a previous segmentation step (Marangoz et al., 2006).

Auxiliary data such as a vector map can be used to improve the performance of this method. However in this paper no additional data has been used for both methods.

4. TEST AREA AND USED IMAGES

Zonguldak city, located in Western Black Sea Region of Turkey, has been selected for this study. This area is known with the mining activities that have continued over 150 years. The mountainous area is partly urban, by a small percentage used for agriculture, otherwise dominated by forest. The build up area is located at the sea side and inclined to north direction. The elevation ranges from the sea level up to 500 m in the city centre. Small houses, narrow roads and partially unplanned urbanization are other main characteristics of the city centre.

Sub-parts of images have been investigated. The selected areas include three urbanization types. First type is urban, planned and unplanned, including also small buildings on inclined topography. The second type is the main campus of Zonguldak Karaelmas University including large buildings. The third type is a residential area located on a semi-sloped area includes double or triple houses partly influenced by trees and bushes. Panchromatic and pan-sharpened images of IKONOS and QuickBird and panchromatic images of OrbView-3 have been analysed for its information contents and compared with 1:5000 scale topographic maps. Pan-sharpened images are generated by Focus in PCI Geomatica 9.1. Colour images of OrbView-3 are not available because the panchromatic and colour images could not be taken together by this satellite. A number of issues are related to the fact that the images have not been taken at the same day (GEOEYE, 2006).

5. RESULTS OF FEATURE EXTRACTION

The vector maps as result of manual extraction have been verified against the existing 1:5000 topographic maps. However the similar comparison has not been performed for the automatic extraction in this study, since a comparison for number or length of layers is unavailable. Only some edges of individuals in building layer are presented by a vector like in manual extraction. Other layers are presented in a classification image (Figure 6).

5.1 General Consideration

In both extraction methods, geometric-, radiometric- and also spectral-resolution are helpful for detection and identification of

objects. The HRSIs include much more details than the images with lower geometric resolution for the purpose of topographic mapping. Comparing IKONOS, QuickBird and OrbView-3 images, one can realize the higher resolution of QuickBird, which includes more details such as for example the lines of a basketball field, which can not seen in IKONOS and OrbView-3 images. Since IKONOS and OrbView-3 have nearly same nominal GSD value, there is no clear difference between their images, but the OrbView-3 images are a little more blurred, caused by its staggered CCD-line technology.

Not only geometric- but also radiometric-resolution is an important factor. IKONOS, QuickBird and OrbView-3 panchromatic images have 11 bits (2048 grey values), but the used range of grey values is not going over the whole range, so under operational conditions a qualified change from 11 bits to 8 bits grey values does not lead to a remarkable loss of information. For manual mapping, no advantage of 11 bit against 8 bit radiometric resolution has been seen. Only in areas with large grey value differences the 11 bit resolution has some advantage, but this is not influencing the generated map. Such details are important only for automatic image matching and also for automatic object extraction

The lower resolution of colour images does not allow the extraction of objects on the same level as with the higher resolution panchromatic images. On the other hand, the use of the colour information together with the panchromatic information by pan-sharpening has advantages for the object classification and identification. In the pan-sharpened images, artificial objects like buildings can be seen quite better as in panchromatic images, but with more intensive inspection, the details also can be seen in panchromatic images. The colour information simplifies the object recognition and avoids the loss of single objects during mapping. The advantages of the higher resolution of panchromatic images against the original lower resolution of colour images for mapping purposes is obvious in Figure 3. It is not a problem to plot the building details with 60cm GSD (Figure 3, centre). The effect of the higher resolution for mapping can be seen in the overlay of the generated building lines in Figure 3 (right). In this case the pan-sharpened image has had no advantage for mapping.

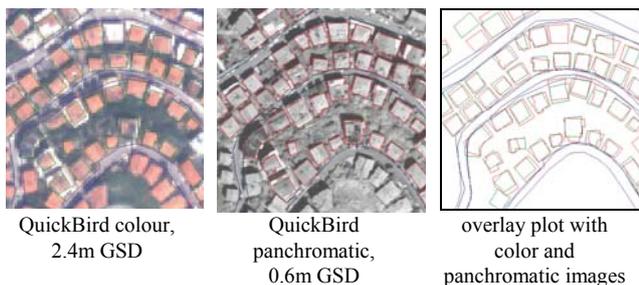| QuickBird colour, 2.4m GSD | QuickBird panchromatic, 0.6m GSD | overlay plot with color and panchromatic images |

Figure 3. Comparison of mapping with QuickBird color image (2.4m GSD) and panchromatic (0.6m GSD).

As mentioned in §4, an important characteristics of the Zonguldak test area is the location on a mountainous topography. It has partially planned but mostly unplanned urbanized areas with small buildings which are very close to each other and also to the roads. Some buildings are partially hidden by trees. Narrow roads are dominating and these roads are close to high buildings. These is shown in Figure 4.

Figure 4. Example of inclined (up to 30°) urbanized area in Zonguldak.

The sun elevation and satellite view direction have not to be underestimated in addition to the object height and location. Since the equatorial crossing time of the spacecraft is 10.30 am in local time and the latitude of Zonguldak city centre is 41.5°, the sun elevation is ranging between 63° and 67°. Relating with the season, length of the shadow is not a negligible problem although some objects like narrow roads or sidewalks are in the shadow. On the inclined, north oriented topography the length of shadows are longer as in a flat area. Not only sun elevation but also sun azimuth is important since the shadow direction is changed by the sun azimuth. The operator can mostly vectorize the details in the shadow by manual extraction whereas some areas in shadow are classified as "sea" layer by automatic extraction.

Different facades of a building are seen on the stereo images due to the view direction, the view angle and object heights which are important for object identification. Because one object can be seen in one image of a stereo pair is can be seen in a different manner in the other image. This situation affects badly the success of automatic image matching for DEM generation, or for automatic feature extraction. However the convergent view is useful for some applications such as single image processing (Willneff et al., 2005).

Detection and identification of objects from high resolution space images depend upon texture of area and object contrast. The success of detection and identification is dominated by the different areas which are planned or unplanned, residential, business or industry, with or without trees etc. Usually the planned areas include large buildings with regular shapes opposite to unplanned areas having small and not regular objects. These unplanned parts located in the inclined parts of Zonguldak city center look dissimilar from different viewing directions. Caused by the different imaging time and different geometric resolution, some negligible discriminations, like shadows or radiometric quality are observed among the images. These discriminations are not dominant over planned area since the objects like buildings or roads have regular sharp shapes and both object types can be detected and identified. Despite that Orbview-3 has some blurring effect since its 2 m size of the projected pixel but 1 m GSD value, the planned area can be easily detected and identified. The same success is not available with the objects in unplanned areas. The problem is with not regular edges of roads and south edge of the roofs which mixes with texture of its neighbor objects or ground. The north edges are detected simpler as south edges thanks to the shadow.

5.2 Results of Manual Extraction

Figure 5 shows the overview of 1:5000 scale topographic vectoral map, i.e. reference map, and manual vectorization results of the images. The reference map includes more details than the maps generated from the images used in this study.

Table 2 shows the joint layers on the reference map and the maps based on space images. The reference map has more buildings than the maps based on images, since a building detected on the image may contain more as one building in the map. Additionally, the real shape of the buildings is not extracted from the images. So the number of buildings is at least 30% more in the reference map. Maps from pan-sharpened images of IKONOS and QuickBird include more buildings than maps based on panchromatic images, caused by the color of roofs supporting the object detection.

Detection of small buildings is difficult since the roof and its neighboured environment are not easily separated from each other. So the number of buildings with undefined shape in the panchromatic images is nearly two times as much as based on pan-sharpened images. Comparing the ratio of buildings between reference map and maps based on images, the percentage in the maps based on images is similar, ranging from 61% to 70%. However, just OrbView-3 panchromatic image has the group of buildings which are not detected as individual buildings. QuickBird pan-sharpened image has one less sport yards than the map of IKONOS panchromatic because during imaging this sport yards was under construction.
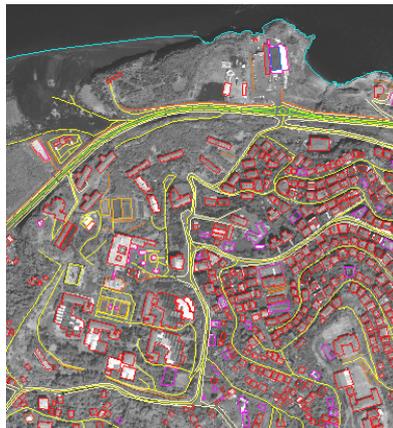
The detected walls are very short compared to the reference map. The walls in maps based on images are mostly the retaining-walls whose surface is wider as 1 m. Other walls at the border between the gardens are not detected because of the limited geometric resolution of the images. Maps based on IKONOS pan-sharpened image include less than two times the walls as the map based on IKONOS panchromatic image. Because the pan-sharpened image has longer shadows as the panchromatic image and many walls are hidden in the building shadows. This situation proves that the shadow is very effective for detecting the line objects even on the pan-sharpened images. The reference map has not a layer named "sidewalks" since the sidewalks are shown by the sidelines of roads and the trotuar. However the study on the image has this layer. The longest sum of sidewalks has been vectorized on the QuickBird image where the shortest sidewalks belongs OrbView-3 panchromatic image. Sidelines of the roads are not detected easily on the IKONOS images because of the building shadows which cover the roads. Only 37% of the sidewalks are extracted from the pan-sharpened QuickBird image, however at least 89% of the roads are detected. The ratio of QuickBird images over 100% is caused by the reference map which has a path-layer while the road-layer of the maps based on QuickBird includes roads and paths in the same layer.
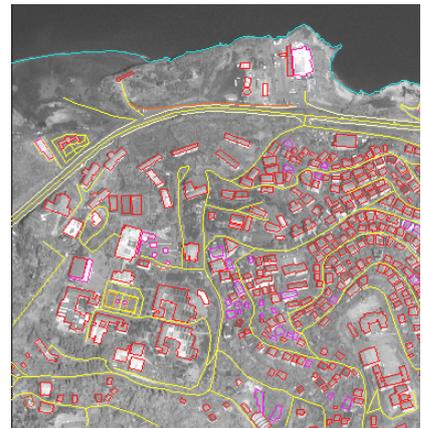
Since the path is not separated from the road, sidewalks are detected but the ratio is below 10%. The curls of the coastal line has not detected as long as in the reference map (at least 68.6%). For the pools, the color is important, because the pools are detected only on the pan-sharpened images.
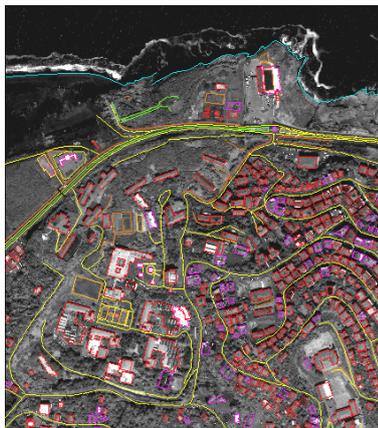
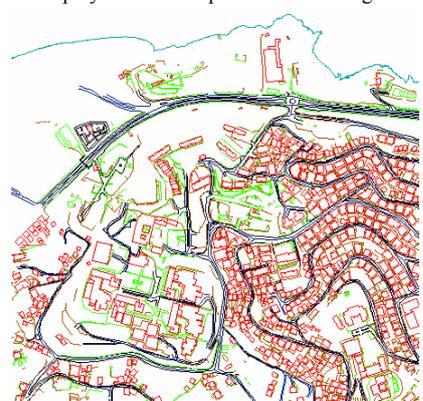Map by IKONOS panchromatic image   Map by QuickBird panchromatic image   Map by OrbView-3 panchromatic image

Map by IKONOS pan-sharpened image   Map by QuickBird pan-sharpened image   1:5000 scale topographic map

■ Unidentified or under-construction building   ■ Concrete-floor   ■ Building   ■ Wall   ■ Pavement
■ Coast line   ■ Bridge   ■ Sport yard   ■ Trotuar   ■ Sideline of roads   ■ Central line of roads

Figure 5. Overplotting of vectorized and reference maps.

	1:5000	IKONOS Panchromatic	IKONOS Pan-sharpened	QuickBird Panchromatic	QuickBird Pan-sharpened	OrbView-3 Panchromatic
# Cemetery area	NA	7	11	10	26	11
% Building	100%	55%	64%	60%	65%	60%
% Building (with undefined shape)		10%	6%	7%	3%	1%
% Sport yards	100%	50%	63%	63%	50%	25%
# Group of building	NA	NA	NA	NA	NA	32
% Wall	100%	4%	1.9%	4.4%	3.4%	NA
Sidewalk	NA	1060 m	1384 m	1671 m	2606 m	354 m
Sideline of road	100%	3.8%	3.9%	26.7%	37.28%	7%
Roads	100%	95%	89%	111%	110.6%	91%
Sidewalk 2	100%	8.6%	6.5%	7.5%	7.3%	NA
Coastal line	100%	71.9%	68.6%	83.2%	83.1%	76.1%
Pool	1	Na	1	NA	1	NA

Table 2. Comparison of joint layers of the 1:5000 topographic map and the maps generated by means of space images.

NA: Layer not existing in reference map or not detected in image

5.3 Results of Automatic Extraction

The layers in automatic extraction are only buildings, green fields, sea and roads. At first, the test areas have been selected for these layers, and then the segmentation process was performed. The segmentation parameters used in this study are listed in Table 3. The segmentation is terminated when the optimal expected extraction is achieved. Excepting the pan-sharpened image of QuickBird, the segmentation is terminated in 4th or 5th levels. For all 2nd segments the spectral mode as the segmentation mode is necessary to combine the segments in the 1st level using the spectral information. The parameters shape and colour, and compactness and smoothness complete together 1 while the segmentation mode is Normal. Since the buildings and roads are the most emphasized layers, the shape factor is not selected under 0.5. Compactness and smoothness are equal to 0.5 in our study.

The final results can be seen in Figure 6. In all images with the exception of OrbView-3, the sea layer existing on land are caused by the similarity of grey values of sea and shadow. The buildings were not generally extracted separately, i.e. this layer includes the pavement around and also among the buildings. Only buildings surrounded by a contrast-texture could be extracted. The road-network is extracted successfully in QuickBird panchromatic image whereas this layer does not exist in IKONOS pan-sharpened and OrbView-3 images. Sea is entirely extracted.

6. CONCLUSION

The panchromatic and pan-sharpened images of IKONOS and QuickBird, and the panchromatic OrbView-3 image of Zonguldak test area have been investigated with respect to information content for topographic mapping by manual and automatic extraction, which depends on different methodologies. In both methods, the geometric-, radiometric- and spectral-resolution, effective GSD, colour, object contrast, atmospheric condition, session time, sun elevation and topographic condition of imaged area are the important parameters for the object identification. For this reason, the high geometric-, radiometric- and spectral-resolution of the images have to be merged in the pan-sharpened image. However, the panchromatic and colour images have to be taken at the same time for producing pan-sharpened image, which is unavailable for OrbView-3.

The length of line objects by manual extraction is shorter as in the reference map. But the same ratio is not valid for the buildings and the roads. This is an important example of the effect of shadow and atmospheric condition on the detection of objects.

Table 3. Segmentation parameters of automatic extraction.

Levels	Scale Param.	Seg. Mode	Shape-Colour	Com. – Smt.
IKONOS PAN				
Level 1	5	Normal	0.9-0.1	0.5-0.5
Level 2	5	SD	-	-
Level 3	10	Normal	0.5-0.5	0.5-0.5
Level 4	10	Normal	0.9-0.1	0.5-0.5
QuickBird PAN				
Level 1	3	Normal	0.9-0.1	0.5-0.5
Level 2	3	SD	-	-
Level 3	5	SD	-	-
Level 4	5	Normal	0.5-0.5	0.5-0.5
Level 5	5	Normal	0.9-0.1	0.5-0.5
OrbView-3 PAN				
Level 1	5	Normal	0.9-0.1	0.5-0.5
Level 2	5	SD	-	-
Level 3	7	Normal	0.5-0.5	0.5-0.5
Level 4	8	Normal	0.9-0.1	0.5-0.5
IKONOS pan-sharpened				
Level 1	5	Normal	0.5-0.5	0.5-0.5
Level 2	5	SD	-	-
Level 3	7	Normal	0.5-0.5	0.5-0.5
Level 4	10	Normal	0.9-0.1	0.5-0.5
Level 5	15	Normal	0.9-0.1	0.5-0.5
QuickBird pan-sharpened				
Level 1	2	Normal	0.9-0.1	0.5-0.5
Level 2	5	SD	-	-
Level 3	5	Normal	0.9-0.1	0.5-0.5
Level 4	6	SD	-	-
Level 5	6	Normal	0.9-0.1	0.5-0.5
Level 6	6	Normal	0.5-0.5	0.5-0.5
Level 7	8	Normal	0.5-0.5	0.5-0.5
Level 8	10	Normal	0.5-0.5	0.5-0.5
Level 9	10	Normal	0.9-0.1	0.5-0.5

SD: Spectral Difference, **Com**: Compactness, **Smt**: Smoothness

IKONOS panchromatic image   QuickBird panchromatic image

IKONOS pan-sharpened image   QuickBird pan-sharpened image

Sea

Green area

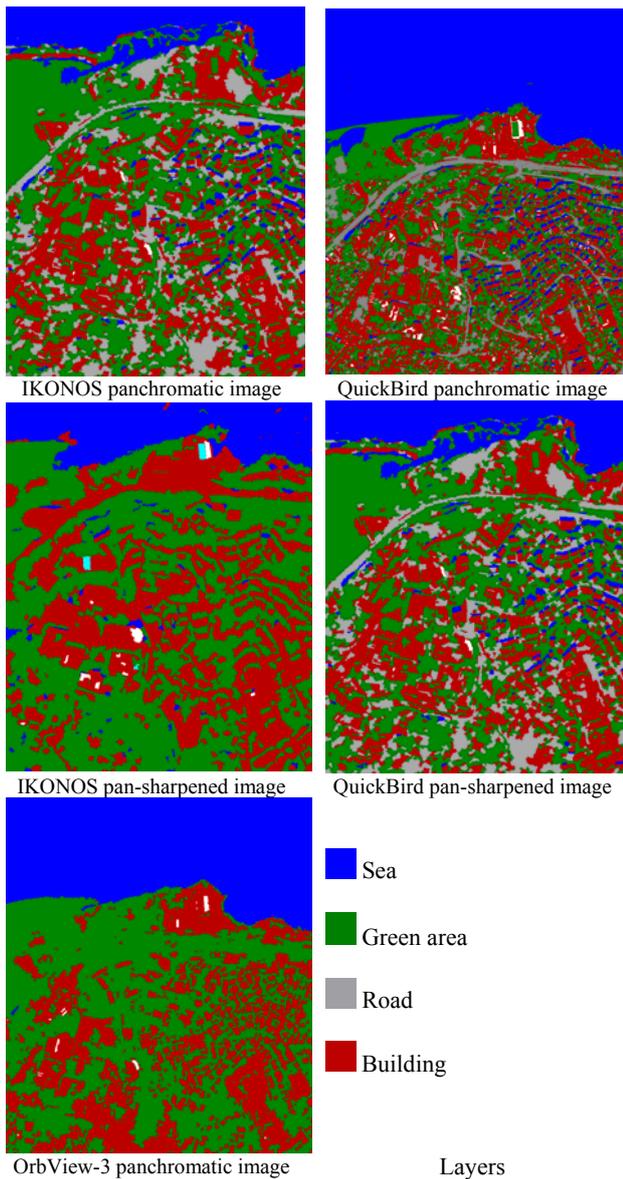Road

Building

OrbView-3 panchromatic image   Layers

Figure 6. Results of automatic extraction.

The topographic condition and the object contrast of the investigated area are the other important parameters. The buildings in the unplanned areas are not detected with their real shape while the buildings are detected easily in the planned areas. But the main problem of automatic building extraction is to get their real shape. The required pixel size for satisfying recognition is below 0.6 m.

By automatic extraction a smaller number of layers compared to manual mapping can be determined. Most of the buildings could not be extracted individually with the exception of buildings surrounding by the contrast. Shadow is an important limiting factor, since several shadowed areas in land has been classified as sea layer. Narrow roads surrounded by buildings can not be extracted as line form, apart from the highway located in the north side of the area.

The manual extraction has more reliable results compared to automatic extraction. However the experience of the operator is very important, and the time spent has to be considered. Automatic extraction can be quite faster. However there are no

fixed segmentation parameters for the images. The experience of the operator is also important.

High resolution space images can be used for topographic mapping. However, the 1:5000 scale maps are not generated by these images in spite of the fact that the accuracy is sufficient. The limited information content corresponds to the map scale 1:10000 of topographic maps.

7. ACKNOWLEDGMENT

8. REFERENCES

GEOEYE Support Services Department, 2006. Personal Communication.

Jacobsen, K., 2002. Geometric aspects of the handling of space images, *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Denver, USA, Vol. XXXIV, Part B1, pp. 89–93.

Jacobsen, K., Büyüksalih, G., Marangoz, A. M., Sefercik, U. G., Büyüksalih, İ., 2005. Geometric conditions of space imagery for mapping. *Proceedings of 2nd International Conference on Recent Advances in Space Technologies Space in the Service of Society*, RAST 2005, Istanbul, Turkey, pp. 511-516.

Jacobsen, K., 2008, *Geometric modelling of linear CCDs and panoramic imagers*. In: Li, Z.; Chen, J.; Baltsavias, E. (Hrsg.): Advances in Photogrammetry, Remote Sensing and Spatial Information Science. Taylor and Francis, London, pp. 145-155.

Aycan M. MARANGOZ, Zübeyde ALKIŞ, Serkan KARAKIŞ, 2007, Evaluation of Information Content and Feature Extraction Capability of Very High Resolution Pan-Sharpened QuickBird Image, Conference on Information Extraction from SAR and Optical Data, with Emphasis on Developing Countries, Istanbul, Turkey, 5 pages on unpaginated CD-ROM.

Schowengerdt, R. A., 1997, *Remote Sensing: Models and Methods for Image Processing*, Academic Press, pp. 78-83.

Topan, H., Mahtav, D., Jacobsen, K., and Büyüksalih, G., 2009, Information Content of Optical Satellite Images for Topographic Mapping, *International Journal of Remote Sensing,* Vol. 30, No. 7, pp. 1819–1827.

Willneff, J., Poon, J. and Fraser, C, 2005. Single-image high-resolution satellite data for 3D information extraction. *ISPRS Hannover Workshop 2005 "High-Resolution Earth Imaging for Geospatial Information"*, Hannover, Germany. 6 pages on unpaginated CD-ROM.