OBJECT-ORIENTED IMAGE ANALYSIS AND SEMANTIC NETWORK FOR EXTRACTING THE ROADS AND BUILDINGS FROM IKONOS PAN-SHARPENED IMAGES

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PS WG III/4

KEY WORDS: Hierarchical, Contextual, Segmentation, Object-oriented, Classification, High resolution

ABSTRACT:

Traditional pixel-based approaches are based exclusively on the grey value of pixel itself. Thereby only the spectral information is used for the classification. The situation becomes worse when extracting the certain features only. An object-oriented image analysis is implemented in order to overcome the limitation mentioned above. The existing software, eCognition v3.0 allows the polygon based classification process. It is based on fuzzy logic, allows the integration of a broad spectrum of different object features, such as spectral values, shape and texture. This study demonstrated the extraction of buildings and roads from the high-resolution Ikonos pan-sharpened image data by first dividing it into the segments and then classifying it using the spectral, spatial and contextual information. The test site was agro-industrial area in the city of Zonguldak which has rolling topography along the Black Sea coast. Land use classification results as well as the spatial information can be exported to GIS environment for evaluation purposes with existing larger scale cadastral maps and other available ground truth materials.

1. INTRODUCTION

Classification relies on the pixel-based approaches is limited at present. Typically, they have considerable difficulties dealing with the rich information content of high-resolution data e.g. Ikonos images, they produce inconsistent classification results and they are far beyond the expectations in extracting the object of interest. This situation brings meaningful operator intervention to the implementation. Due to mentioned nature of classical methods, new and object-oriented image analysis of eCognition software can be used. Such algorithm requires one or more image segmentations which should also be supported by the additional information like contextual or textual to make the segments more appropriate for improve classifications.

Object-oriented approach takes the form, textures and spectral information into account. Its classification phase starts with the crucial initial step of grouping neighboring 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. This segmentation can be done in multiple resolutions, thus allowing to differentiate several levels of object categories. Automatic recognition and segmentation of the common objects, eg. buildings and houses from high-resolution images, eg. Ikonos and Quickbird was investigated some users with a certain degree of success (see, Hofmann, 2001a, b and c).

In this study, object-based classification of buildings and roads in the Zonguldak testfield of Turkey has been realized by eCognition v3.0 software. Classification procedure has been implemented using pan-sharpened Ikonos image of the interest area. Such an image can be easily formed by the pan-sharpening module of PCI Geomatica 9.1.1 system. Several tests have been carried out to match with the successful segmentation, then the classification by entering different parameters to the used software. Authors, finally comments on the pros and cons of the object-oriented based image analysis with the detailed explanation of the obtained results.

2. EXPERIMENTAL AREA AND DATASETS

Zonguldak testfield is located in Western Black Sea region of Turkey. It is famous with being one of the main coal mining areas in the world. Although losing economical interest, there are several coal mines still active in Zonguldak. Area has a rolling topography, in some parts, with steep and rugged terrain. While partly built city area is located alongside the sea coast, there are some agricultural lands and forests in the inner part of the region. The elevation ranges roughly up to 800m inside the area covered by Ikonos imagery. Two Ikonos Geo PAN images of this testfield were purchased from SI Eurasia which is the regional affiliate of SI and located in the Turkish Capital, Ankara. Important characteristics included in the metadata files of these images are given as follows:

Characteristics	Ikonos Geo-product PAN images	
	Image I	Image II
Date, Time	02/07/2002, 08:52 GMT	02/10/2002 08:59 GMT

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Nominal collection azimuth (deg)	41.2363	10.5023
Nominal collection elevation (deg)	69.6502	63.2446
Sun angle azimuth (deg)	138.2219	166.2923
Sun angle elevation (deg)	67.2403	41.5399
Nadir angle (deg)	20.3498	26.7554
Image size (pixels in row, column)	11,004x11,000	11,004x11,000
Reference height (m)	206.78	208.04

While the scene named as mage I was acquired on July 2002, Image II was taken on October, 2002. These images are almost covering the same area on the ground and studied part of the Image II is shown in Fig. 1. In the upper part of the Ikonos image, Black Sea is lying and other parts of the image includes central part of the Zonguldak city which covers nearly 10x10km area with the elevation range up to 450m. When the images first received, they were analysed for selecting suitable GCPs distributed on them uniformly. As a result of this determination, 43 distinct GCPs were measured by GPS survey with an accuracy of about 3cm. Since those points can be seen very well on the images, they were selected as building corners, crossings, etc. Because of the fine resolution of Ikonos imagery, many cultural features can be identified and used as GCPs. The manual measurements of GCPs' image coordinates were carried out by GCP Collection Tool under PCI Geomatica-OrthoEngine software package with zoom factor 4. Thus, accuracy of image coordinates could be expected in the range of 0.2-0.3 of a pixel. Geometric correction of these by different mathematical models produced the rmse values of about 1 pixel.

Results of geometric correction of Ikonos Geo-product imagery has been given in detail in Buyuksalih, et al., 2003.

Figure 1. Ikonos pan-sharpened image of the study of area

Before analysing the Ikonos image with eCognition it was enhanced by applying a pan-sharpening method used in PCI system. This method makes it possible to benefit from the sensors spectral capabilities simultaneously with its high spatial resolution. Thereby the first principal component of the four spectral IKONOS channels (4m resolution) was substituted by the 1m resolution IKONOS panchromatic channel. This new combination of principal components then was re-transformed applying an inverse principal components transformation.

3. IMAGE SEGMENTATION AND CLASSIFICATION BY ECOGNITION V3.0

Segmentation is the main process in the eCognition software and its aim is to create meaningful objects. This means that the shape of each object in question should ideally be represented by an according image object. This shape combined with further derivative colour and texture properties can be used to initially classify the image by classifying the generated image objects. Thereby the classes are organised within a class hierarchy. Each class can have a sub- or super-class and thus inherit its properties from one or more super-classes or to its subclass (es). With respect to the multi-scale behaviour of the objects to detect, a number of small objects can be aggregated to form larger objects constructing a semantic hierarchy. Likewise, a large object can be split into a number of smaller objects which basically leads to two main approaches of image analysis: A top-down and a bottom-up approach (see Benz, U., et al., 2003 and eCognition User Guide, 2003).

In eCognition both approaches can be realised performing the following steps:

- Creating a hierarchical network of image objects using the multi-resolution segmentation. The upper-level image segments represent small-scale objects while the lower-level segments represent large-scale objects.
- Classifying the derived objects by their physical properties. This also means that the class names and the class hierarchy are representative with respect to two aspects: the mapped real-world and the image objects' physically measurable attributes. Using inheritance mechanisms accelerates the classification task while making it more transparent at the same time.
- Describing the (semantic) relationships of the network's objects in terms of neighbourhood relationships or being a sub- or super-object. This usually leads to an improvement of the physical classification res. the class hierarchy.
- Aggregating the classified objects to semantic groups which can be used further for a so called 'classification-based' segmentation. The derived contiguous segments then can be exported and used in GIS. The semantic groups can also be used for further neighbourhood analyses.

These steps describe the usual proceeding when working with eCognition. While the first two steps are a mandatory, the latter two steps may be advisable according to the user's objectives and content of the image.

In the segmentation phase, following parameters should be assigned as accurate as possible, of course, suiting with the reality:

- **Scale parameter**: this parameter indirectly influences the average object size. In fact this parameter determines the maximal allowed heterogeneity of the objects. The larger the scale parameter the larger the objects become.
- **Color/Shape**: with these parameters the influence of color vs. shape homogeneity on the object generation can be adjusted. The higher the shape criterion the less spectral homogeneity influences the object generation.
- **Smoothness/Compactness**: when the shape criterion is larger than 0 the user can determine whether the objects shall become more compact (fringed) or more smooth.

Segmentation phase is followed by the classification of images. eCoginition software offers two basic classifiers: a nearest neighbour classifier and fuzzy membership functions. Both act as class descriptors. While the nearest neighbour classifier describes the classes to detect by sample objects for each class which the user has to determine, fuzzy membership functions describe intervals of feature characteristics wherein the objects do belong to a certain class or not by a certain degree.

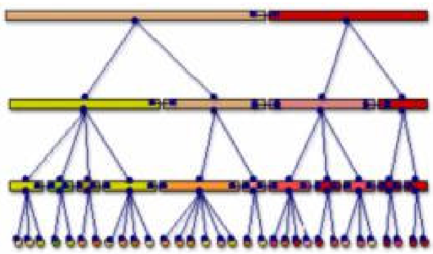


Figure 2. Hierarchical network of image

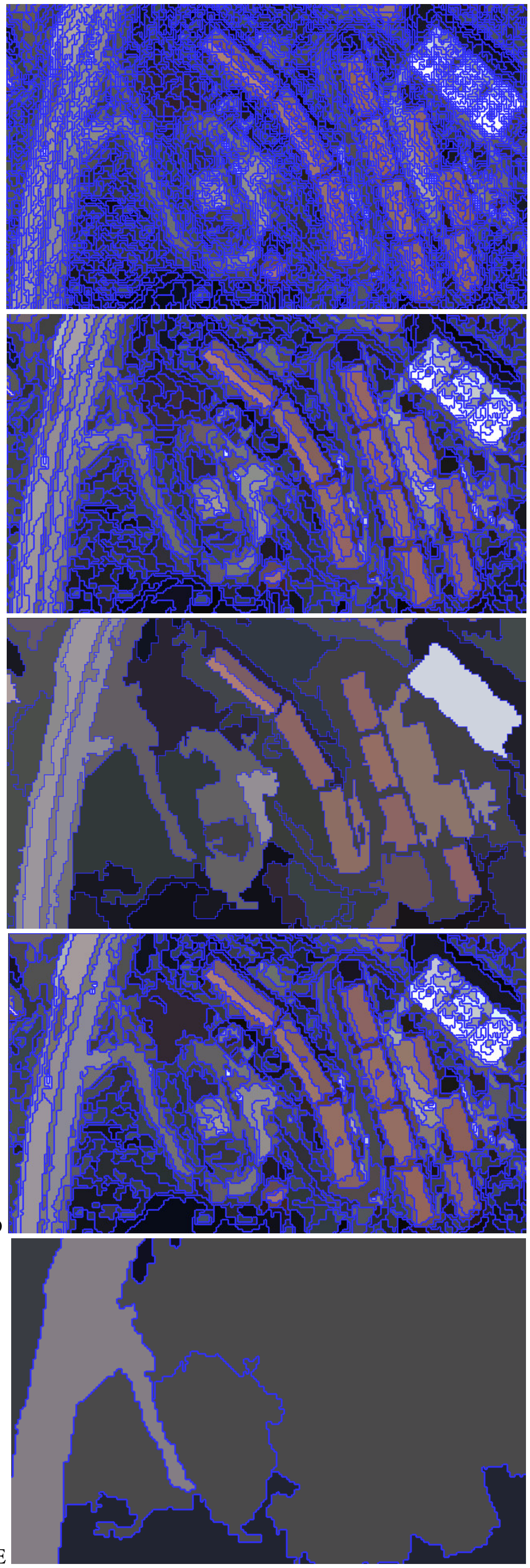
Thereby each feature offered by eCognition can be used either to describe fuzzy membership functions or to determine the feature space for the nearest neighbour classifier. A class then is described by combining one or more class descriptors by means of fuzzy-logic operators or by means of inheritance or a combination of both (see Fig. 2). As the class hierarchy should reflect the image content with respect to scale the creation of level classes is very useful. These classes represent the generated levels derived from the image segmentation and are simply described by formulating their belonging to a certain *level*. Classes which only occur within these levels inherit this property from the level classes. This technique usually helps to clearly structure the class hierarchy.

4. CLASSIFICATION AND ACCURACY ASSESSMENTS

Object-based segmentations were tried using different scale parameters (see Table 1). As can be realized that the smaller scale increases the dimensionality and dividing the object into the sub-groups, while the larger scale combines the multi-segments into one (see Fig. 3).

Level	**1**	**2**	**3**	**4**	**5**
Scale par.	5	10	16	25	250
Color	0.7	0.5			0.4
Shape	0.3	0.5			0.6
Smoothness	0.9	0.9			0
Compactness	0.1	0.1			1
Seg. mode	normal	normal	Spect. Diff.		normal

Table 1. Segmentation parameters used for image



A B C D E

Figure 3. Image segmentation using five different scale parameters. Scale parameter A = 5, B = 10, C = 16, D = 25, E = 250

Especially, in the proximity of the buildings, this situation causes interference in the segmentation phase. In the first step, classes were assigned and the convenient criteria were selected to include the segment in those classes. Results of the classification procedure are shown in Fig. 4.

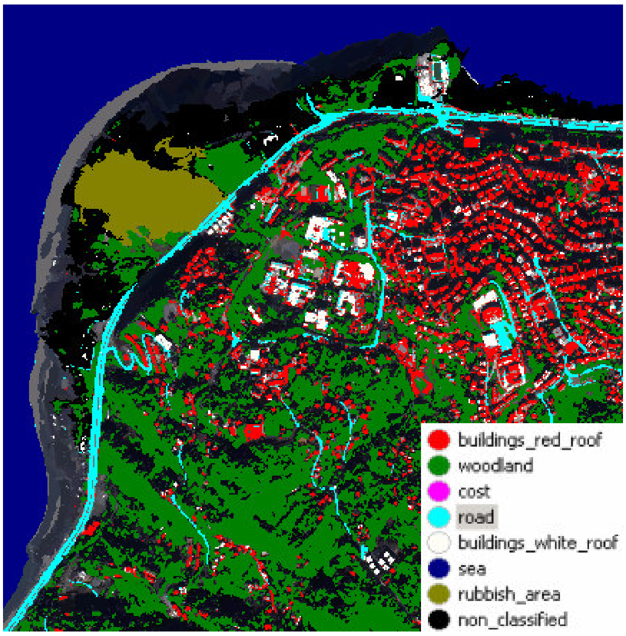


Figure 4. Result of object-oriented classification

Regarding the results gained from the created class hierarchy, most of the buildings and roads could be identified. However, manual revision of the classification could not be avoided and the objects that are misclassified with buildings and roads should be manually erased from these classes. Classification quality seems strongly depends on the quality of the initial segmentation and the DEM information used in the generation of pan-sharpened image. In this case, the geometrical shift and noise of DEM data used should be taken into consideration. Based on the classification results, eCognition software can produce statistical information for the users. Table has an emphasis because of it shows the error matrix in addition to the different accuracy values. Kappa of 0.84 shows the results suits with the expectation, however, for more reliable results suitable vector layers can be additionally be used.

5. CONCLUSIONS

Because of its high spatial resolution, Ikonos data is well suited to extract buildings and roads. To take advantage of its spectral properties, principal component image enhancement method can be used. In this case, image with 1m ground pixel size, but covering four spectral channels can be generated. It was seen that object-oriented analysis technique can reveal satisfied result for extracting the main land objects, e.g. roads and buildings.

6. REFERENCES

Benz, U. C., Hofmann, P., Willhauck, G., Lingenfelder, I. and Heynen, M. 2003. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information, *ISPRS Journal of Photogrammetry & Remote Sensing,* 58 (2004) pp. 239-258

Buyuksalih, G., Kocak, G., Oruc, M., Akcin, H. and Jacopsen, K. 2003. Handling of Ikonos Images from Orientation Up to DEM Generation. *Proceeding of the Workshop on Mapping from Space 2003,* Hannover, (on CD-ROM)

eCognition User Guide 3. 2003. Definiens Imaging, pp.3.2-108

Hofmann, P., 2001a. Detecting buildings and roads from IKONOS data using additional elevation information. In: *GIS Geo-Information-System,* 6/2001.

Hofmann, P., 2001b. Detecting informal settlements from IKONOS image data using methods of object oriented image analysis - an example from Cape Town (South Africa). In: Jürgens, Carsten (Editor): *Remote Sensing of Urban Areas/* Fernerkundung in urbanen Räumen. (=Regensburger Geographische Schriften, Heft 35), Regensburg.

Hofmann, P., 2001c, Detecting urban features from IKONOS data using an object-oriented approach. In: *RSPS 2001, Geomatics, Earth Observation and the Information Society,* 2001

7. ACKNOWLEDGEMENTS

Parts of the presented results have been supported by TUBITAK, Turkey and the Jülich Research Centre, Germany. The authors wish to thank Serkan KARAKIS for his help during this study.