3D CULTURAL HERITAGE DOCUMENTATION OF SAFRANBOLU TEST SITE USING HIGH RESOLUTION SATELLITE IMAGERY

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ABSTRACT

The city of Safranbolu in Turkey contains well-preserved items of many civilizations (Roman, Byzantine, Seljuk and Ottoman). Although the city has been well preserved in comparison to other heritage sites and studies have been done by different groups at different times, there is a lack of an integrating study covering all aspects of the cultural heritage components (like urban planning with pre-feasibility of the proposed functionalities of the different zones and integration of the citizens into the planning steps).

In this study, the location and characteristics of historical, cultural and art monuments situated at a site will be determined using high resolution satellite imagery and related processing technologies. In this case, pan-sharpened IKONOS imagery was segmented and then classified using eCognition v4.0.6 object-oriented analysis software. Ground truthing of acquired results by the available maps, aerial photographs and site checks follows. It was seen that, based on the extracted results, development of an information and management system for recording analysis, protection and revitalization of cultural heritage sites of Safranbolu can successfully undertaken and integrated to the GIS environment.

INTRODUCTION

Classification relies on the pixel-oriented 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, 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 differentiating several levels of object categories. Automatic recognition and segmentation of the common objects, e.g. buildings and houses from high-resolution images, e.g. IKONOS and QuickBird were investigated some users with a certain degree of success (i, ii and iii).

In this study, object-oriented classification of historical buildings in the Safranbolu test field has been realized by eCognition v4.0.6 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 9.1.6 system. Several tests have been carried out to match with the successful segmentation, then the classification by entering different parameters to the used software. On the other hand, classification results were compared with available maps, aerial photographs and vectorized buildings from image using on-screen digitizing method.

Authors, finally comments on the pros and cons of the object-oriented image analysis with the detailed explanation of the obtained results.

IMAGE SEGMENTATION AND OBJECT-ORIENTED CLASSIFICATION

In remote sensing applications, the process of image segmentation is defined as: “the search for homogenous regions in an image and later the classification of these regions”. Available approaches can be grouped into three categories: pointbased (e.g. grey-level thresholding), edge-based (e.g. edge detection techniques) and region-based (e.g. split and merge). In the region-based category, image objects are generated according to a certain homogeneity criteria (iv).

In this study, image segmentation and object- oriented classification phase were derived by using eCognition v 4.0.6 software. This software offers a relatively segmentation technique called Multiresolution Segmentation (MS). Cause of MS is a bottom-up region-merging technique; it is regarded as a region-based algorithm. MS starts by considering each pixel as a separate object. Subsequently, pairs of image objects are merged to form bigger segments.

The merging decision is based on local homogeneity criterion, describing the similarity between adjacent image objects. The pair of image objects with the smallest increase in the defined criterion is merged. The process terminates when the smallest increase of homogeneity exceeds a userdefined threshold (the so called Scale Parameter – SP). Therefore a higher SP will allow more merging and consequently bigger objects, and vice versa. The homogeneity criterion is a combination of color (spectral values) and shape properties (shape splits up in smoothness and compactness). Applying different SPs and color/shape combinations, the user is able to create a hierarchical network of image objects. (vi).

Image segmentation phase is followed by the classification of images. eCognition 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.

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. 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 (v).

EXPERIMENTAL AREA AND DATASET

The city of Safranbolu contains well-preserved items of many civilizations (Roman, Byzantine, Seljuk and Ottoman). It is a city which preserves all its values: monuments, sites, groups of buildings, and an historic shopping area. There is a great homogeneity between these elements. It is a typical Ottoman city that has survived to the present day. Safranbolu was placed in the world Cultural Heritage list by UNESCO in appreciation of the successful efforts in the preservation of its heritage as a whole. The city has deserved its real name for its cultural houses. It also displays an interesting interaction between the topography and the historic settlement. The architectural forms of the buildings and the streets are illustrative of their period (viii).

Safranbolu consists of four distinct districts - the market place area of the inner city, known as Çukur (The Hole), the area of Kıranköy, Bağlar (The Vineyards), and an area of more recent settlement outside the historic area. The city has about 2000 traces that are being protected in the natural tissue as an expression of the historical and cultural wealth. Rock Graves, mounds, Caravanserai and Turkish Baths, The Old Mosques, Shopping Districts, Water Vaults, Fountains, Tombs and Historical Houses are some of the traces that have survived (Fig. 1).

Figure 1: Architecture buildings at the test field of Safranbolu.

Safranbolu has won its first fame with its buildings that have a traditional and special architecture. These houses are wonderful architecture samples that show Turkish society life of 18th and 19th centuries. These splendid houses which carry the effects of crowded family structure, economic wealth and local climate properties are defined as "five sided architecture" because of their roofs. Safranbolu houses are the buildings with 2-3 floors, 6-8 rooms, balconies, and lots of windows in every room. In these buildings; esthetical use of stone, unbelievable quality of wood work, ornaments of wall and ceilings, pools inside the houses, stairs and door knockers (ix).

The test field is chosen from subset of pan-sharpened image of Safranbolu which includes the area of the inner city (This area includes the given architectural buildings: Cinci Caravanserai, Cinci Turkish Bath, Clock Tower, The Old Government Building, The Old Jail, Köprülü Mehmet Pasha Mosque and İzzet Mehmet Pasha Mosque) (Fig. 2). Important characteristics included in the metadata files of this IKONOS image are given in Table 1.

Table 1: Characteristics of IKONOS image of Safranbolu.

Characteristics	**Image**
Date, Time	30/11/2002, 08:54 GMT
Nominal collection azimuth (deg)	31.54100
Nominal collection elevation (deg)	83.69071
Sun angle azimuth (deg)	168.73870
Sun angle elevation (deg)	26.48958
Image size (pixels in row, column)	11608 x 8316
Reference height (m)	869.889

Before analyzing the IKONOS image with eCognition software 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 (v).

Figure 2: IKONOS pan-sharpened image of the study area.

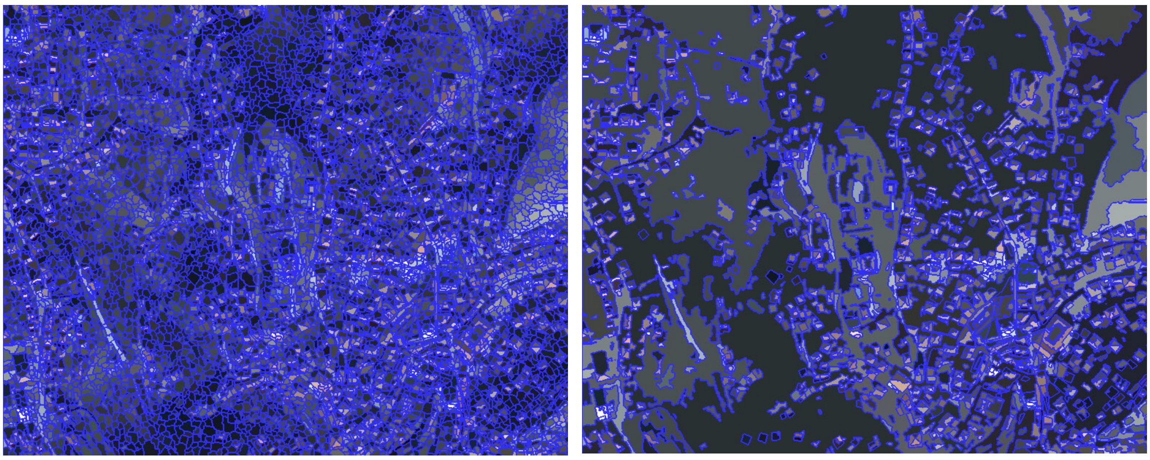
Two vector datasets and available aerial photographs were used to enhance this study. The two vector datasets were 1:1000 scale old line map and digitized buildings from IKONOS image using on-screen digitizing method.

CLASSIFICATION PHASE AND RESULTS

The image was segmented using the previously described MS technique to generate 9 different object-oriented segmentations. In the background, a vector layer which was vectorized from 1:1000 scale old line map was used for this step. So, it could be reached to better segmentation results. Table 2 reports the used scale parameters and criterion combinations. 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).

Table 2: Segmentation parameters used for image.

Level	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Scale parameter	7	7	8	8	9	9	10	10	35
Color	0.1	0.1	0.1	0.1	0.1	0.1	0.1	Spectral Difference	Spectral Difference
Shape	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
Compactness	0.4	0.3	0.3	0.2	0.2	0.1	0.1		
Smoothness	0.6	0.7	0.7	0.8	0.8	0.9	0.9		
Seg. Mode	normal	normal	normal	normal	normal	normal	normal		



Level 1 (Sp = 7) *Level 9 ((Sp = 35)*

Figure 3: Image segmentation using different scale parameters (Level 1, 9).

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 (Fig. 4).

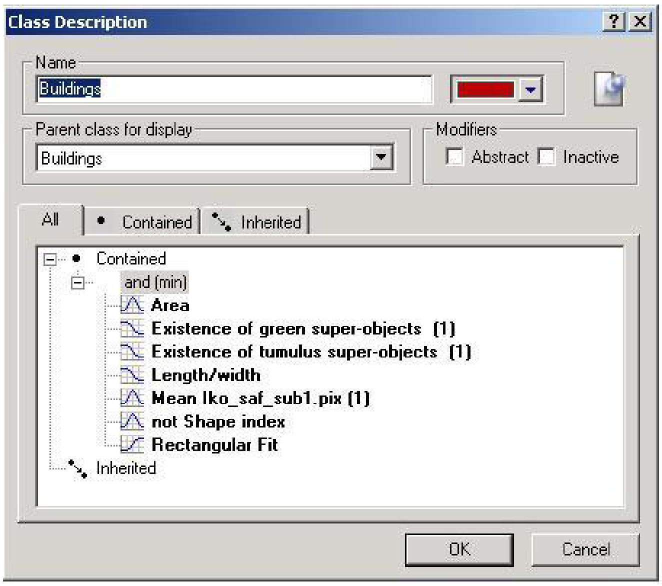


Figure 4: Membership functions for Buildings class.

As shown in Figure 4, gray value, area, shape and class-based criterias were used. First three of these were used for incorporating the segments into the class and others were for separating the objects which were not belong to this class. Then, object-oriented classification was started and the classification results were derived as shown in Fig. 5.

Figure 5: Results of object-oriented classification.

Regarding the classification results gained from the created class hierarchy, most of the architectural buildings in Safranbolu test field could be identified. Classification quality seems strongly depends on the quality of the initial segmentation. For this purpose, a vector layer was used to enhance the quality of segmentation, so well-shaped segments were created.

Based on the classification results, eCognition software can produce statistical information for the users. Overall accuracy of 0.814 shows the results suits with the expectation. Also, some misclassification results caused by similar spectral reflectance between buildings and other objects can be seen from the Fig. 5.

Sun elevation of used IKONOS image is very important for extracting buildings (vii). Hence, the variable shadow length cause of sun elevation was one of the problems at this study. In Safranbolu test field, the historical buildings have roofs which are highly inclined. So, with a low sun elevation of 26.5°, it is difficult to identify west sides of roofs because of shadows. As mentioned above, the assistance vector layer which was integrated to segmentation phase helped to save shadowed roof parts from non-classification.

In eCognition software, producing of vector file can be done easily as a program step. So, the results shown in Fig. 5 were extracted and integrated to GIS software and table data was entered to used GIS software. Thus, the object-oriented results and vectorized buildings using on-screen digitizing results were easily compared and shown in Fig. 6.

Object-oriented classification results

On-screen digitizing results

Figure 6: Comparison of object-oriented results and on-screen digitizing results.

By this comparison, it was seen that, some objects cannot be extracted separately, for instance some of the small buildings were not extracted automatically and close buildings were extracted as one building.

CONCLUSIONS

Turkey has a lot of historical cities and areas under different threat and they should be restored as soon as possible. During these relief or restoration studies the mapping step is certainly needed and the time is another important phase. Safranbolu has been included in the "List of World Inheritance" by UNESCO in 1994 and as a world city because of its success in protecting its natural heritage is just an example of these all heritages in Turkey.

Recording analysis, protection and revitalization of cultural heritage sites are being undertaken by different approaches. Nowadays, information contents of high resolution images can not give sufficient results at pixel-based approaches in remote sensing applications. Thus, object-oriented image analysis is being used next to pixel-based approaches. In the eCognition software which is used for object-oriented image analysis, segmentation is the first and important phase and its aim is to create meaningful objects. In this way, using stereo-images and assistance of vector data help to extract objects easily and increase the accuracy. Then classification follows segmentation phase.

In this study, object-oriented classification of historical buildings from pan-sharpened IKONOS image of Safranbolu test field has been realized by eCognition v4.0.6 software. Because of its high spatial resolution, IKONOS image is well suited to extract objects. To take advantage of its spectral properties, pan-sharpening method can be used. In this case, image with 1m GSD (Ground Sampling Distance), furthermore covering four spectral channels can be generated.

With small GSD of IKONOS image, it was possible to get much more geometric resolution and to identify details on the images. However, based on the extracted results, some problems were occurred because of shadows. With a low sun elevation of image, incorrect classifications were produced by building shadows. In other words, not only the GSD is important, but also the image quality, the spectral range and the number of spectral bands and the sensor type are important for the object extraction. Additionally GSD, atmospheric condition, sun elevation angle, incidence angle and detail contrast are the items effecting on the information contents (vii).

Nevertheless, it was seen that object-oriented image analysis approaches can reveal satisfied result for extracting the buildings using high resolution images. It was seen that, based on the extracted results, development of an information and management system for recording analysis, protection and revitalization of cultural heritage sites of Safranbolu can successfully undertaken and integrated to the GIS environment.

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