CLASSIFICATION ENHANCEMENT IN URBAN AREAS

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ABSTRACT

Within the past years cities have attracted an accelerating growing number of people. The urban environment has such a dynamic that monitoring the urban changes has become very difficult. The advance of remote sensing systems has imported new ways of proceeding and reception of satellite images with improved spectral and spatial resolution. Consequently satellite images are very useful in urban areas for the creation and updating of orthomaps, thematic maps and generally for the study of the urban dynamic.

The aim of this project is the implementation of two different classification methods for the creation of thematic maps by high-resolution imagery. Firstly the object-oriented classification was applied in two steps, segmentation and fuzzy classification of the resulting image objects. Multiresolution segmentation is the procedure of extracting image objects at different optional resolutions- scales. The physical and contextual characteristics of the generated image objects can be described by means of fuzzy logic which quantifies uncertain statements in a mathematical way. Then a traditional pixel-based classification method was implemented on the same study area.

The analysis of the results of this project demonstrates that the classification of urban scenes can be improved considerably by implementing a fuzzy approach of object-oriented classification.

INTRODUCTION

Remote sensing systems provide such an amount of geographical data that new remote sensing analysis methods are required for the extraction of information (i). The application of the conventional algorithms of classification rely on pixel-based processing methods develops many difficulties in the extraction of land-cover information from high-resolution images. Concerning high resolution images neighboring pixels are likely to belong to the same land cover class in spite of their different spectral characteristics (ii). This is mainly the case when classifying urban areas due to the heterogeneity of objects within an urban area (iii). The urban environment is composed of distinct objects constructed of similar material and the recognition of land use categories is a complex procedure.

A new approach of object-based classification is currently implemented in order to overcome the problems in discrimination of land use categories. Object-oriented image processing is based on grouping neighboring pixels into meaningful areas according to their spatial and spectral homogeneity. The segmentation and object generation must be set according to the resolution and the scale of the expected objects. Because an 'ideal' object scale does not exist, objects from different levels of segmentation (spatially) and of different meanings have to be combined for many applications. Contrary to the traditional pixel based methods, object oriented approach takes into account not only the spectral information but also the form, the texture, the shape and an additional great variety of features that computed based on image objects (iv).

The research described in this paper aims to exploit the full potential of high resolution satellite imagery by investigating new classification methods. A further attempt was also realized in order to extract certain land use categories and particularly in order to detect the urban vegetation of the study area.

DATA

In this project the study area is the city of Thessaloniki in the north part of Greece. The area was selected because it is a densely populated urban area characterized by a rapidly growing inhabitation and expansion. Furthermore it has a land cover variety that makes it adequate for the investigation of classification methods and the analysis of the results.

The satellite data used is a multispectral image of 3-m resolution, acquired in July 2003 by Quickbird. The multispectral image has been orthorectified using the Rational Function model. The elevation data consist of a DTM with a 25-m grid size.

In this research eCognition Professional 4.0 was used for object-oriented classification and Erdas Imagine 8.7 for further image processing.

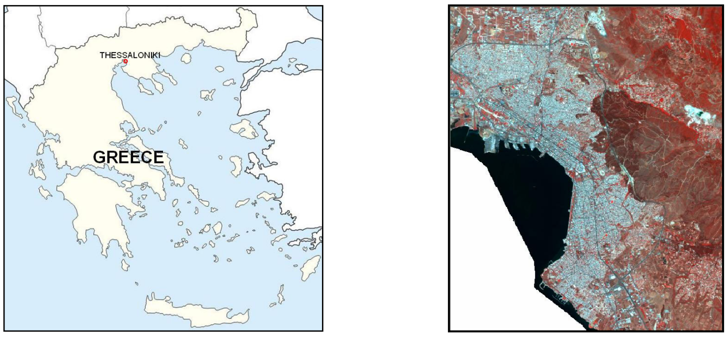


Figure 1: The study area of Thessaloniki

METHODOLOGY

Object Oriented Classification

Object-oriented image analysis consists of two steps, segmentation and fuzzy classification of the generated image objects. The segmentation of the multispectral image aims to divide the image into different meaningful regions; this means that the objects should approach objects of the real world so as to provide optimal information for further processing. The classification of the image is based on fuzzy logic by either using the Nearest Neighbor method or the combinations of fuzzy sets on object features, defined by Membership Functions (iv).

The image segmentation

The procedure of segmentation in eCognition starts considering each pixel as an object and after subsequent steps the neighboring image objects are merged into new bigger ones. The algorithm of this clustering process is based on the homogeneity in color and shape of the neighboring image objects.

A resolution is considered appropriate when the image objects are closer to real objects in shape and form. In this case the human eye is the most robust criterion for the evaluation of segmentation techniques. The size of the object is determined by the scale parameter and there is a possibility to represent various sizes simultaneously by constructing a hierarchical network of objects from fine to coarse resolutions. The composition of the homogeneity criterion and the definition of the scale parameter were defined after some tests by examining the objects in the study area. The Shape factor was set 0.9, the Compactness 0.6 and the Smoothness 0.4. The segmentation was generated on 4 levels with 4 different scale factors (10, 20, 50, and 100) which resulted in different level of detail. To each of the multispectral bands equal weight was assigned.

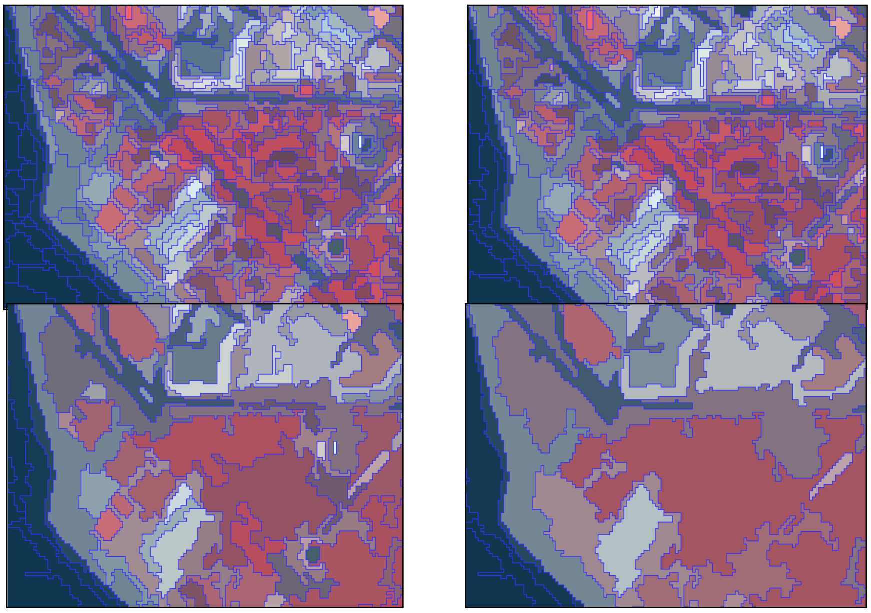


Figure 2: A part of the segmentation result in the 4 different levels of segmentation

The study area is so densely populated that there is a great number of neighboring objects which belong to different land cover types. In order to separate all the obvious land cover types and avoid the misclassification of the objects, level 1 was selected as the most suitable one for the classification.

The following important step is the definition of classes. Based on the visual inspection of the image the following land cover classes were distinguished: cement, tiled roofs, trees, low vegetation, soil, streets-shadow and sea.

Fuzzy Classification by the Nearest Neighbor method

The selection of the classifier Standard Nearest Neighbor requires the assignment of specific image objects as samples. After a representative set of samples has been chosen, the algorithm searches for the closest sample in the feature space for every image object. The distance in the feature space between a sample and an image object depends on its feature value. In this phase the selected feature was the band mean value calculated from the band values of all pixels composing an image object.

The result of classification with the specific data and method was not satisfactory as many misclassified objects were detected. This confusion was obvious mainly between classes 'streets-shadow' - 'sea' and 'tiled roofs' - 'soil' which have similar spectral reflectance. In order to minimize this error another approach was developed involving the following:

- DTM information
- New features for the discrimination of the classes

Classification enhancement using the DTM

Objects which belong in class 'sea' can be separated from other classes by using the DTM information. For this purpose a membership function was defined according to the mean value of the DTM layer. An image object was classified as 'sea' if its mean value of DTM was between -0.5 and 1m.

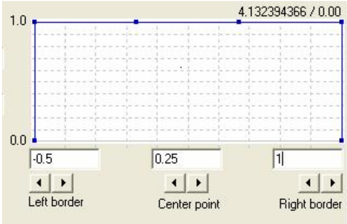


Figure 3: Membership function for the discrimination of class 'sea'.

Classification enhancement using more features

It should be noted that if two classes cannot be separated by one feature they cannot be distinguished by using membership functions. Instead they might be distinguishable by using nearest neighbor classification since nearest neighbor separates the distributions of classes in a high dimensional feature space far better (iii). By selecting the classes which are difficult to determine and a set of features, the eCognition software tracks the features which maximize the distances between samples. In this research 10 features were finally selected to determine the feature space for the best separation of the classes.

Pixel- based classification

Due to the spread use of the object-oriented classification, interest is being drawn to the investigation of whether it actually produces better results. In order to compare the traditional pixel-based with object-oriented method of classification, the supervised method of maximum-likelihood was applied in the image. For this purpose the same classes were selected in type and number as for the object-oriented approach. The training regions were chosen carefully so as to achieve the most accurate spectral definition for each class.

Accuracy of the Classification results

The most important stage of the procedure of classification is accuracy assessment because it determines the degree of success of the procedure. For this reason a comparison is made between classified data and reference data and the error matrix, the accuracy report and the Kappa coefficient are calculated. The results are presented in Table 1 and 2.

Table 1: Accuracy results for classified image by pixel-based classification and object-oriented classification

Class	Object-Oriented Classification			Pixel-based Classification		
	Producer's Accuracy %	User's Accuracy %	Kappa Statistics	Producer's Accuracy %	User's Accuracy %	Kappa Statistics
Sea	100	100	1	100	100	1
Low vegetation	93,3	96,6	0,923	76,47	86,67	0,843
Soil	53,3	80	0,486	45	60	0,514
Cement	100	85,7	1	53,85	87,50	0,859
Streets-Shadow	93,3	100	0,924	90	60	0,561
Trees	93,3	93,3	0,923	93,75	100	1
Tiled roofs	93,9	100	0,929	100	66,67	0,634

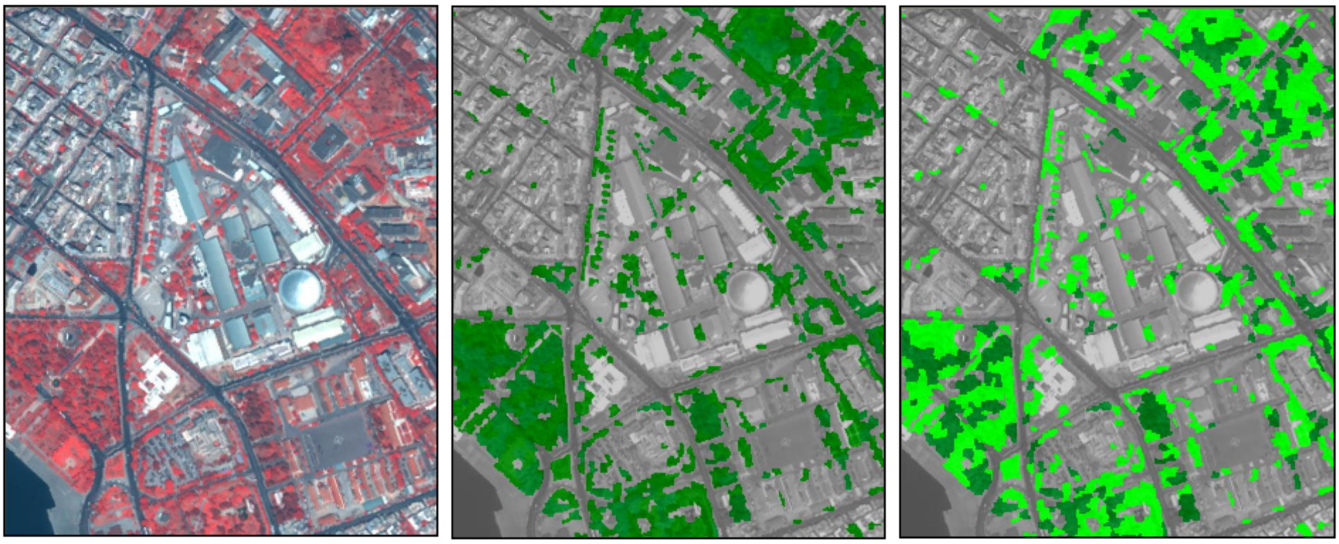
Table 2: Overall accuracy results for classified image by pixel- based classification and object-oriented classification

Accuracy Statistics	Object-Oriented Classification	Pixel-based Classification
Overall Accuracy (OA)	87,6 %	77,88 %
Overall Kappa Statistics	0,856	0,747

Further processing for urban vegetation detection

The detection of urban vegetation plays an important role in urban planning as it determines cities viability. Within this framework in this project the process of determining the vegetated regions was completed in two phases; at first urban vegetation was detected and then low vegetation and trees were separated.

The data used were the multispectral Quickbird image and the generated NDVI and VI images which highlight vegetated areas (v). The imagery was segmented with a scale factor: 10. In order to build a mask and exclude the areas with no vegetation from further processing, the generated objects were firstly classified in classes 'vegetation' and 'non-vegetation'. The feature used for the class description was the mean value of the NDVI image. Then the vegetated area was classified at the same scale level, so as to distinguish classes, 'low vegetation' and 'trees'. The feature space in this case was defined by the mean value of the VI image, the Stddev of the NDVI and VI image and the Stddev of all bands. The Nearest Neighbor classifier is used in both stages to classify the objects.



(a) (b) (c)

Figure 4: (a) The subset of the test area, (b) the vegetated area, (c) low vegetated area and area with trees

RESULTS

The evaluation of the accuracy assessment of the object-oriented and pixel-based classification method is shown in Tables 1 and 2. In Table 1 the per percent accuracy values and Kappa statistics of each class indicate that class 'soil' was difficult to distinguish, as it has the lowest values in both methods. In Table 2 the overall accuracy and kappa statistics for both methods are presented. Given that a classification is considered satisfactory when its overall accuracy is more than 70-75% and its Kappa coefficient is more than 65%, it should be noted that both methods have high accuracy. The results in both tables demonstrate the precedence of the object-oriented approach while it produced more accurate and stable results.

Apart from the classification accuracy estimation, the difference between the two methods can be easily noted if the classified images are compared visually. This is justified by the fact that in the object-oriented classification homogeneous objects are classified and the “salt-and-pepper” effect that is typical in the pixel based classification is reduced. Additionally, the object-oriented classified image has far better interpretability, as the meaningful image objects used give more clear and stable aspect of the real world.

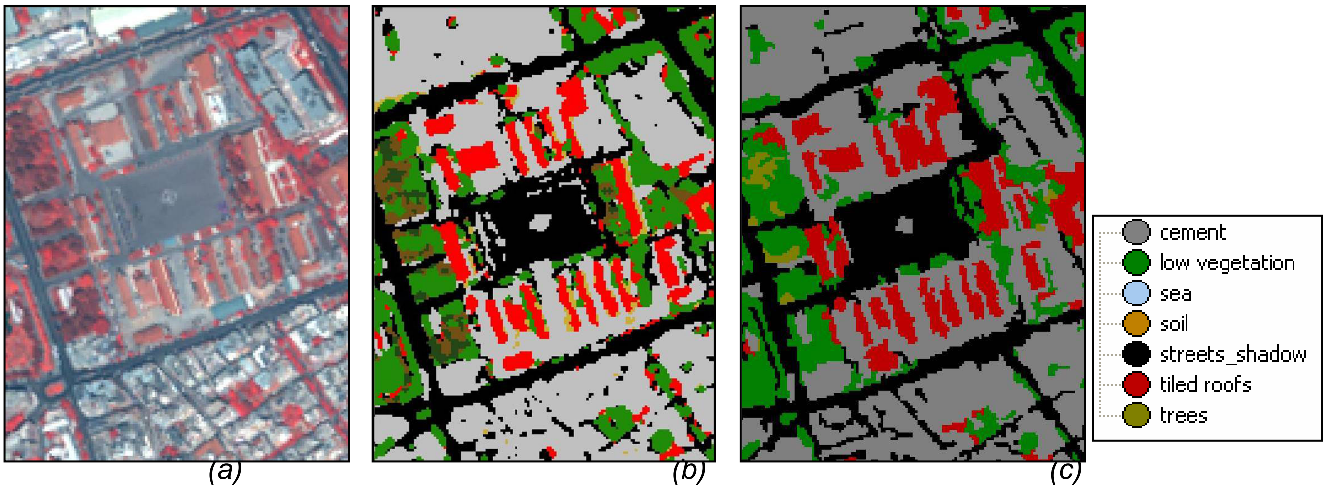


Figure 5: (a) The multispectral image and the classified images of (b) Maximum-likelihood and (c) Object-oriented method

The application for the vegetation detection confirms that the object-oriented method is a powerful tool for the extraction of certain land uses. Various data can be combined in order to automatically identify information contained in remotely sensed data and improve its interpretability.

Moreover, this project demonstrated that object-oriented approach is more handy and flexible, not only because it is easier to handle objects rather than pixels, but also because fuzzy logic provides the opportunity to handle effectively the relations between the objects and the classes (vi). This benefit turned out to be very useful in this research which had to do with a densely populated area and the diversity of image objects made difficult their accurate classification.

CONCLUSIONS

In this study the capability of the object-oriented classification of urban areas was investigated. Very high resolution satellite data were used which although they contain more detailed information, cause problems from their high spectral variance (vii). In any case an image of a densely populated urban area is difficult to be classified having complex structures of various materials.

Object-oriented image analysis enables the exploitation of the information contained in high resolution imagery because it takes into account spectral information, shape and texture. It was shown that the classified image can be significantly enhanced by including membership functions as well as by using various features according to the application. Moreover the procedure was based in fuzzy logic which offers the possibility of an object to have a membership degree in all classes. The main advantage of this is that it offers information about the second or the third possible classification of an object especially when discrimination of the classes is difficult (viii). In this point the pixel based approach was also implemented having satisfactory results. Even so, object oriented classification proved to be more effective in terms of accuracy and flexibility.

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