

# HYPERSPETRAL DATA CLASSIFICATION BY OBJECT-ORIENTED APPROACH FOR THE MANAGEMENT OF URBAN LANDSCAPE

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## ABSTRACT

Recent developments in remote sensing products provide high quality image data, enabling detailed analysis to update land use/land cover, environmental impact assessment and road network maps. To explore the value of these data, the appropriate information has to be extracted and presented in standard format to be imported into geo-information systems for an efficient decision process. The object oriented approach can contribute to a powerful automatic and semi-automatic analysis. Definien's eCognition is used to evaluate object-based classification. The system allows intelligent classification of aerial and satellite imagery in different scales simultaneously by different object layers. Object-based classification attempts to describe relationships in terms of several categories of characteristics. Object features include properties such as colour, texture, shape, area and scale; furthermore it is possible to include other relationships by spatial terms or statistical similarities. All segmentation procedures provided by eCognition operate on arbitrary levels in a strong hierarchical network. This network provides the base for successful information extraction. Furthermore, context and semantic information can be used to distinguish between trees in a green area or within an urban area, or roads by roof. To obtain this task it is possible to use a DEM by LIDAR data too. Image objects not only enhance automatic classification of remote sensing data, they also support the export of the extracted information to GIS converting the classification in vector structures like polygons. This vector information can be produced in different resolutions for different purposes. This study investigates the use of high resolution hyperspectral imagery and LIDAR (Light Detection And Ranging) data to distinguish trees and urban elements (buildings and roads). The hyperspectral images were acquired by ROSIS with a spatial resolution of 1 meter in 102 bands, in 2002 on the city of Pavia (Italy).

## 1. INTRODUCTION

The development and the employment of several high-resolution sensors have increased more and more the importance of remote sensing data overcoming the limitations of geometrical and spectral information. A variety of techniques are available to distinguish the entities of the urban scene (buildings, roads, green area) starting from unsupervised per-pixel classifiers to sophisticated segmentation algorithms, such as region growing or split-and-merge procedures, which take into account the neighbouring pixels. An overview about the recent developments in the field of image segmentation is given by Blaschke et al. (2000). The simple spectral or pixel-based classifiers, developed in 1970's, evaluate spectral reflectance and emittance within each pixel to find meaningful patterns. Both unsupervised and supervised approaches are routinely applied to remotely sensed data based on spectral or pixel-based schemes. Even if the increase of spatial resolution of new sensors reduces the problem of mixed pixels on the other hand it increases the internal variability and the noise within land use classes (Schiewe & Tufte & Ehlers, 2001) producing, by means of the traditional classification approaches, too many or not well defined classes. At this point it is obvious that new approaches are required to overcome some of the fundamental problems: for example the supervised classification techniques requires the acquisition of a certain number of training sites to derive some descriptive statistics for every used category, they are poor at discriminating between urban land use categories.

So new methods based on the automatic extraction of specific features have to be used, even if these automatic procedures can have some difficulties to differentiate the features themselves (Hoffmann & Van der Vegt, 2001). This very complex task has to be done not only with the help of spectral information, but also with other kind of spatial information (e.g. DEM by LIDAR). In fact only combining spatial and multispectral information we could obtain an accurate identification of categories and realize a truly urban land use map (Fung & Chan, 1994; Barnsley & Barr, 1996; Gao & Skillcorn, 1998).

A new approach is offered by the multiresolution segmentation in the eCognition software for object oriented image classification (Definien 2001). The system allows intelligent classification of aerial and satellite imagery in different scales simultaneously by different object layers and it has already been proven to be a satisfying alternative solution. The

experiences of several applications demonstrate that segmentation-based classification is superior to traditional per-pixel methods in many instances. Furthermore the combination of high resolution images and high resolution elevation information in an object-oriented method promises good results for the automatic updating of GIS data sets. In fact the final result of object-oriented classification is in form of vectorial polygons in opposition to the raster form coming from the per pixel approach. In this regard the product is more suitable for the GIS expectations and it overcomes the traditional standard canons of the thematic cartography.

## 2. AN OVERVIEW OF IMAGE ANALYSIS BY MULTI-RESOLUTION OBJECT-ORIENTED APPROACH

There are many segmentation approaches such as clustering, region-growing and so on, in eCognition the classification includes fractal-based approaches. In fact it is possible to detect the discontinuities as well as fractal-based or texture-based algorithms (Ryherd & Woodcock 1996) to find homogeneous areas (Blaschke & Strobl, 2001).

Human vision at first tends to generalise images into homogeneous areas, later it characterises these areas more carefully. Following this observation, it can be argued that by successfully subdividing an image into meaningful objects of the land surface, in this way more intuitive features will result. One problem is to define the term “meaningful objects”: the nature consists of hard boundaries but it is also rarely a true continuum. There are clear, but sometimes soft, transitions in land cover. These transitions are also subject to specific definitions and subsequently they dependent on scale. Therefore, the segments in an image will never represent meaningful objects at all scales and for any application. The basic aim of the segmentation process should be to generate meaningful objects. This means that the shape of each real-world-object is represented by a corresponding image object. This shape is used to initially classify the objects in a image by their physical properties. After this physical classification, additional semantic information can be used to improve the image classification. Some semantic information necessary to interpret an image are not represented by single pixels but by meaningful image objects and their mutual relations (Baatz & Schäpe 1999). Object-based classification describes relationships in terms of several categories of object features such as colour, texture, shape, area and scale, including other relationships by spatial terms or statistical similarities. You can customize some features expanding the already large number of predefined functions to find the best discriminating features for a given task. eCognition allows a knowledgebase classification, using a set of rules, including spectral and textural information, shape, neighbourhoods, logical expressions and many more.

The technique for object segmentation extracts image object-primitives in variable resolution from fine to coarse structures. The obtained hierarchical network allows to represent the image information content at different scales simultaneously. To control the average image object size the scale parameter is used that determines the object resolution, for the segmentation of all bands. Applying various scale parameters as well as different weights a hierarchical scene representation can be obtained. In the class hierarchy different image objects can be aggregated into groups. Segmentation in eCognition is a bottom up region-merging technique starting with one-pixel objects. In numerous subsequent steps smaller image objects are merged into bigger ones. Regarding the multi-scale behaviour of real-world-objects, it is obvious that a number of small objects can be aggregated to form a larger object constructing a semantic hierarchy. Likewise, a large object can be split into a smaller objects (Fig. 1).

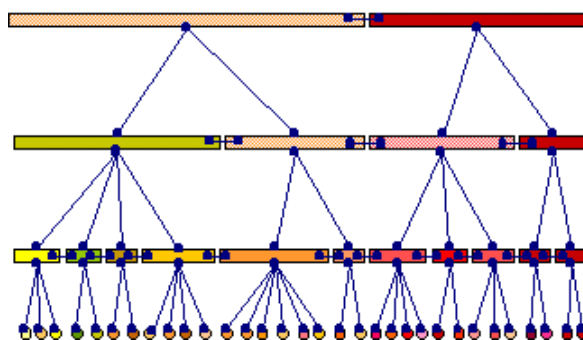


Fig.1. A multi-resolution segmentation scheme

The criteria for the evaluation of segmentation results are quantitative. They minimize the average heterogeneity of image objects for a given resolution over the whole scene. Heterogeneity itself is based not only on the standard deviation of image

objects but also on their shape. Weighting between spectral and shape heterogeneity enables an adjustment of segmentation results to the considered application. The stop criterion for the region-merging process is given by the parameter “scale” which determines the maximum allowed overall heterogeneity of the segments. The larger the scale parameter for one data set, the larger the image objects. This formulation emphasizes the requirement that each arbitrary area of an image needs to be taken into account in a similar way compared to any other.

Concerning the robustness of the approach actually it produces a significant progress compared to traditional methods. It is possible to extract homogeneous regions with unique semantic meanings and sufficient geometrical accuracy.

If the segmentation is performed at multiple scale levels, optimal spatial resolutions for the different sizes, shapes and arrangements of the objects under investigation, can be considered. As a result one obtains connected regions which in general are more homogeneous compared to the results of the traditional approaches.

The multi-resolution segmentation is object oriented: each decision for a merge is based on the concrete recent attributes of the image objects merged in previous steps. This is the advantage of the method: each decision is based on attributes of homogeneous structures of a recent scale.

Furthermore eCognition offers a variety of possibilities for simultaneously using different data types for analysis. In the segmentation process, different layers can be weighted as to their suitability for shaping resulting image objects. Thus, information from different layers can be represented on different levels in the image object hierarchy, allowing for the evaluation of the different information layers in relation to each other. Segmentation phase is followed by the classification. Two basic classifiers are possible: a nearest neighbour classifier and fuzzy membership functions. While the nearest neighbour classifier describes the classes to detect by means of the training samples, the fuzzy membership functions describe intervals of feature characteristics wherein the objects do belong to a certain class or not by a certain degree. The advantage of fuzzy-logic is the possibility to integrate most different kinds of features and to connect them by means of Boolean operators (Baatz & Schäpe 1999). The fuzzy rule base operates on fuzzy sets on selected object features. The fuzzy sets are defined by membership functions which can be edited in a convenient graphical interface. These membership functions identify those values of a feature which are regarded as typical, less typical, or not typical for a class. The fuzzy sets are combined with the logic operators or, and, not. The fuzzy classification process is a costly process which is not automated so it is possible with an iterative segmentation and classification process to optimize the results. Compared to neural networks the advantage is a transparent and adaptable set of classification rules. Each single step of classification can be retraced for each image object in detail.

Final remarks regarding the difficulties to select features by means of an automatic or semiautomatic detection based only on spectral characteristics especially in heterogeneous areas such as dense urban areas. A typical problem in urban remote sensing is the handling of shadows.

The use of a DEM and additional semantic information can help to detect such cases and to manage them adequately. Airborne laser scanning represents a new and suitable technology for the automated generation of digital elevation model in a fast and relatively low cost way. The additional elevation information from LIDAR are very important for interpretation. The quality of the classification depends on the quality of the DEM. A limitation is the difficulty to process precise DEM in urban areas, especially in zones with narrow streets and in shady areas. When using a DEM during the segmentation, its weight should be adjusted adequately, depending on the objects which are to be extracted.

In this work an object oriented classification approach has been applied to hyperspectral images combining sometimes LIDAR data and some preliminary results will be presented.

### **3. EXPERIMENTAL AREA AND GEO-DATASETS**

This experimentation reports on the hyperspectral sensor ROSIS, in the frame of the HySenS project financed by EU and proposed by German DLR. The sensor ROSIS (Reflective Optics System Imaging Spectrometer) has a spectral range of 102 bands between 430 nm and 850 nm and 1 meter of ground geometric resolution. In 2002 were acquired 4 ROSIS images related to the urban area of Pavia, a city in North of Italy. First of all the set of images were georeferenced using a Rational Function with a centimetre geometric accuracy, in order to optimise the classification algorithm task (Galli & Malinverni, 2003, 2004). We have integrated this information together with some other information organized in a geodatabase: the numerical cartography of the town of Pavia, at the scale 1:2000; the Technical Map of the Lombardia Region at the scale 1:10000; some other thematic maps and the LIDAR DEM with a grid resolution of 1m x 1m. The employment and the integration of data of different nature validate the obtained results (ground individualization truth, quality of the classification etc.) and improve the GIS tools.

#### 4. AN APPLICATION USING MULTIREOLUTION SEGMENTATION AND A KNOWLEDGE-BASED CLASSIFICATION TECHNIQUE

In this paragraph we present some results obtained by means of the software eCognition on hyperspectral ROSIS images. Previously we georeferenced the images and the LIDAR DEM on the same study area. In fact all the data sources have to represent exactly the same subset with the same reference system and the same pixel size.

Basing upon the underlying concepts of eCognition to generate and classify image objects, we developed different strategies. One procedure is consisted in the application of the Standard Nearest Neighbor method (SNN) using only the hyperspectral images, the second one used the fuzzy approach on a set constituted of the same ROSIS images and the DEM. The classification procedure started with the image segmentation; after that the hierarchical network was defined, proceeding from the most general classes, or parents, to those more detailed, or children, in the same features. The last step consisted in the choice of an algorithm of classification whose can follow an advanced post-classification.

##### 4.1 The multi-resolution segmentation

The image segmentation has been performed using only a part of 102 spectral bands of the ROSIS images (the first 14 spectral bands presented an excessively noise). The segmentation has been articulated on 3 levels based on 3 different scale factor (10, 40, 80), deriving 3 outputs with a level of detail very diversified (from fine to coarse) (Fig. 2).

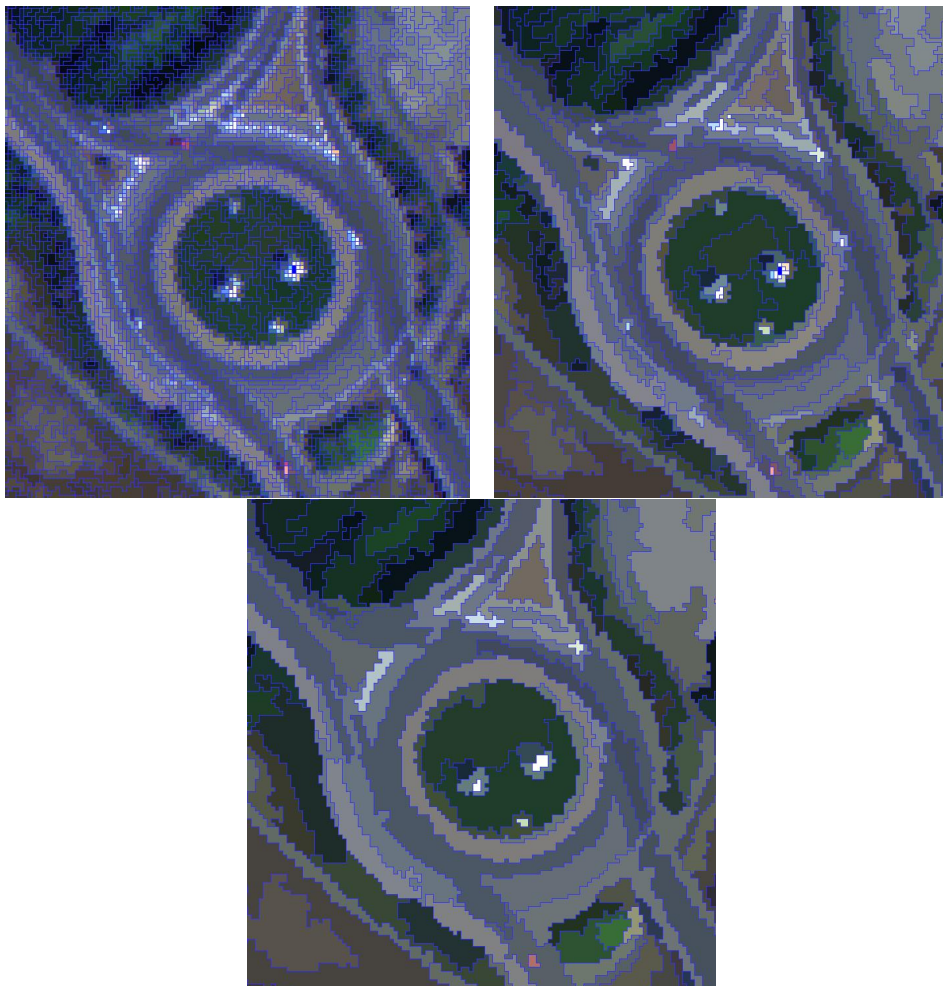


Fig 2. The results of the segmentation (scale factors 10, 40 and 80 respectively from top to bottom)

The other input parameters of the segmentation have been chosen related on the feature objects (attributes): Color (0.8), Shape (0.2), Smoothness (0.5), Compactness (0.5) The choice of the scale factor and the other parameters are derived from some tests performed analyzing the characteristics of the objects present in the studied urban area.

As next step of this work, we defined the hierarchical network of the classes, which is the definition of an object catalogue of all visible objects within the image subset. The hierarchy has been structured in 4 principal levels: urbanized, roads, vegetation, shadow/water. Successively every level has been subdivided in other more specified classes for a total of 10 classes in the more detailed level (Fig 3).

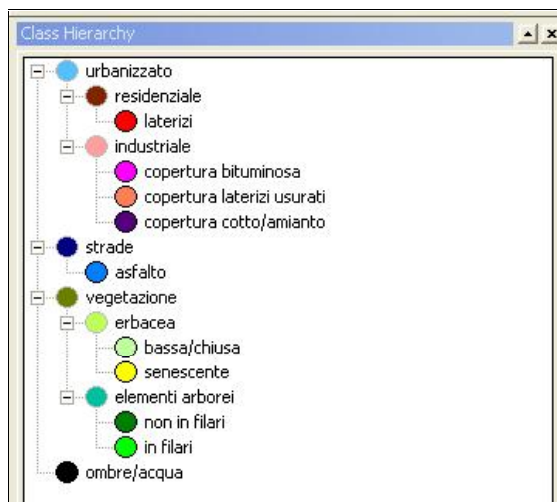


Fig. 3. The workflow of the class-hierarchy generation

#### 4.2 The application task of the Standard Nearest Neighbor method (SNN)

After the multi-resolution segmentation we performed a supervised classification using a nearest neighbour classifier selecting samples for every different class. We looked for a proper selection of input data and homogeneity criteria to obtain accurate results shown in Fig. 4.

The accuracy has been evaluated comparing some selected test samples in the different classes and generally it results good (equal to 0.94, 0.95 and 0.92 respectively for the scale factors 10, 40 and 80), it decreases when the scale factor increases. So it could be observed that the multi-resolution segmentation technique and the object oriented classification are able to underlying the importance of the geometric component of the remote sensing images. For this purpose the approach could take advantage of the better geometric resolution of new sensors even when the spectral resolution decreases (such as number of usable spectral bands). Nevertheless the approach SNN needs specific knowledges of the examined area and a good ability in the choice of the parameters and in the individualization of the samples objects.

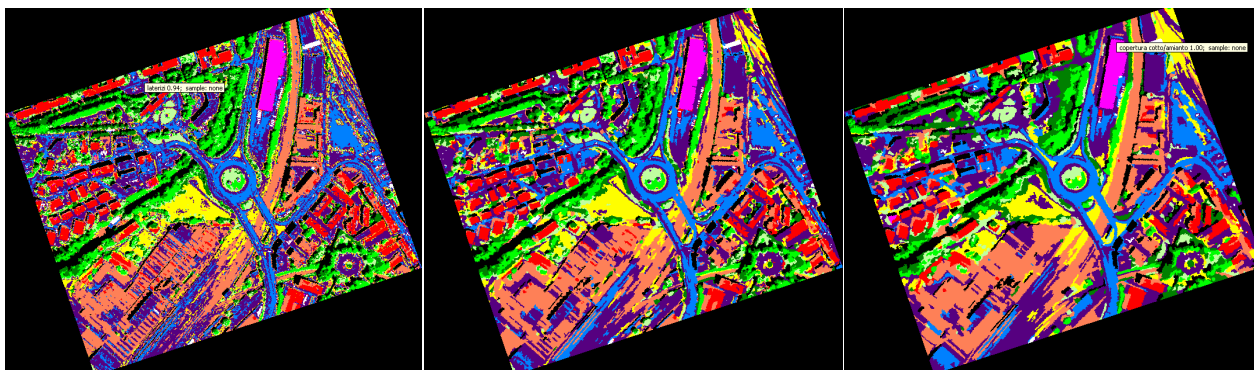


Fig. 4. SNN classification on the three levels (scale factor 10, 40, 80) respectively from left to the right

Finally with a specific function in eCognition, we evaluated the stability of the obtained classifications as the degree of agreement between the polygons of a segmentation level and a corresponding class. The results demonstrate that the classifications for every level of segmentation are strongly unstable. This means that a polygon assigned to a class in reality would not be far away to belong to another class.

### 4.3 The application task of the fuzzy method (membership functions)

The second approach has used the classification of image objects by means of fuzzy logic. We performed different classifications which have brought different results with different accuracy. Generally this method resulted to be much more stable in comparison to the method shown previously. The phase of the segmentation and the definition of the class hierarchy have been realized in the same way, but the diversity has been to assign some membership functions to every class. In Fig. 5 two examples of membership functions are shown.

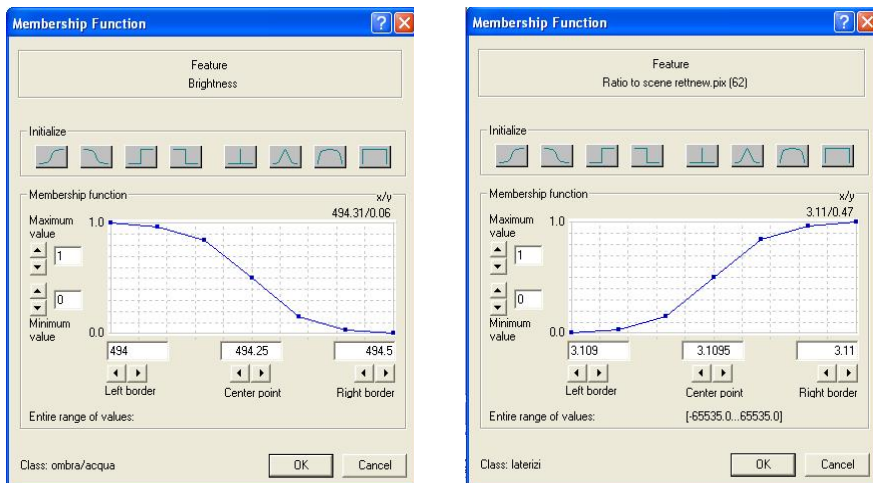


Fig. 5. Membership functions to classify the class shadow/water using the brightness feature (on the left) and the class tiles using the ratio (on the right).

The fuzzy classification results are improved by using the elevation information for analysis. Combining the laser elevation with the spectral data we introduced a further information for the characterization of the different classes. Particularly, the DEM has been useful to classify the road class avoiding the confusion with other artificial coverages which have similar spectral characteristic (Fig. 6).

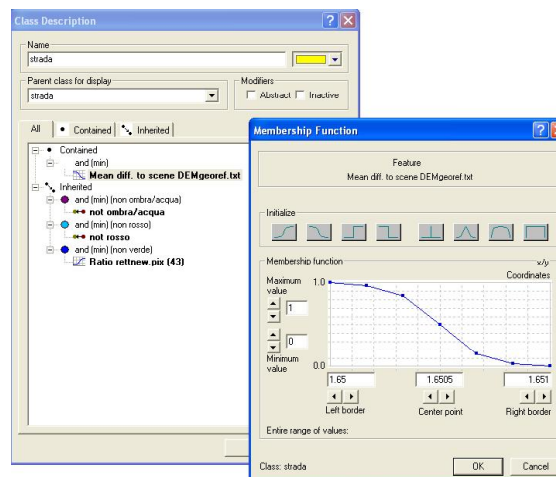


Fig. 6. Membership function of the road class based on DEM

The results of fuzzy method are presented in Fig. 7.



Fig. 7 Fuzzy method results applied to segmentation with scale factor 10 (on the left) and 40 (on the right) in the center a portion of the original ROSIS image.

The accuracy for the both classifications is more satisfactory and better than the SNN method. Above all, the stability of the classifications is very high and it demonstrates the correct choice of the membership functions. This involved that the polygons have been assigned to the different classes with an elevated degree of certainty (Fig. 8).

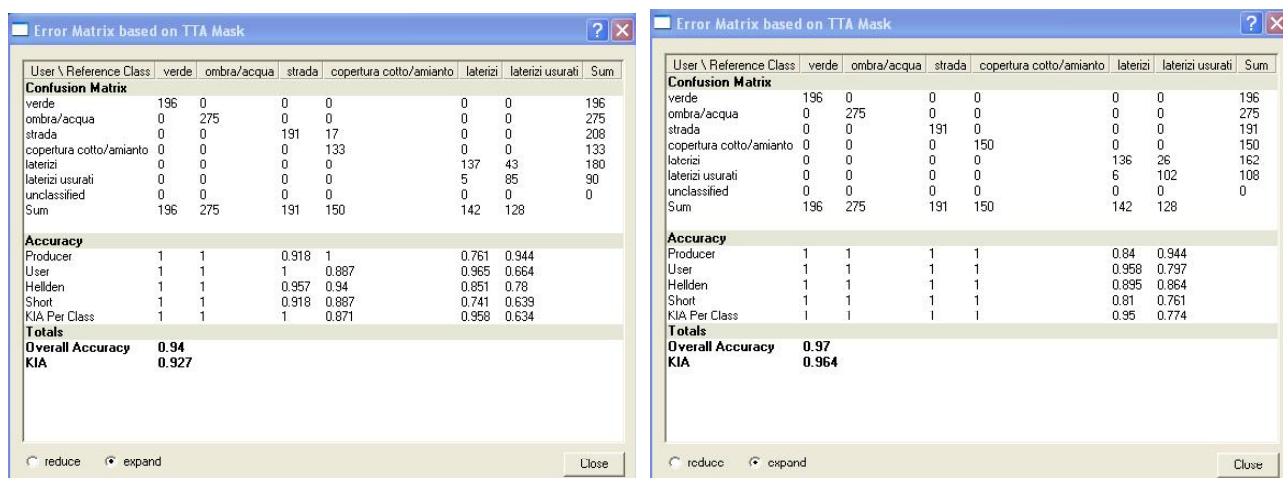


Fig. 8 Accuracy related to the fuzzy classifications. On the left for the scale factor 10 and on the right for the scale factor 40.

## CONCLUSION

The examples prove that object-oriented approaches can result a powerful tool for the interpretation of high resolution data. The segmentation results build a methodology useful for the GIS. To update a GIS database, the classified image objects in the scene can be exported in vectorized format as polygons with an attached attribute list. Beside the classification, this list can contain any chosen property for each image object. So remote sensing data become an important source for generating or updating GIS databases in a variety of applications (Galli & Malinverni, 2004). We can update a specific geodatabase, from which to realize thematic maps considering the Corine Land Cover program, useful to describe and to analyze the actual situation and to delineate the future possible scenarios (Fig. 9, 10). Nowadays GIS to become the basic tool to prepare spatially related decisions must have the quality and actuality which its data allow. For this reason it would be desirable to utilize results of exploited remote sensing data to a great extend for updating a GIS.

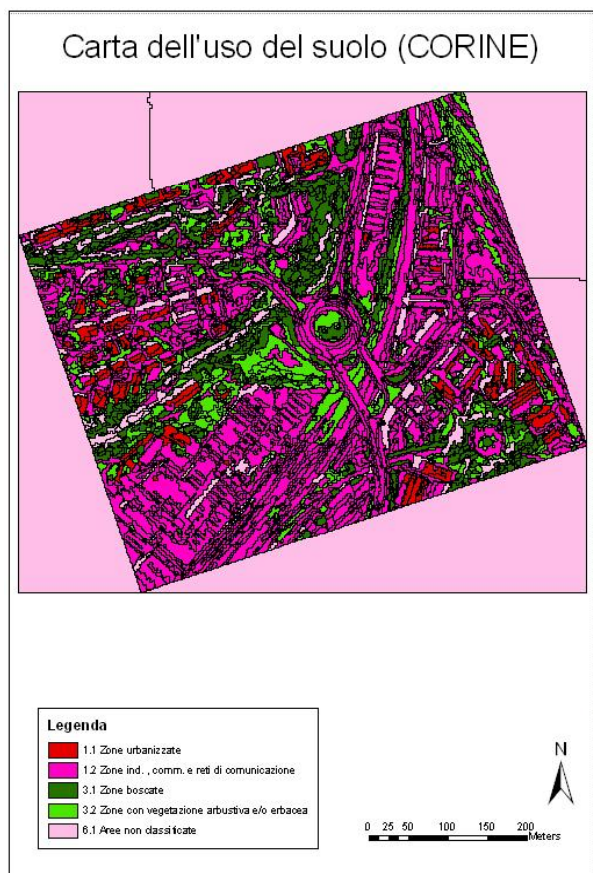


Fig. 9. Land Use Map generated by the SNN method and scale parameter 80



Fig. 10. Land Use Map generated by the fuzzy method and scale parameter 40

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