Improvement of Land Use and Land Cover Classification of an Urban Area Using Image Segmentation from Landsat ETM$^+$ Data

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Abstract - Remotely sensed imageries are an important source for generating and updating GIS databases for land use and land cover change detection in urban areas. The interpretation of these data is a complex task because of the high variability of the image material under investigation. The purpose of this project was to compare the traditional classification approaches like the maximum likelihood method with an alternative object-oriented method. For this project Landsat ETM+ image with a ground resolution of 30-meter was used. Results show that object-oriented approach yielded a more accurate classification compared to pixel-based method.

Keywords: Object oriented, segmentation, remote sensing

1. INTRODUCTION

Remote sensing has made enormous progress over the past two decades in terms of improved resolution, data availability, and public awareness. The availability and deployment of high spatial resolution sensors have also opened a much more precise land-cover classification and a new range of applications (Franklin, 2001). In recent years, the significance of spatial data technologies, especially the application of remotely sensed data and geographic information systems (GIS) has greatly increased. Nevertheless, a vast majority of applications still rely on basic image processing concepts developed in the early seventies, classification of single pixels in a multi-dimensional feature space.

In the classic image classification approach the unit is a single pixel. This approach utilizes spectral information of the pixels to classify the image. Unfortunately, the high spatial resolution of advanced satellite and airborne sensors increase the spectral within-field variability and therefore may decrease the classification accuracy of the classic pixel-based methods. The ability of this method to classify the image is also limited when objects have similar spectral information. Two most evident differences between pixel-based image analysis and object-oriented analysis are:

1. In object-oriented image analysis, the basic processing units are image objects (segments) not single pixel
2. Object-oriented image analysis uses soft classifiers that are based on fuzzy logic not hard classifiers.

The main objective of this project was to compare the two classification systems for the development of urban area land use and land cover using Landsat ETM+ imagery.

2. STUDY AREA AND DATA

The study area is Huntsville, AL and surrounding cities located in north Alabama, USA. Huntsville, an industrial city is currently one of the most changing urban areas in the southeastern region of the United States. These changes have been driven by an increasing growth of industrial and commercial companies leading to a rapidly growing population. The data used is the Landsat-7 ETM+ was acquired on July 7, 2002 (Figure1).

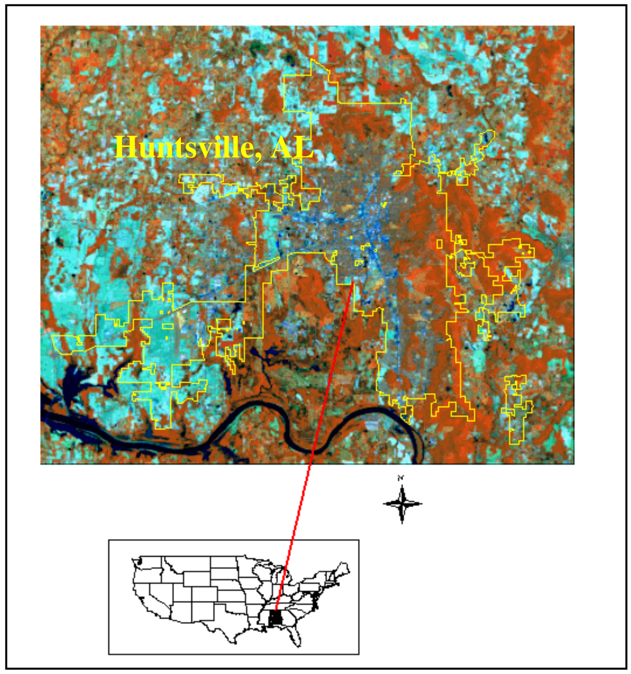

Figure 1. Landsat ETM+ image (band 4,5,3) of the study area.

The TM sensor collects surface reflectance data in the visible and near infrared (bands 1-5, 7), and the thermal infrared (band 6) portions of the electromagnetic spectrum. Spatial resolution of the TM data is 30 meters per pixel. As with earlier Landsat systems, the Landsat-7 satellite launched on April 15, 1999, along with its enhanced thematic mapping sensor (ETM+), provides for new capabilities in remote sensing of the Earth's land surface. The ETM+ sensor is an enhanced version of the TM sensor flown aboard Landsat-4 and -5 satellites, but most closely approximates the ETM sensor lost on board the Landsat-6 satellite. Sensor enhancements include the addition of the panchromatic band which has 15-meter spatial resolution and two gain ranges, improved spatial resolution for the thermal band, and the addition of two solar calibrators.

3. METHODOLOGY

3.1 Object oriented classification

The *eCognition* software, developed by Definiens Imaging (http://www.definiens-imaging.com) is commercially available software for object-oriented image analysis. The concept behind eCognition is that important semantic information necessary interpret an image is not represented in a single pixel, but in meaningful image objects and their mutual relationship (Baatz et al., 2001). The segmentation approach allows the generation of image objects on an arbitrary number of scale levels taking into accounts criteria of homogeneity in color and shape. *eCognition* offers a technology for multiscale analysis of different Earth observation data by including context information, allowing extensive data fusion and supporting the integration of remote sensing and geographic information systems. It is particularly suited for the analysis of very high resolution optical and radar data.

The first step of the analysis is to generate homogeneous image objects or segments on the basis of the spectral and contextual information using the parameters scale, color, shape, smoothness and compactness. These parameters govern size, shape and spectral variation of each object. This is done by using the multi-resolution segmentation approach as implemented in the software package. The segmentation results in a hierarchical network of image objects, whereas each segment is connected to its vertical and horizontal neighbors.

The segmentation algorithm within *eCognition* used in this study was a bottom up region-growing technique starting with one-pixel objects. In subsequent steps smaller image objects are merged into larger ones through a pair wise clustering process. The procedure simulates an even and simultaneous growth of segments over a scene in each step. Heterogeneity is based not only on the standard deviation of image objects but also on their shape. Weighting between spectral and shape heterogeneity enables the adjustment of segmentation results to the considered application. After segmentation, all image objects were automatically linked to a network in which each image object knows its neighbors, thus affording important context information for the classification step. In the second step the image segments are classified by generating class hierarchy, which is based on fuzzy logic. Each class of a classification scheme contains a class description and each class description consists of a set of fuzzy expressions allowing the evaluation of specific features and their logical operation. A fuzzy rule can have one single condition or can consist of a combination of several conditions that have to be fulfilled for an object to be assigned to a class. The fuzzy sets were defined by membership functions that identify those values of a feature that are regarded as typical, less typical, or not typical of a class, i.e., they have a high, low, or zero membership respectively, of the fuzzy set. The advantage of fuzzy logic compared e.g., to neural networks is a transparent and adaptable set of classification rules. The rules are defined using nearest neighbor or membership functions (Baatz et al., 2001).

3.2 Pixel-based classification

There are two primary types of pixel-based classification algorithms applied to remotely sensed data: unsupervised and supervised. Unsupervised classification algorithms (such as ISODATA) cluster data according to several user-defined statistical parameters in an iterative fashion until either some percentage of pixels remain unchanged or a maximum number of iterations have been performed. This method of classification is most useful when no previous knowledge or ground truth data of an area is available. However, the classes determined by the algorithm still require land cover identification by an experienced analyst, which can be a significant disadvantage in using this method. In supervised classification, the image analyst supervises the pixel categorization process. In this project the supervised classification methods was applied.

4. RESULTS AND DISCUSSION

In the segmentation step the study area was segmented and image objects generated by adjusting criteria of homogeneity in color, and shape. The segmentation parameters used are listed in Table1. A visual inspection of the number of segmented images using the different parameters and prior knowledge of the study area was used to select the scale parameter setting of 25, color 0.7, shape 0.3 for the final classification procedure.

Table 1. Segmentation parameters used for Landsat ETM+

Level	Scale parameter	Color	Shape	Smoothness	Compactness
1	5	0.7	0.3	0.9	0.1
2	10	0.5	0.5	0.5	0.5
3	25	0.7	0.3	0.9	0.1

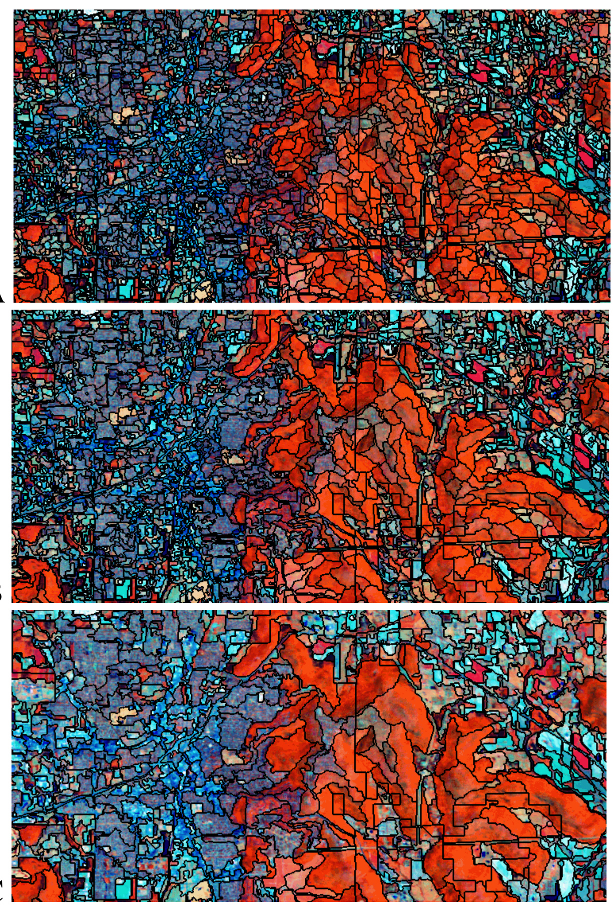

Figure 2. Image segmentation using three different scale parameters Scale parameter A= 5, B=15, and C=25

Figure 2a, 2b, and 4c show the results of segmentation at different settings of scale parameters. Adjusting the scale parameters influenced the object's size. Table 2 shows the Accuracy assessment of the classified image by best classification result. The accuracy assessment performs basic statistical operations on the best degrees of membership of the image objects for each class listed (number of image objects, mean, standard deviation, minimum value and maximum value) (Baatz et al., 2001). Thus it is possible to evaluate how the objects of a class fulfill the class description. In this project the values for all classes are significantly high.

Table 2. Accuracy assessment of the classified image by Best Classification Result

Classes	Objects	Mean	Std Dev	Min	Max
Water	84	0.647	0.243	0.268	1
Commercial	492	0.829	0.185	0.108	1
Residential	456	0.912	0.073	0.600	1
Evergreen Forest	585	0.846	0.172	0.217	1
Mixed Forest	26	0.989	0.016	0.918	1
Deciduous Forest	737	0.921	0.063	0.736	1
Pasture	1610	0.915	0.060	0.626	1
Agriculture	1330	0.874	0.113	0.351	1
Bare land	201	0.824	0.116	0.377	1

Figures 3 and 4 show the results of the object-oriented and pixel-based maximum likelihood classification approaches, respectively. The pixel-based classification is based on the spectral mean of the digital number. A close look at the results revealed that object-oriented classification accurately identified some of the urban built-up features. The overall classification accuracy was found to be 89.4%. This is higher than the overall accuracy of the pixel-based classification, which is 80.2%. The same trend was also observed for each classified land cover class (Producer's and User's Accuracy). The same training areas were used for both classification approaches and accuracy assessment. The software utilized for the pixel-based classification was ERDAS Imagine Version 8.6 (ERDAS, 2002).

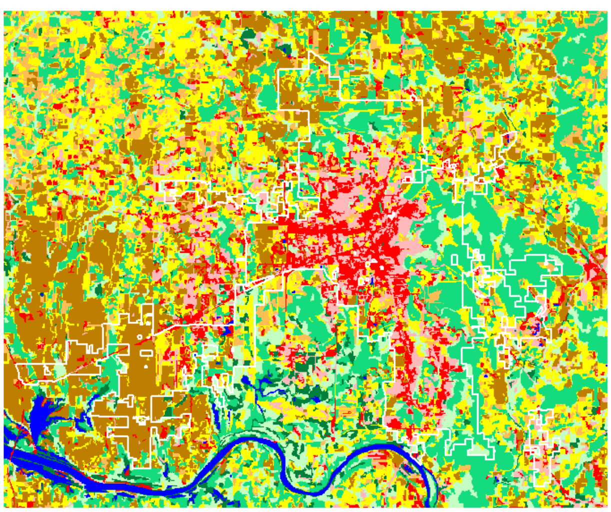

Figure 3. Result of object-oriented classification

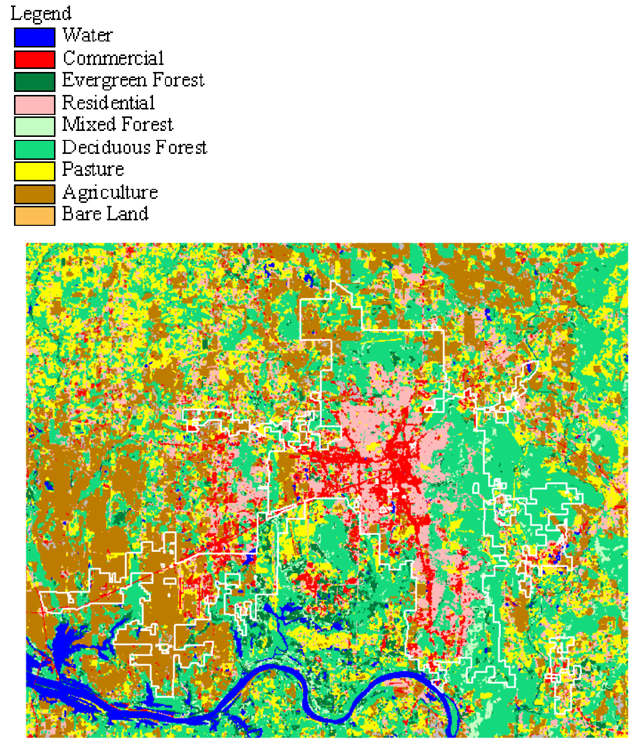

Figure 4. Result of Maximum-Likelihood classification

5. CONCLUSIONS

The multi-resolution segmentation method applied proved to be very efficient in extracting the segments required for the classification of urban features. The object-oriented approach produced a better classification result than the pixel-based classification.

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