AUTOMATIC EXTRACTION OF BUILDINGS FROM HIGH RESOLUTION SATELLITE IMAGES

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ABSTRACT:

For obvious economic reasons, buildings and roads are topographic features of great importance for a variety of users. Remote sensing remains a complementary tool when aerial photos reach their limits. When using satellite images two parameters have to be considered: the spatial resolution and the range of spectral channels of the imaging system. Regarding the extraction of buildings and roads, the priority is given to the spatial resolution rather than to the spectral resolution. In this respect, a great improvement of the spatial resolution of the images of the new satellite generation has opened up new perspectives in term of the extraction of precise and global information. However, the pixel-based classification techniques that proved their efficiency on images of medium resolution seems to reach its limits when it comes to high resolution images, due to high heterogeneity that characterizes these images. Therefore, approaches combining spatial and spectral characters are developing.The objective of this paper is to try to implement and experiment an area-based expert classification that draws from the results of a spectral-textural classification. In this approach the research is combining pixel-based classification and area-based classification.In a first stage, we compute for each pixel a set of spatial and spectral parameters, then we assign it to a given class based on these parameters and on probabilistic laws.In the second stage, we will group the pixels within homogeneous regions that will be labeled based on their spectral and geometric characteristics. In fact, at the beginning we apply a spectral-textural classification to the multispectral image. Then, homogeneous regions are extracted using segmentation. The thematic information is hence the first characteristic that will describe regions to be classified using an expert classification. The spatial information is used in the spectral classification and the post classification process as the texture channel.Testing are done on a 2.5m Spot 5 image covering the Beni Amir (Beni Mellal, Morocco) region, and on a QuickBird image (panchromatic and Multispectral) covering the city of Rabat (Morocco). In this research, 11 spatial models were programmed under Erdas using SML language: 8 models describing the texture channels, 2 models to derive spectral indices and 1 model to describe the segments.Qualitative and quantitative evaluation of the results showed that the proposed approach will help improving the results of pixel-based conventional classification

1. INTRODUCTION

“The remote sensing act” signed in 1992 by the American government has enabled the commercialization of images at metric and submetric resolutions that was exclusively of the military domain. These images of the third generation have enhanced the resolutions and broadened the field of remote sensing applications. These images are being used for applications that were using up to now aerial photos, like urban planning and cadastre (Corlazzoli and Fernandez, 2004; Alexandrov et al, 2004).

Buildings and roads are topographic features of primary interest and their extraction from aerial photos is of high stakes to many users. With the availability of high resolutions satellite images, the extraction of these features from satellite images becomes conceivable. Most researches dealing with buiding extraction from high resolution images have focused mainly on applications to urban and suburban areas. Departments of the ministry of agriculture in Morocco have tried SPOT 5 (Farhi et al, 2004) to monitor agriculture land loss due to urban extension.

Results from classical methods of classification do not seem to lead to reliable extraction of the buildings in rural areas, because of the variation in nature and form of the roofing (clay, concrete, straw…) and therefore building tend to be confused with the soil.

Studies that used traditional pixel classification approaches based only on spectral information have proved to be inefficient when applied to high resolution satellite images. These methods are in fact to slow and are unable to correctly identify the cartographic features to levels that meet user’s needs. High resolution images are in fact characterized by an important heterogeneity mainly in urban areas where the structures are too complex. It becomes then necessary to introduce the spatial and contextual information during the classification process.

The objective of this research is to develop a methodological approach adapted to high resolution images and that can enable extracting buildings from these images either in urban than in rural areas.

2. BACKGROUND

2.1 Approaches used for classification

One can distinguishes mainly three different approaches:
<u>*Classification process integrating texture*</u>: although visually perceptible, the concept of texture can hardly be quantified. This concept is characterized by the spatial distribution of grey levels in a neighborhood (Lisaka, 2000). This is equivalent in a sense to the roughness of a surface to which the image is compared. Three types of parameters are used to estimate texture:

- Parameters derived from a simple difference between minimal and maximal values within a neighborhood.
- Statistical parameters of first order: variance, rmse. These parameters are less sensitive to extreme values (Russ, 1995).
- Statistical parameters of second order: like the 12 Haralick indices (homogeneity, dissimilarity, contrast, angular moment, entropy, correlation…) and indices based on Fourrier spectrum (maximal magnitude, amplitude's variance, amplitude's energy….)

These parameters are used to derive a texture image that can be directly introduced in the classification process or submitted to some thresholding to subdivide the image into homogeneous regions. Different studies showed that the accuracy of classification improves when texture data is combined with spectral information (Akono et al, 2004 ; puissant, 2003). For buildings essentially, the improvement is of 10% for 1m resolution images and 5% for 2.5m resolution, due mainly to elimination of confusion rising from shadow and buildings classes.

Morphologic filtering: morphologic filtering uses mathematical morphology tools to analyze and recognize the structure and geometric properties of objects on the image. The theory of mathematical morphology was initiated by Mathéron in 1975. The concept is based on the sets theory which is inspired from human vision that tries to analyze objects by decomposing them into structuring elements playing the same role as spatial filters. Algorithms based on this theory tend to overestimate the results, as for finer resolutions they detect contours rather than regions (Knudsen, 2004).

Object-oriented classification: The object-oriented classification was developed in the mid 90's. The method classifies regions derived from image segmentation rather than spectral classification based on the pixel. The process is done in three steps:

- ✓ A segmentation where the image is subdivided into homogeneous and independent regions using spectral and geometric criteria.
- ✓ A characterization of objects derived from segmentation, based on their intrinsic properties (geometric, spectral and contextual).
- ✓ The classification step where the objects of similar characteristics are grouped into thematic classes. Three algorithms are used to discriminate classes: fuzzy logic, Bayesian probabilities and knowledge injection.

The object oriented method is well suited for high resolution images. However it is not obvious to establish recognition rules that are able to identify all the thematic classes of interest. In fact an absolute and generic formalism characterizing different objects is a hard task due to the diversity and the complexity of the structure of features.

2.2 Experiences with buildings extraction

Methods used to extract buildings from high resolution satellite images belong to one of the three following categories: those based on the extraction of regions (delineating of polygons representing buildings), those based on the identification of building's contours and those combining both. These approaches use techniques of segmentation and classification and contours detection. These methods adopt either the zonal analysis or object oriented, or techniques focusing on the enhancement of pixel based processing.

Shan and Scott-lee (2002) have used an oriented segmentation to detect buildings on high resolution images. The approach is based on the following reasoning: On a multispectral image zones representing the buildings are easily detected by their spectral properties, but objects are badly delineated (badly classified pixels due to confusion between building and roads). Panchromatic high resolution images will however enable a good delineation of objects, but different features are not discriminated. The solution then is to combine both images, using the classification results from multispectral image to segment the panchromatic one. The process is done in three steps:

- ✓ A supervised maximum likelihood classification is applied to the multispectral image
- ✓ and polygons representing buildings are delineated. These polygons present many artifacts.
- ✓ Elimination of artifacts and false polygons through thresholding on dimensions (length and width).

These polygons will determine a working window where the segmentation of the panchromatic image is to be done. The segmentation used is based on an ISODATA unsupervised classification. Precise delineation of buildings is based on pixel where the overlapping with initial regions is maximal.

Jonathan Li and Yu Li (2004) used morphologic filtering to delineate building's roofs on a multispectral image. For this they started adapting dilatation and erosion operators to multispectral images using a classification with several variables based on principal component analysis.

The AMOBE II system developed at Zurich (Zimmerman, 2000) uses for the automatic detection of buildings a combination of a multitude of indices (color, texture, form) and other data (DTM, Lidar…).

Lhome, Weber, Morin and Puissant (2004) have proposed an approach based on the variance of grey levels to detect the center of buildings on images of urban areas.

From previous studies one can conclude that the building extraction is a very hard task due to the nature of objects, their spatial pattern and distribution and to the image itself (resolution, contrast, noise…). The classic methods are no longer operational for high resolution images; it is therefore necessary to integrate spatial information.

To extract any particular theme no unique algorithm is sufficient; but the new approaches are based on a combination of algorithms.

3. EXPERIMENTAL STUDY

The method adopted in this experiment combines two approaches usually used to extract buildings from aerial images: pixel classification and areal or zonal classification.

In the first approach we compute for each pixel a set of spectral and spatial parameters then we allocate it to a particular class or a theme based on these parameters and on probabilistic laws. In the second approach we group pixels within homogeneous regions before labeling them based on a set of spectral and geometric characteristics.

Hence in the first step a spectral-textural classification is applied to the spectral image. Then homogeneous regions are extracted by segmentation. The thematic information will make up the first characteristic that describes regions that will be reclassified using expert classification. Hence, the spatial information is used during the spectral classification as texture channel, and during the post classification process.

This approach will enable combing images with different resolutions: a rough resolution in the multispectral mode for classification and a finer resolution in the panchromatic mode for segmentation.

3.1 Study area and data

For the purpose of testing, we used:

- ✓ Spot 5 satellite image with three spectral bands (G, R, IR) with 2.5 m spatial resolution covering irrigated rural area of Beni Amir –Tadla (Morocco).
- ✓ A map of the habitants of the region established by photo interpretation in 2004.
- ✓ A QuickBird satellite image covering the City of Rabat (Morocco) in both multispectral (R,G,B,IR) and panchromatic modes (60 cm).
- ✓ Urban map of Agdal-Riad county (Rabat) at scale of 1/7500

3.2 Methodology

Analysis of the texture the texture was analyzed adopting a statistical approach of second order based on the co-occurrence matrix of Haralick grey levels. Comparative study done by Dulyakaram (2000) has proved its efficiency. The process of deriving the texture indices is shown on the following diagram

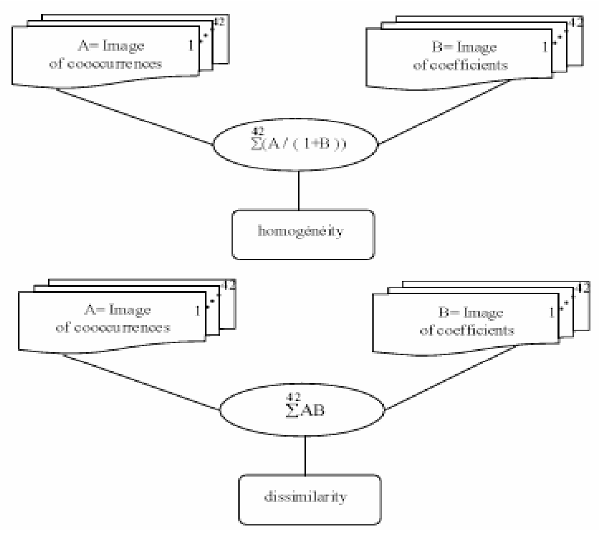

Figure 3.1. Derivation of texture indices

Haralick indices amount to 13, the most important of which are (Russ, 1995): homogeneity, dissimilarity, contrast and entropy. In this research homogeneity and dissimilarity are the two indices retained.

On the image of homogeneity, the lighter structures represent homogeneous zones: water, shadows, important roads, building of large size. Heterogeneous structures are appearing darker.
The dissimilarity index however, gives an indication on the level of organization of the co occurrence matrix elements. Complex structures correspond to finer texture (large values of grey levels). On the image of dissimilarity they are represented by lighter zones (building of small size, threes, highways)

Spectral indices: spectral indices are parameters computed from different channels in order to bring out a particular class or theme or in order to reduce the amount of information to process. Usual ones are the indices pertaining to vegetation. The integration of these indices as new channels improve and enhance the contrast.

In this research the normalized difference vegetation index (NDVI), the soil gloss index and the index of buildings

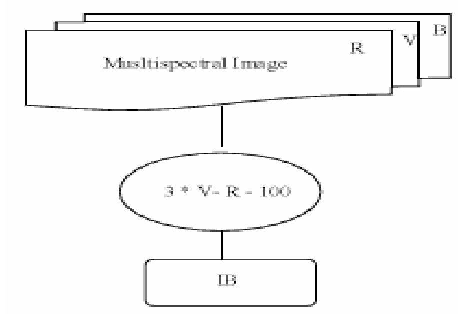

Figure 3.2. Computation of building index

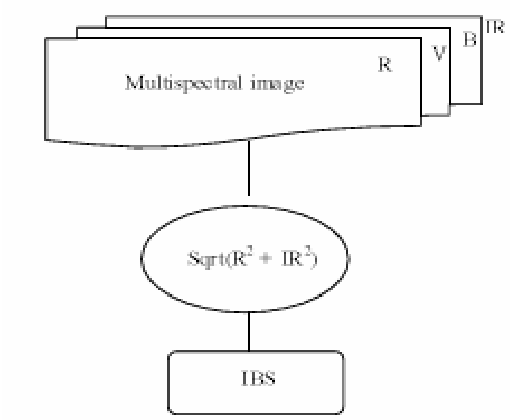

Figure 3.3. Computation of soil index

Principal component analysis: The objective of this operation is to reduce the number and the amount of information by suppressing redundant data and retaining only data of significant interest. In our case, as some channels (spectral and textural indices) are derived, some correlation may arise and a principal component analysis is then necessary.

All the models used in this research have been programmed within ERDAS using the Spatial Modeler Language (SML) and implemented through user interface programmed using Erdas Macro Language

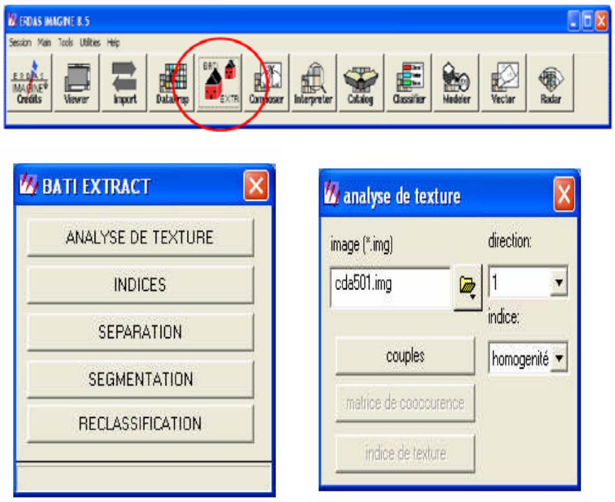

Figure 3.4. Some of menus developed

3.3 Results

The extraction of thematic information is done applying supervised classification to the image containing the new channels derived from principal component analysis.
Segmentation: the objective is to identify entities containing connected homogeneous pixels. Regions resulting from the segmentation are described by a set of parameters used to discriminate buildings class and are to be used in the procedure of expert classification if they are accepted as a part of the buildings class otherwise they will be rejected.

In this respect, the texture channels were first derived according the homogeneity index in the eight principal directions, then a principal component analysis was done to extract the first principal component to be integrated in the classification.

With regard to agriculture land, the buildings are characterized by an important heterogeneity and they appear darker on the image of texture. A priori this will help discriminating the land from buildings and eliminating in part the spectral confusion that may result from buildings with straw roofing and the bare soil.

Figure 3.5. The texture channel (homogeneity) (Spot5)

Figure 3.6. Result of spectral-textural classification (Spot5)

We notice, from the result of spectral-textural classification that in the building class, both the grouped and sparse habitant is well delineated as compared to the spectral classification.
There is however some artifacts in the transition zones corresponding to the land parcels borders that end to be confused with buildings. Another problem also is the high degree of similarity between roads and buildings. These problems will be solved using reclassification

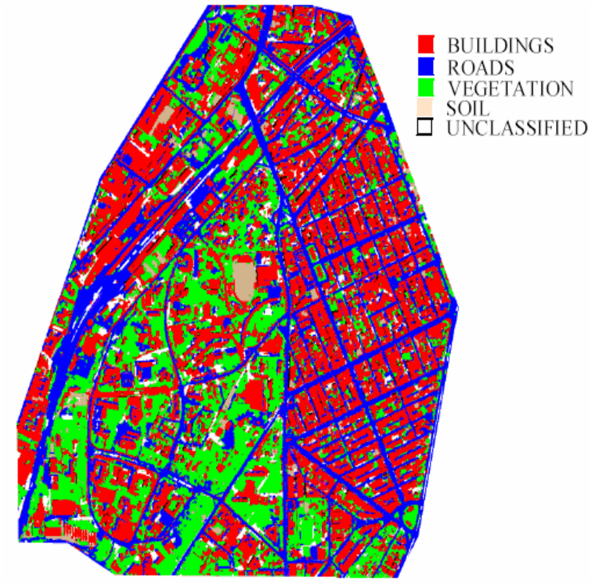

Figure 3.7. Result of reclassification (QuickBird)

3.4 Conclusion

One can conclude from testing that the approach advocated brought significant improvement with regard to the conventional pixel-based classification. The testing concerned urban and rural areas. Quantitative evaluation showed that there is 12% improvement compared to the conventional classification. The major drawback, however, is to the subjectivity in the process of extraction, when deciding on the samples, the choice of segmentation parameters and the rules on which to base the reclassification.

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