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Identification of urban objects through IKONOS images

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Abstract. The large quantity of details observed at high spatial resolution imagery created many possibilities in terms of offering geo-spatial information. However, the separability of urban objects using IKONOS image remains a challenge due to the high diversity of spectral responses in urban areas and related aspects such as local texture, spatial arrangement and geometric properties. Optimizing the extraction of information and improving the processing time of the high resolution imagery imply in imagery processing techniques which need to be refined or discovered. This article uses the principal components analysis to reduce the IKONOS image dimensionality and to reduce the processing time of the image. Next, the first principal component image was submitted to the region segmentation techniques to delineate the main texture features. Bhattacharyya distance was applied as a supervised method of image classification to identify urban targets. Despite the low spectral resolution of the image used it was reasonably successful in terms of distinguishing some urban objects.

Keywords: remote sensing, population growth, Ikonos, urban basin

1. Introduction

High spatial resolution remote sensing data are specially important to a variety of applications related to urban planning and management. Due to the quantity of details present at the 1-metre resolution imagery, it enables analysis and mapping of the terrain to a level which has not been attempted before (Herold et al, 2002).

The land cover extraction object depends on physical properties and on homogeneity measurements. But, especially in urban areas, another important aspect to be considered is the local texture, spatial arrangement and geometric properties (size, shape, orientation etc.) of land cover objects (Zhan et al., 2002). The high degree of spatial heterogeneity in terms of artificial and natural land cover categories, the high-spatial, low-spectral resolution of the satellite data, remains largely untested in mapping the urban environment.

Few exceptions can be considered in developed countries where studies to separate urban land cover classes have been conducted. In their studies, they have been taken into account, acquisition and analysis of spectral patterns of urban areas. On the other hand, in developing countries the spectral response of urban materials and their texture patterns are largely unknown, so their class separability still needs to advance considerably. The aim of this article is to evaluate the separability of urban objects using IKONOS image through statistical methods (region segmentation) in a suburban area of the Sao Paulo city (Brazil).

2. Methods

In this article an IKONOS orthorectified multispectral image (channels 1, 2 and 3) with 4-meter-spatial resolution acquired on October 19, 2002 was used and, as part of the image processing, radiance values were converted to reflectance values (Small, 2002) .

Due to the quantity of data generated by high resolution sensors, associated to the redundancy present in the images provided by the three IKONOS channels, the processing of this kind of data requires high computacional costs (time, memory, hard disk capacity).

Consequently, a specific method to reduce the image dimensionality is required. Different methods have been proposed to decrease the dimensionality for land cover classification including the Principal Component Analysis (PCA), class separability measures, and band correlation measures (Price, 1997). However, the PCA method considers the data distribution as a single hyper-ellipsoid and does not take into account the statistical properties of specific land cover types of interest (Jimenez and Landgrebe, 1999). The PCA image processing resulted in three new images, where the first principal component (PC1) was chosen as the image of reference since it concentrates most information of the three original channels and it is more correlated with the original multispectral image values.

Before the classification of the PC1 values, the segmentation technique (specifically, the region growing method) was used aiming at identifying regions of common property in the image. The urban objects provided by this technique used 50 similar neighbouring pixels as homogeneity criterion (least absolute difference) and 10 pixels as minimum object size to be detected. The supervised method of image classification used to separate spectral classes was the Bhattacharyya's distance, which measures the distance of the probability distributions among the ten spectral classes considered: high density green areas (tree), low density green areas (bush), grass, bare soil, red tile roof, light-gray metal roof, light-gray tar roof, concrete, light asphalt streets and dark asphalt streets.

3. Discussion and results

The land surface spectral response is strongly related to the sensor spatial resolution (Price, 1997). The spatial resolution determines:

- if the spectral information for a pixel results from a homogenous ground object of interest, resulting in a spectrally pure pixel, or,
- if the land surface objects are smaller than the pixel size, resulting in a spectrally mixed pixel.

Accordingly, several studies have reported problems in urban area remote sensing due to limitations in spatial resolution in mapping urban land cover objects (Roessner et al., 2001). The few studies up to date suggest a spatial resolution of finer than 5 m for an accurate spatial representation of urban land cover objects such as building structures or urban vegetation patches (Welch 1982 apud in Herold et al., 2002).

The object-oriented image processing techniques rely on successful image segmentation of image features based on contextual information such as texture, connectivity, and multi-resolution hierarchy.

The dimensionality reduction of IKONOS image using PCA techniques resulted in an image (PC1) with high content of information. Also the threshold of segmentation applied to this image presented successful results in terms of detecting edges, avoiding over-segmentation and reducing the processing time of the image. On the variability range of PCA digital values, Bhattacharyya's technique reasonably identified and mapped some urban objects.

The initial expectation is that it wouldn´t be possible to separate kinds of asphalt of the streets, however, this was not difficult since the streets with high traffic has frequent asphalt maintenance making asphalt layer new, darker and with less rugosity. Another possible aspect is that public cleaning service is more efficient in the high traffic streets, resulting in streets with less dirt (sand, paper etc.) (Figure 1-a).

The limitations in terms of distinguishing urban features, occurred between the following classes:

1) shadow of the high density green areas had 35%of confusion with dark asphalt streets (new) (35% of the shadow cases was confounded with dark asphalt cases);
2) light asphalt streets(old) had 25% of confusion with concrete.

In case 1 (shadow of the high density green areas and dark asphalt streets), the digital number for the dark asphalt streets was 2 ± 4 (average 2), while the digital number for the shadow of the high density green areas was 5 ± 9 (average 5). Evidently both distribution features have close values variability and a confusion during classification was expected due to mixed signs.

a) b)

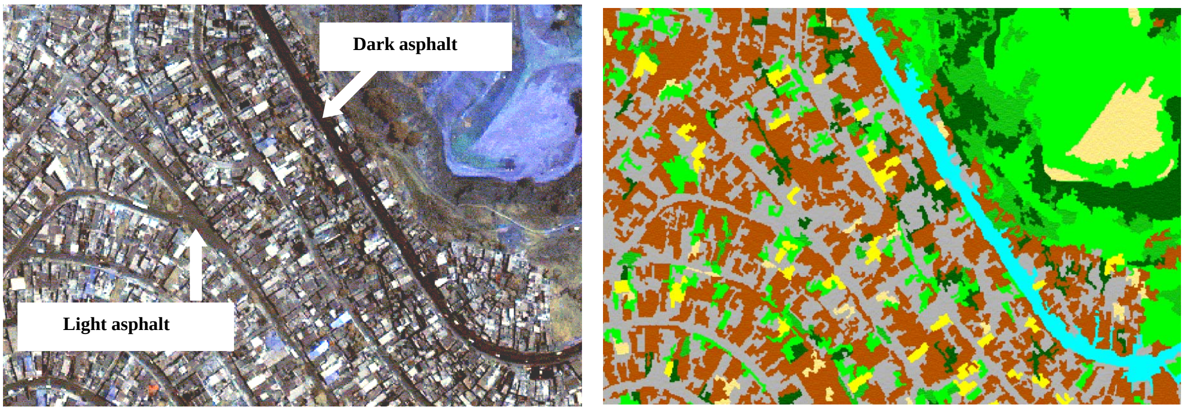

Figure 1: a) PC1 image and b) classified image.

In case 2 (light asphalt streets and concrete), both materials have the same nature (hydrocarbons) and the digital number for the light asphalt streets was 80 ± 28 (average 77), while the digital number for the shadow of the high density green areas was 91 ± 40 (average 93).

A primary cause to explain it could be the low spectral resolution of IKONOS. Herold et al. 1(2002), using a field spectrometer have compared the spectral confusion between some urban land cover classes acquired from IKONOS, LANDSAT TM and AVIRIS hyperspectral sensor. Using Bhattacharyya's distance, these authors have demonstrated that the differences of the urban targets are small for the three sensors and the same targets showed in IKONOS image present some significant low peaks which greatly limit the separability among some targets.

Limitations of the software that was used (*System of Georeferenced Imaging Processing* - SPRING, 1996), resamples 11-bits IKONOS image to 8 bits. This degradation of the digitization level obviously reduced the separability among urban classes.

The spectral response of materials used in urban constructions in developing countries and the effect of the tonal and textural structure of some objects need specific studies in the sense of building a spectral library. Moreover, the effect of land use practices and their effects in the spectral response are still misunderstood. The simultaneous use of field spectrometer and hyperspectral sensors are valuable tools to understand the spectral response variabilitity of materials and their relation to land use practices.

The use of orbital platforms for image generation of high spatial resolution has resulted in important advances in urban studies. However, these benefits created new necessities in terms of detecting and distinguishing a wide diversity of urban objects that spectral resolution of those sensors doesn´t seem to be able to do. Moreover, new image processing techniques are necessary to improve computer performance and to extract the high content of information of those images.

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