EXTRACTION OF BUILDINGS IN BRASILIAN URBAN ENVIRONMENTS USING HIGH RESOLUTION REMOTE SENSING IMAGERY AND LASER SCANNER DATA

Jorge Antonio Silva Centeno, J. A. S., Miqueles, M.A.

Geomatics Department, Federal University of Paraná - UFPR. (centeno@ufpr.br, miqueles@pop.com.br)
C.P. 19001, CEP 81531-990, Curitiba, PR, Brazil.

Commission VI, WG VI/1-3

KEY WORDS: Laser scanner, Quickbird, Classification.

ABSTRACT:

The paper describes the resulst of recent experiments of a project that deals with the combined use of high resolution satellite images, Quickbrid, and laser scanner data to analyse urban images. The aim of the projetc is to recognize buildings and point out the ocurrence of new buildings or detect new compartments within old constructions, based on a more comprehensive description of the visible objects within the image. For this purpose, Quickbird images and laser scanner data of a region in south Brazil are analysed using an object oriented approach. The results of the experiments are used to describe de advantages of the approach compared to the traditional pixel-based classification.

1. INTRODUCTION

Recent improvements in sensor technology, especially in terms of spatial and spectral resolution, enabled to better use remote sensing data to describe, monitor and model land-use and land-cover. Considering information contents, higher spatial resolution enables the visualize smaller objects on the surface, which makes it possible to increase remote sensing applications, specially in urban areas. A better definition of the object in the image is, nevertheless, still not sufficient to guarantee efficient recognition.

Although high resolution imagery provides a better description of the surface in terms of spatial information, the discrimination of objects and land-use classes became more difficult. On one hand, smaller objects are visible within the scene, which enables to detect objects like houses and streets. On the other hand, these smaller objects are mixed with other unwanted objects, like cars and also shadows. Using a low resolution image like Landsat, for instance, cars and shadows are melt together within the pixel and are not visible, because of the pixel size. With a pixel around 0,5m to 1m, unwanted objects occupy a significant area in the image and the presence of such unwanted information becomes a problem in the classification step.

A solution for high spatial resolution classification is to adopt approaches based on image segmentation and classification of the segments. Previous work on this specific topic are reported in the literature. For example, Centeno et. al. (2004) used segmentation to classify high resolution data of the visible part of the spectrum in order to map impervious areas and Ivits et al. (2003) used the same approach to study landscape connectivity in high resolution images, obtained fusing Landsat ETM and IRS data.

Recent developments of laser detection and ranging reduced the time and effort needed to model the surface of the objects. This information, poor in spectral terms, can complement the spectral data provided by remote sensing sensors. The potential use of laser scanner data is interesting for urban applications, because an urban scene is complex in terms of geometry. The spatial resolution of laser scanner data is compatible with the spatial resolution of available satellite imagery, but the nature of the information is different. The altitude of the pixels can be computed from a laser scanner survey, providing a new dimension to the identification and classification problem.

Recent studies, like Maas and Vosselman (1999) and Haala (1994), proved that altitude data derived from laser scanner surveys is useful for the detection of buildings. The main problem using such approach is the fact that the discrimination between buildings and other objects, like trees, is difficult, because they use only the elevation of the objects as source. In order to find a solution for the confusion of objects with the same elevation, Brunn and Weidner (1997). Proposed an approach based on the analysis of the roughness of the selected regions, derived from the laser scanner data, assuming that vegetation and roofs have different textures.

We propose an approach to improve the result of image classification using additional height information, derived from laser scanner data. The combined use of both data sources, remote sensing spectral images and laser scanner altitude data, enables to obtain a better description of the objects, since a new dimension is added.

The main idea was already tested by Haala and Brenner (1999), who used multispectral information combined with geometric information from a laser scanner during the classification step. They used simultaneously geometric and radiometric information by applying a pixel-based classification, whereby the elevation of the objects was used as an additional channel. Here, we use an object oriented approach that performs segmentation and classification of the segments.

2. METHODOLOGY

Earlier experiments proved that the use of laser scanner data or multispectral images can be used to classify an urban scene and detect buildings, but errors are expected for each data source(Centeno et al, 2003; Centeno and Miqueles, 2003). Therefore, the project aims at the cooperative use of both data sources in the classification, attempting to detect buildings. A Quickbird image and laser scanner data were used as sources. The methodology consistes of three basic steps. Image registration, region based segmentation and a posterior classification of the regions, based on spectral and spatial features. A supervised classification approach, based on fuzzy logic, allows to describe and combine membership functions derived for spatial and spectral features. The whole processing was performed using the eCognition software. The quality of the obtained result was evaluated, comparing it to the result of a monocular restitution of the same area. In this section, we introduce the study site and data set used. We then briefly describe three different steps.

2.1 Study area and available data

The study area lies on the urban perimeter of the city of Curitiba, Brazil. It is part of a residential area, characterized by a mixture of elements such as residential and commercial buildings, paved streets; stone covered pavement in the gardens, roofs of different materials, and vegetation of different sizes (trees and bushes). Two different data sets were available for this region: a Quickbird image and a laser scanner data set. Since both data sets don´t cover exactly the same area, a region within the overlap was chosen.

The Quickbird image was obtained on march, 2002. All four multispectral channels and the panchromatic channel were available. The pixel size of the multispectral image is about 2,8m while the pixel of the panchromatic image is about 0,7m.

Figure 1 shows a part of the Quickbird image of the study area. The color composition uses the three bands of the visible.

Figure 1.Quickbird image of the study area

The laser scanner data consist of XYZI-ASCII files. The ASCII files contain the 3-dimensional coordinates of each point and also the intensity of the returned pulse. When the reflected beam produced more returns, the first and the last pulse were recorded. The laser scanner survey was obtained on may 2002, using the Optech ALTM system by LACTEC (Instituto de Tecnologia para o Desenvolvimento). In order to use laser scanner data together with the satellite imagery within the image processing software, a grid was interpolated from the point data, with the same spatial resolution of the quickbird image. The resulting grid, a digital surface model (DSM) was later coded in integer values, taking a centimeter as unit.

The altitude grid is not relevant for the discrimination of objects, because it includes the height of the terrain, the topography. In order to avoid the effect of the topography, a normalized DSM was computed, subtracting a DTM, already available, from the original DSM. The so-called normalized DSM (nDSM) is a representation of objects rising from the terrain put on a plane (Weidner and Forstner, 1995). Figure 2 displays a perspective view of the nDSM. Darker pixels are associated to lower elevations.

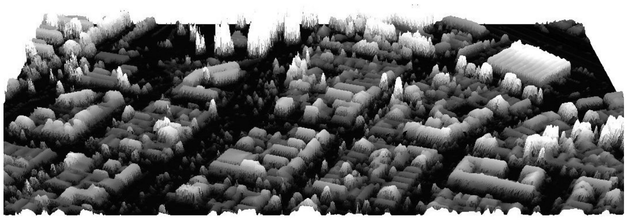

Figure 2 – 3D view of the laser scanner survey

2.2 Image Registration

Registration is a fundamental task in image processing used to match two images. In our study, the laser data was considered to be geometrically correct and was used to correct geometric distortions of the satellite image. It must be taken into account that both data were taken from different viewpoints and that the laser data are post-processed and corrected in terms of geometry, being represented in an orthogonal system. The satellite image has distortions caused by the perspective view and the inclination of the sensor in relation to the nadir. The study area lies within a flat region. Therefore, the effect of topography is minimal, but the effect of the height of the buildings is a serious problem. In order to compensate the relative displacement of the top of the buildings, a projective model was used, based on the height of each building, derived from the laser data. The result is a new image where the roof are shifted closer to the base of the building.

2.3 Image Segmentation

The segmentation step consists of the division of the image in uniform regions that correspond to the objects of interest, for example roofs, vegetation and streets. A region growing segmentation was used to obtain the elementary regions. This algorithm merges adjacent pixels that have similar spectral properties, forming regions that grow in an iterative process as similar regions are melted together. The result is a new image, where each pixel is labeled as member of only one region. The algorithm called "fractal net evolution approach" (Baatz and Schäpe 2000) avaliable in the eCognition software was used. The algorithm allows to guide the region growing, using a weighting function that controls the shape and spectral uniformity of the regions. This guided segmentation allows to improve region extraction, since the form of the elements within an urban scene is, in many cases, regular. According to Antunes

(2003), it is necessary to take into account the scale of the problem to be solved and the type of image data in order to choose de parameters of the segmentation.

2.4 Classification

In the classification step, the degree of association of a region to each chosen soil cover class is described by a fuzzy membership function $f_A(x)$, which can assume values in the interval between 0 the 1. The membership functions, obtained from different features, as shape or spectral properties, can be also combined, in order to model an object. Fuzzy logic operators are available to combine the membership functions of different features and to draw a conclusion about the most suitable class for each object. Therefore, training regions are chosen in order to compute parameters that describe each class.

For the classification, a large set of variables is available since, after the segmentation, the image is composed by segments, that can be described using spectral and spatial features, as well as topological relations within segments. The main problem consists in selecting the most appropriate features and combine them using the fuzzy logic approach. This task requires experience and good knowledge of the data set. The classification can be performed using a hierarchical tree approach, which builds up a hierarchical network of image objects. For the purpose of the hierarchical analysis, each segment is considered as an object that has relation to other objects within the same level or in other levels. At the bottom of the hierarchical tree, coarser objects can be found, results of a more generalized segmentation. At the other end, small objects, results of a fine segmentation are located. Smaller objects can inherit properties of objects on a lower level, and are considered specializations. The relations between objects stored in the network allows to use local context in the classification.

3. RESULTS

The data set was processed using the described approach and a thematic image was produced. For the classification of the image, a hierarchical tree was proposed after analyzing different possible networks. The used hierarchical networks is mainly based on the elevation of the objects, derived from the normalized DSM, and the spectral information derived from the satellite image. Spatial parameters, like form or texture, were not considered, because their performance was considered low compared to the spectral and altitude information.

After deriving a satisfactory land-cover classification, the regions were grouped in 6 categories: “trees”, “grass”, “roads”, “yards”, “roofs” and “bare soil”. The main problem was associated to “bare soil”, which is easily confused with “roofs”. Because the main objective of the study is to detect buildings, the thematic image was simplified, producing a binary image of the buildings. Figure 3 shows the segments classified as buildings.

In the result, the blocks can be identified and the buildings are separated from the other objects. Nevertheless, erros are still present. For example, small regions remained and the contours of the objects were not exactly located are at the borders of the buildings in the data set. The first problem was solved using a size filter that discarded small areas. The second problem is difficult to solve since it occurs during the segmentation step. In some cases, the error is caused by errors in image registration and in some cases it is caused because of the poor spectral resolution of the image, which causes objects to have similar spectral response and difficults the delineation of the borders, even during a visual analysis.

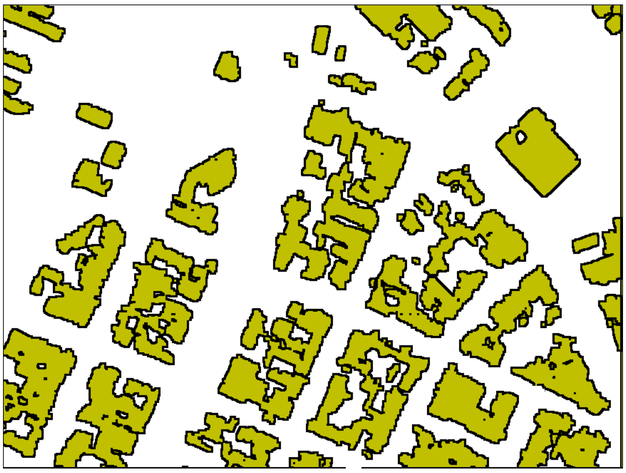

Figure 3 – Result of the classification of buildings

Figures 4 and 5 show a perspective view of the data set before and after the process. The view was obtained using the geometry of the laser data and the colours of the green red and near infrared channels of Quickbird. In the first image, the elevation (nDSM) of every pixel is displayed. In the second one, only the pixels of the normalized DSM that belong to buildings have elevation information. It ca be seen that the vegetation was successfully eliminated and the buildings were recognized.

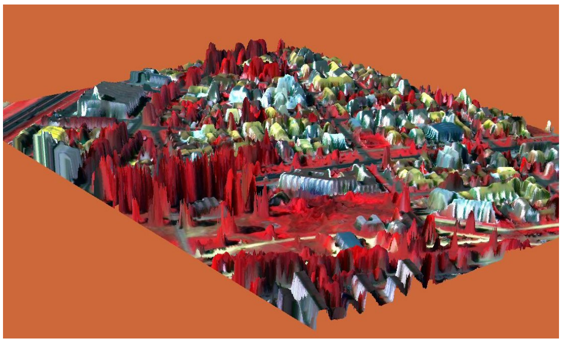

Figure 4 – Coloured nDSM.

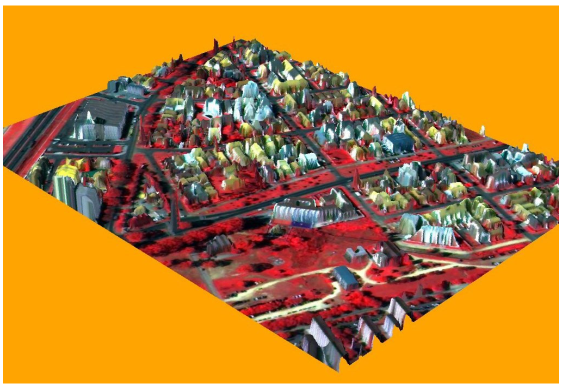

FIgure 5 – Coloured nDSM of the buildings.

4. CONCLUSIONS

The increased spatial resolution of Quickbird imagery is a powerful information source for the identification of buildings, but the complexity of an urban scene makes it difficult to get a satisfactory results based only on spectral information. On the other hand, laser scanner data are rich in spatial information, but poor on spectral information, which makes it difficult to use only altitude data to separate object with the same height. In the present study, the integrated use of both data sources was presented. The great amount of data and the different nature of the features require a different treatment than the classical pixel based analysis. Therefore, the object oriented approach was used. In the analysis of the segments, spatial features, like form and texture parameters were not sufficient to classify buildings. The best results were obtained using laser data, because the objects can be well delineated in a nDSM. The separation of trees and buildings can be performed using the spectral information of the satellite image. In this manner, both data cooperate and the best aspect of each data source can be used. The resulting thematic map does not allow to identify each building, but only blocks. The results encorage to use high resolution imagery together with laser scanner data to locate new buildings in urban regions. It ca be used in a second step, where the geometry of the buildings can be reconstructed, analyzing only a small part of the image arround the selected regions.

5. REFERENCES

Antunes, A.F.B. 2003. *Classificação de ambiente ciliar baseada em orientação a objeto de imagens de alta resolução espacial.* Ph.D. Thesis. Universidade Federal do Paraná, Curso de Pósgraduação em Ciências Geodésicas.

Baatz, M. and Schäpe, A. 2000. Multiresolution Segmentation – an optimization approach for high quality multi-scale image segmentation. In: Strobl, J., Blaschke, T., Griesebner, G. (eds.): *Angewandte Geographische Informationsverarbeitung XII*, Wichmann-Verlag, Heidelberg, 12-23.

Centeno, J.A.S., Antunes, A.F.B., Trevizan, S.J., Correa, F. 2003. Mapeamento de áreas permeáveis usando uma metodologia orientada a regiões e imagens de alta resolução. *Revista Brasileira de Cartografia*. Brasil, v.55, n.01, p.48 - 56.

Centeno, J.A.S.; MIQUELES, M.A. Detecção e caracterização ed vegetação usando dados do laser scanner aerotransportado. In: *III Colóquio Brasileiro De Ciências Geodésicas, 2003*, Curitiba.

Haala N.; Brenner C. 1999. Extraction of buildings and trees in urban environments. *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 54, iss. 2, pp. 130-137(8).

Ivits, E. ; Koch, B.; Blaschke, T. And Waser Lars. 2002. Landscape connectivity studies on segmentation based classification and manual interpretation of remote sensing data. In: *eCognition User Meeting*, 22-24 October, 2002, München.

Maas H.-G.; Vosselman G. 1999. Two algorithms for extracting building models from raw laser altimetry data. ISPRS *Journal of Photogrammetry and Remote Sensin*g, vol. 54, iss. 2, pp. 153-163. Elsevier Science.

Weidner, U. and Förstner, W., 1995. Towards automatic building extraction from high resolution digital elevation models. *ISPRS Journal of Photogrammetry and Remote Sensin*g . vol. 50 iss. 4, pp. 38–49. Elsevier Science.

6. ACKNOWLEDGEMENTS

The authors would like to thank the support of the Federal University of Paraná and CNPq for providing the scholarship and finantial support for the research, and also LACTEC and Tese for the cooperation.