

CHARACTERIZATION OF THE GROWTH OF URBAN AREAS BY MEANS OF QUICKBIRD IMAGES THROUGH OBJECT ORIENTED SEGMENTATION

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KEY WORDS: object-oriented segmentation; hierarchical classification; Fuzzy Logic; high resolution images; urban areas mapping

ABSTRACT:

The dynamics and complexity of urban growth call for new ways to guide development in order to guarantee the sustainability of cities and the quality of life of its inhabitants. Rapid urbanization and the growth of large urban centres demand new strategies in urban planning and territorial organisation, especially at present when unplanned urban growth menaces the limited natural environment. The purpose of this paper is to verify the feasibility of high resolution images for recognition and the classification of features indispensable in urban planning. It tries to establish a methodology that could guide and generate thematic as well as analytical maps showing the dynamics of urban growth using the easiest and most reliable way to obtain spatial information from the image. The methodology applied is based on three norms: the organization of knowledge base from the semantic net; generate objects or features by means of image segmentation. In order to identify which descriptors could discriminate better the interest features multivariate statistic and principal components and discriminant analysis techniques were used, as a result potential descriptors were selected. Contextual information is important in creating objects closer to real features of the terrain and thus optimizing the segmentation process; in other words a creation of more realistic objects neither too fragmented nor too generalized. The proposed method will result in the behavior comprehension of relevant objects by estimating color, shape and dimensional parameters, which control the segmentation process. It should improve the vector representation and consequently the quality of the information extracted from high-resolution imagery. Box-plot were generated to evaluate better relationship between classes and object distribution besides descriptive statistics were also calculated to provide variables selection. Finally the classification process was achieved using those previously chosen descriptors to start up the classification process based on hierarchical classification. The image used in this study contains a panchromatic band and four multi spectral bands from the Quickbird sensor. The study is based on an informal settlement by the name of Guarituba, in the town of Piraquara, in the State of Paraná. The area is important as it is the location of springs which supply water to Curitiba, the capital of the State of Paraná, and its Metropolitan areas. The methodology proposed sounds very promising by means of Statistic Degree of Discrimination created based on bi-variate correlation and descriptive statistics. The graphic Box-plot, was a useful tool to sort out the functions and parameters definition to perform the classification at urban environment.

1. INTRODUCTION

The digital classification relevant objects to the urban planning still faces great challenges. Considering of the complex nature and diverse composition of land cover types found within the urban environment, the production of urban land cover maps from high-resolution satellite imagery is a difficult task. The materials found in the urban environment include concrete, asphalt, metal, plastic, glass, shingles, water, grass, trees, shrubs, and soil, to list just a few are hard to sort out. Moreover, many of these materials are spectrally similar, and this leads to problems in automated or semi automated image classification of these areas. As many classes of interest in the urban environment have similar spectral signatures, spatial information such as texture and context must be exploited to produce accurate classification maps. Fuzzy classification techniques allow pixels to have membership in more than one class and therefore better represent the imprecise nature of the data. In this paper, a hierarchical fuzzy classification method that incorporates both spectral and spatial information is presented. Fuzzy logic classification efficiency depends on the

variables and parameters (spectral, form, textures) chosen (Baaz&Schape 2000; Hofmann, 2000).

The methodology proposed sounds promising by means of Statistic Degree of Discrimination created based on bi-variate correlation and descriptive statistics. The graphic Box-plot, was a useful tool to sort out parameters definition to perform a better classification of urban environment (Duarte, 2007).

2. STUDY AREA AND IMAGES

To evaluate the method a Planning Territorial Unit Planejamento (UTP) was chosen, situated in Piraquara metropolitan region of Curitiba (figure 1). This Unit integrates the Region Metropolitan of Curitiba and has at least 70% of its territory comprises water springs. These springs is responsible for more than supply 50% of the population of the Curitiba, Metropolitan Area. The UTP considering de demographic growth some irregular settlements has been detected in this region menacing the ecological balance. It is one of the biggest irregular settlements of the Curitiba Metropolitan Area.



Figure 1- State of Paraná, South Brazil. In red Study Area

An image of September of 2004 was selected, captured from *Quickbird* sensor with space resolutions of approximately 2,4m for the multispectral bands and of 0,6m for the panchromatic. The vegetation index- NDVI was generated as a complementary band.

3. METHODOLOGY

This article proposes identify and classify urban objects of high resolution image. The methodology focuses on three main processes: the construction of hierarchical levels from the knowledge base (classes are organized within a class hierarchy), expressed by semantic network; the formation of objects of interest consistent with reality by means of object-oriented segmentation using contextual information; and classification of objects from the statistical modeling of their behavior and the use of fuzzy functions (Blaschke, 2010).

Using the method of determining the parameters of segmentation and classification based on the knowledge generated by the context information allows the user to better understand the process of creating objects and estimate values of scale, color and shape to ensure a closer segmentation and classification of human cognition.

Given the understanding that the process should be iterative and empirical understanding of it depends on the user's location, the satellite and application, the method guides the researcher in selecting parameters that guide the formation of objects closer to the features of ground. This optimizes segmentation for objects that are not created nor too fractionated, not to confuse different objects merged.

The methodology is based on knowledge of the behavior of features for estimating parameters of color, shape and dimension which, when inserted in the segmentation process, improve the quality of the vectorization and therefore the information extracted from the image.

The solution propose seeks to enhance the capabilities of remote sensing data by means of identification and parameterization of the variables and attributes necessary for the discrimination of urban objects. This will reduce the time to check and processing variables, facilitating the analysis and the human use of a priori knowledge of the area, reducing the subjectivity in defining the roles for the classification of satellite images.

The classification process uses as its main axis multiresolution segmentation and object-oriented classification models from the membership functions of fuzzy logic.

Conducted from the structure of objects relevant to the area of interest, this methodology (Table 1) help the user to respond to

select which variables and parameters to distinguish objects with greater parsimony defined if no interactions between variables, which function to choose each type of distribution, where the tolerance range of the function attributed to not make the class very sensitive or very specific.

Basis	Entry	Process	Output
High Resolution Image	Visual Interpretation of urban features	<i>Hierarchy of classes</i>	<i>Semantic Network</i>
Processed Image	Growth region	<i>Image Segmentation</i>	<i>Objects and superobjects</i>
Segmented Image	Spectral values : Form , Spectral and context	<i>Objects behavior</i>	<i>Definition of objects and its properties</i>
Segmented Image	Statistical Parameters and attributes Selection	<i>Parameters and Descriptors Classification of objects</i>	<i>Decision rule and classification model Thematic Map</i>
Image Segmented and Semantic structure and classification model	Fuzzy Logic		
Thematic Map and Original Image	Interpretation parameters and Classified objects	<i>Classification Assessment</i>	<i>Accuracy Index</i>

Table 1- Methodology Steps

The objects of interest to urban planning and land use map are identified in fact different scales that will be worked on different levels of segmentation, but without losing the hierarchical relationships. As new classes of objects are created on smaller scale segmentation, they begin to belong exclusively to one of the classes of larger scale. This relation hierarchy assists in the classification process (figure 2)

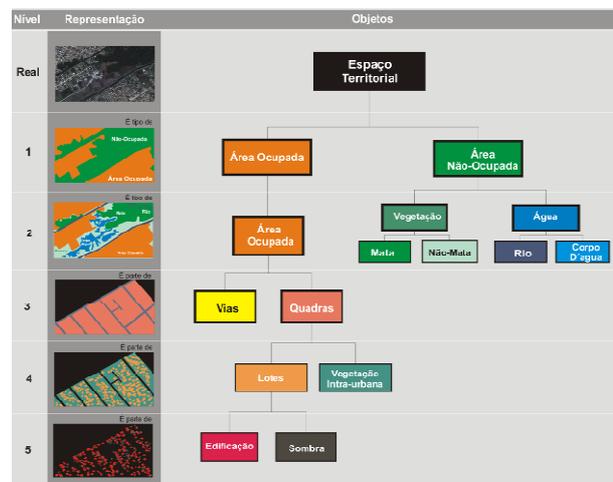


Figure 2- Class Hierarchy of urban features

Next step is the classification of urban features previously identified and related. Classification is the process of

identification the objects formed in the segmentation into categories set arbitrarily by the user. For this, you should inform the classifier algorithms which are the descriptors, the functions and parameters that will be used to discriminate each object in its class (Antunes, 2003).

According Pavuluri (2003), there are numerous organizations in the world working with classification of high resolution images, using existing techniques or developing new methods, but as the remote sensing data have become increasingly complex, it demands different approaches for different purposes. The classification of urban areas growth requires models built specifically for its characteristics and properties.

For this reason, the classification requires the study of the statistical behavior and physical descriptors for each class of objects set out in the semantic of each studied reality and there is no set formula robust enough to adapt to any environment and urban settings and different types of sensors (Antunes, 2003).

The classification, unlike the segmentation process begins by its larger-scale objects, based on the more general to specific. This enables the construction of hierarchical relationships, since the larger objects of the merger are lower, allowing you to create inter-relationship between the levels (Baaz & Schape 2000). This process helps in classification, avoiding redundancy and unnecessary processing in an area where, according to the semantic network, there is no interest to classify a given object that has a specific super object.

From the knowledge of the behavior of the descriptors for the classes and the hierarchy of objects created in the semantic network, it is necessary to develop models and decision rules can make the distinction, with the least possible uncertainty.

In some situations, the levels of uncertainty are large and can not be determined from exclusive and scientific way that an object belongs to a particular class. Because there is this level of subjectivity, the fundamentals of fuzzy logic are appropriate to assist in decision making because operationalize a set of rules that indicate which class a particular object would be assigned with the highest degree of assertiveness.

4. RESULTS

Fuzzy functions allow the establishment of membership for each object to a prescribed set of classes. Ranging from 0 (zero) to 1 (one), where zero represents the absence of an association with the class and the certainty of belonging to the same, the fuzzy logic allows an object has membership greater than zero in two or more classes .

To use two or more functions in characterizing a class of objects, it uses a logical operator that combines the degrees of relevance, resulting in a single value. The types of operators used are "E" (minimum), "Or" (Max) and "average" (arithmetic or geometric). When it is necessary to work with three or more variables to discriminate the object, it is possible to use more than one operator, but to facilitate the procedures and reduce the number of logical operators variables may be combined to form a new, more powerful separation .

Objects with low degree of relevance or very close to another class have a higher risk of misclassification, increasing the need to find keywords and parameters that improve the distinction of classes. In order to help this process of choosing discriminatory variables, selected samples were manually sorted to extract variables from each of the descriptors: spectral, shape, texture and neighborhood, among others, allowing an understanding of the behavior of classes of objects created by the segmentation.

In order to avoid the evaluation the behavior of each variable one by one, is proposed to calculated the degree of

discrimination. It allows to rate the discrimination of objects classes.

This process eliminates variables that have similar behavior between classes, not relevant to the classification process. The test is whether the variable has to some combination of two objects-a-two, significant differences in the distribution of data, can contribute to discrimination of classes of objects.

The degree of discrimination varies from 0 to 1, where 1 means that the variable has the power to discriminate all objects between these two classes 0 and that one object is completely contained in the other, not allowing them apart (figure 3).

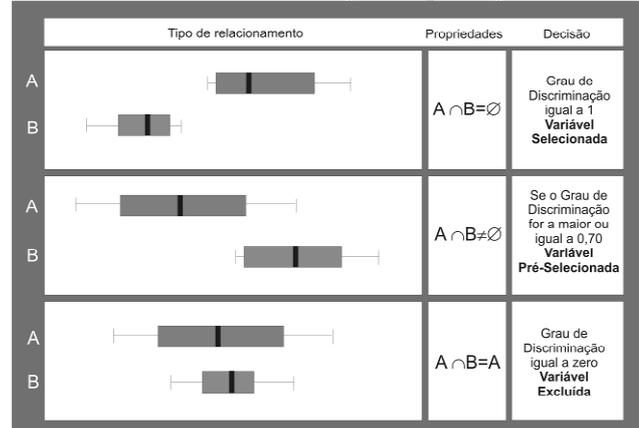


Figure 3- Discrimination Degree/ Grau de discriminação.

The Box Plot chart shows the representation of the data distribution and is composed of the median, 1° and 3° quartiles, upper and lower bounds, beyond the representation of extreme values (outlayer). The simultaneous representation of several features allows viewing of properties, position, variability and asymmetry and, when applied to multiple categories, permits comparability between the distribution of different objects. Figure 3 illustrates the types of possible relationships between the data distribution of the object classes using the Box Plot chart.

The calculation of the degree of discrimination is accomplished by the following procedure:

- 1- First step: calculate the percentiles 5% and 95% of the object A.
- 2- Second Step: Calculate the percentage rank of percentile values of the object in relation to data set B.
- 3- Third Step: assign a grade equal to 1 percent when the order for the two percentiles is equal to 0 or equal to 1 (no intersection) and assign grade 0 for the variables that do not have at least one value of the order of 1 or 0 (contained).
4. Step: for the other variables, calculate the degree of discrimination according to the equation:

$$(1) D_Degree = 1 - |Ordem_B(Percentil_{A,0.95}) - Ordem_B(Percentil_{A,0.05})|$$

Where :

D_degree= discrimination degree ;

Order_s= ordered data set in ascending order, represents the position of a percentage value relative to the whole. In order to reduce the effects of extreme values, instead of working with the maximum and minimum values will be used percentiles of 5% and 95% as far as the limits of each class.

The variable level of detail with greater than 0.70 were analyzed with greater accuracy by graphing box plot. Were also analyzed

the correlations, two by two, to reduce the redundant selection of variables in the process of classification.

The percentile and quartile information also helped in the choice of parameters that determine the membership of an object to its class.

Figure 4 presents the behavior of object classes for selected variables. One may present a number variation of pattern distribution of the data and the other with the color scale in the segmented image. It allows you to view spatially in the study area.

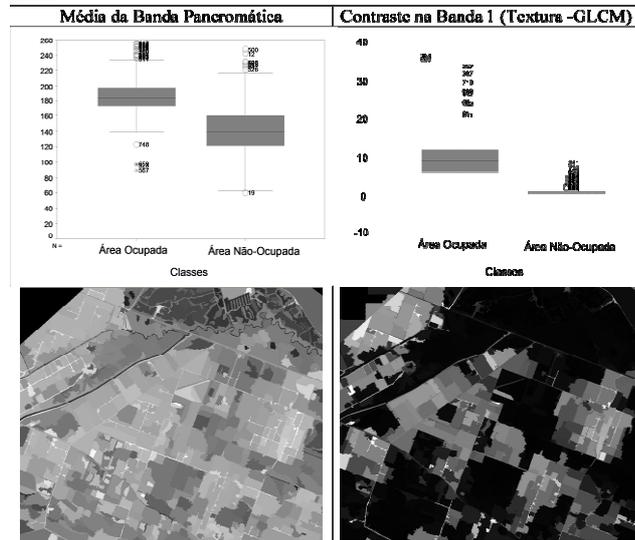


Figure 4- variation between classes

The objects of class "unoccupied" (area não-ocupada) the variable "GLCM Contrast" presents little variation, and a more powerful separation of classes, since their degree of discrimination is 0.94. The variable "Average Panchromatic Band" (Media Banda Pancromatica), despite having a lower power of discrimination (0.76), it also helps to explain the parameter behavior. (correlation = 0.60).

This result permits identify the behavior of the descriptors for each class, it became easier to recognize the best combination of attributes for the discrimination of objects. During the classification process before perform fuzzy logic function one study of discriminate degree of variables was performed. It has optimized the classification process and improves assertiveness in the discrimination of objects.

The multiresolution segmentation process generated objects into five distinct levels of scale, as the spatial dimension. Each level has its own combination of layers and weights (figure 5).

5. CONCLUSION

The main purpose of this work was to analyzes of urban environment and the establishment of a methodology for selecting the information required to classify a Quickbird image. The knowledge of the behavior of objects, contributes to reductions in the levels of error and computational processing. The methodology applied was useful since the object-oriented segmentation allows you to create a multitude of descriptive parameters, previously not available in the pixel-by-pixel classification. The use of more contextual information to local realities, exploring variables such as shape, texture and neighborly relations and not only the original spectral bands of sensors, and operations and the merger between bands with different resolutions improve performance classification.

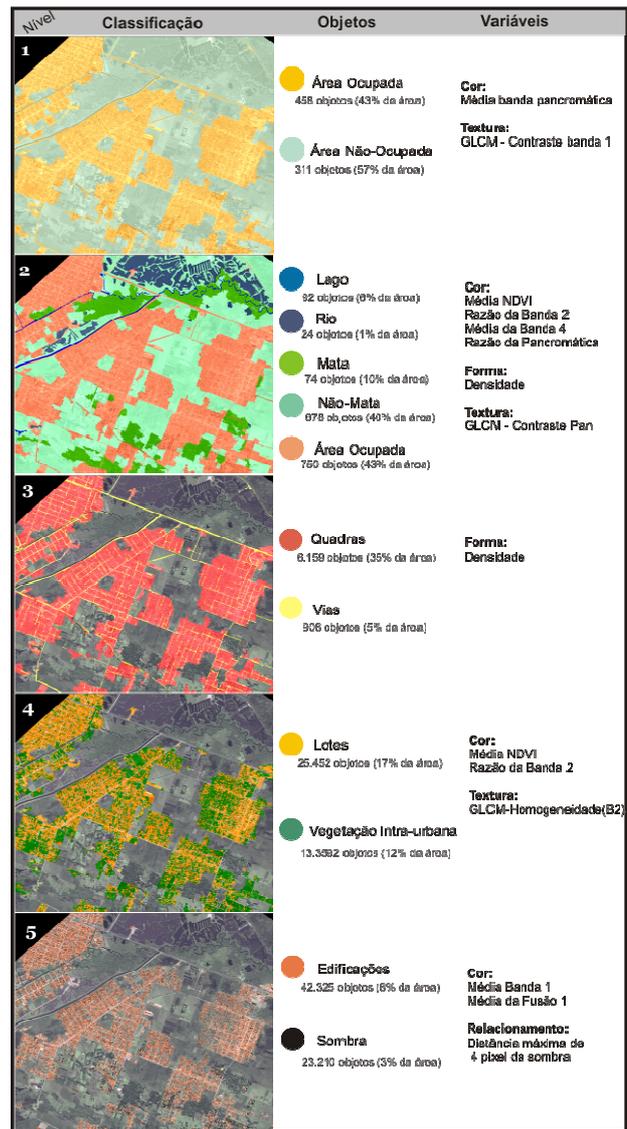


Figure 5- Output- Classification from multiresolution segmentation

Although a software segmentation and classification algorithms have been used already defined (ecognition), the automation of the segmentation and classification depend on the user's understanding of the area and the objective of the study. The use of the membership functions (fuzzy logic) creates a decision criterion on the class closer to human reasoning, which facilitates establishing classification rules. The concepts of artificial intelligence used in the structuring of the semantic network, establishing relations as "is part of", "is taken from", "synonym" and "related" help better classification.

The object segmentation, especially for urban areas, proved decisive for the classification quality and practical relevance. The multiresolution segmentation helps in getting objects from different levels of scale and hierarchy, but it is still a challenge to create objects "pure" fragmented and little, if within the same class of objects there is a large disparity in spatial dimensions and low internal homogeneity.

The behavior of objects and its attributes is crucial both to guide the segmentation and to establish decision rules for classification. To understand the behavior of objects, it is

necessary to study a representative sample of each class and determine which keywords and variables are important for their discrimination. The process of selection of variables reduces the subjectivity and makes more efficient choice of membership functions that lead to the classification.

The application of the methodology, since the pre-processing the image to the classification level and construction of thematic map, shows satisfactory results for the proposed objective of the study. The thematic output was relevant urban planning it allows the evaluation of urban dynamics.

The increasing importance of integration of Land Information System – LIS/Remote Sensing requires the continued improvement of methods of segmentation and classification. In this work, the objects created and classified could be export to LIS (Land Information System).

According to Brazilian Guidelines of Multipurpose Cadastre, the updating and maintenance of LIS is crucial for urban planning.

ACKNOWLEDGEMENT

The authors likes to thank Federal University of Parana, Geomatics Department and it Phd Program in Geodetic Sciences for the support.

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