HIGH-RESOLUTION SATELLITE IMAGES FOR URBAN PLANNING, STUDIES IN PROGRESS AT INPE (NATIONAL INSTITUTE FOR SPACE RESEARCH), BRAZIL

Hermann J. H. Kux (*), Carolina M.D. de Pinho (*), Iris de Marcelhas e Souza (*)
(*) INPE – Instituto Nacional de Pesquisas Espaciais, Avenida dos Astronautas 1758, São José dos Campos, SP, Brazil, 12.201-970
hermann@dsr.inpe.br
carolina@dsr.inpe.br
íris@dsr.inpe.br

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ABSTRACT:

The availability of high-resolution satellite images allowed new applications, especially in urban areas. In Brazil, where up-to-date information is frequently missing in data banks at Municipal, State and Federal level, the information obtained from these images could eventually fill this gap. In this paper, a case study, performed in the city of São José dos Campos, São Paulo State, Brazil is presented. A QUICKBIRD scene was classified using an object-oriented approach. After presenting the fundamentals of this new approach, a land cover map of a section from this city is presented and discussed. This is a contribution for urban planning.

1. INTRODUCTION

This paper is focused on the object-oriented classification of a QUICKBIRD scene referring to land cover mapping in the intra-urban space of São José dos Campos, (Brazil). While until recently digital classifications considered essentially color and tone for each pixel, at high resolution images characteristics such as texture, form, localization and context became more important (Sharma & Sarkar, 1998). The segmentation algorithm from *eCognition* 4.0 software package (Definiens, 2004) used in this study, slices the image based on 4 criteria: scale, color, smoothness and compactness. Using this procedure, it is possible to extract homogeneous areas in the image, optimizing the analysis of the specific spatial complexity in urban environments. Antunes (2003) proposed a conceptual model for object-oriented classification which synthesizes very well the concepts used in *eCognition* 4.0, summarized in Fig. 1.

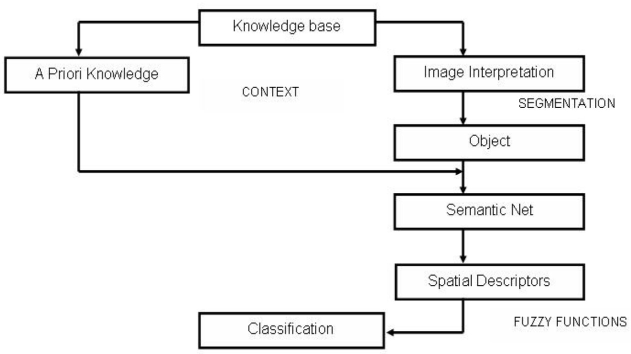

Fig. 1 – Conceptual model for object-oriented classification after Antunes (2003).

Here vector data, created by image segmentation, get attributes which allow a semantic construction, where the descriptors can be associated to fuzzy logic rules, allowing the context analysis (Pinho & Kux). The segmentation algorithm referred to above, known as "multi-resolution segmentation" (Baatz & Schäpe, 2000) uses the concept of Fractal Net Evolution Approach (FNEA), which considers the image as of fractal nature. The resulting objects of segmentation are associations of spectral information and forms of image elements. Considering the segmentation of urban space through the integration of both spectral and contextual information, it is possible to classify an individual object as such and not as a chaotic mixture of pixels (Thomas et al., 2003).

Pinho (2005) analyzing IKONOS and QUICKBIRD images of an urban area, introduces knowledge to the classification of a section from São José dos Campos (Fig.2, last page of this paper), in order to overcome the low spectral resolution of these sensor systems, allowing a better discrimination between urban targets. In this paper, due to space limitations, we will present only the results achieved with the analysis of a QUICKBIRD scene.

2. METHODOLOGY

The image segmentation strategy considered in this study was bottom-up, i.e., objects at level I (Table 1) are successively aggregated until they formed objects at level IV. This sequence was followed because, according to Hofmann (2001), the direction of the segmentation process (bottom-up or top-down) affects the limits of the objects, and it is wise to start the segmentation at the level where the objects of interest are located.
Referring to the main parameter used during segmentation, at Levels IV and III a higher weight was attributed to "Form", while at Levels I and II "Color" was higher weighted. In the first case, the limits of objects from these levels were already previously defined by vectors of quarters and blocks, used during segmentation. At the second case Color was higher valued because the spectral content is more important to distinguish land cover classes than Form.Level IV aggregates all objects of the lower levels to analyze a series of data grouped by the spatial unit "Quarter". So e.g. one can map the level of tree cover of the quarters, calculate this cover, given by objects of class of arboreal vegetation at level I. This level was defined in order to get data for the creation of urban indicators. Level III was created to restrict the existence of some classes, because some classes occur only within blocks or at streets. An example of restriction refers to class "Ceramic tiles", which is located only within the blocks. This level can also be used to relate texture patterns of blocks with its occupation. Being so, a block with small buildings, irregular forms and low vegetation, can be associated to low income occupation.

Level	Objects of interest	Objective	Data used	Priority parameter
IV	Quarters	Generate urban indicators by quarters.	Base of quarters	Form
III	Blocks, Streets	Basis for restrictive rules for the occurrence of certain classes.	Base of quarters, Base of blocks	Form
II	Large land cover classes: vegetation, built-up areas, bare soil, shadow	Generate a vegetation map in a coarser scale and restrict the existence of some classes from level I.	Base of quarters, Base of blocks, four multispectral channels of the fused image.	Color
I	Detailed land cover classes: arboreal vegetation, grass vegetation, swimming pools, asphalt, bare soil, clear ceramic tiles, etc	Map the classes of soil cover at a detailed scale.	Base of quarters, Base of blocks, four multispectral channels of the fused image.	Color

Table 1 – Information on segmentation levels

Level II was generated to map the class "Vegetation" at a little coarser level and to serve as a restriction to Level I. So an object could just be classified as "Arboreal vegetation" if it is an sub-object of any super-object of class Vegetation at Level II.

At Level I land cover classes in a detailed scale were identified. The definition of segmentation parameters at this level was more laborious, since it was necessary to built-up objects which represent all land cover types but that should not generate an excessive number of objects.

Referring to the main parameter used during segmentation, at Levels IV and III a higher weight was attributed to "Form", while at Levels I and II "Color" got a higher weight. In the first case the limits of objects from these levels were already previously defined by vectors of quarters and blocks, used during segmentation. At the second case Color was higher valued because the spectral content is more important to distinguish land cover classes than Form.
After elaboration of a hierarchical net, followed the strategy of elimination keys, because the class vegetation is easier to distinguish by spectral attributes. It is characterized by high values of digital numbers at bands 3 and 4 and shadow (low brightness). Sequentially other classes were defined by specialization relations, based on attributes analyzed from classification keys.
Afterwards the net was tested considering the behavior of classes for selected descriptors. Since many classes presented a similar behavior for a certain attribute, they were grouped in super-classes. On the other hand, classes belonging to a defined super-class did not have nothing in common with the mother-class and due to that, they were replaced in another super-class. In brief: during the procedure of analysis of class behavior, the hierarchy net underwent several changes till the final structure, when it was applied to the QUICKBIRD image. The definition of attributes and membership rules was done as follows: initially some training samples were selected for each one of the classes. Afterwards, the behavior of these samples related to the attributes, was analyzed by histograms, dispersion graphics and spatial analysis of attributes. Taking into account that there is a large number of descriptors available in the program used (over 100), those attributes identified by the interpretation key were prioritized.

In any classification there is a need of quality evaluation. When using fuzzy logic for classification procedures, the same object at the same time can be associated to several classes, with distinct degrees of membership, which means that the classification result may not be unique (Laba et al., 2002).

So there is an uncertainty at the classification, which cannot be evaluated by standard procedures like confusion matrix (Foody, 2004). Some authors, like Woodcock and Gopal (2000) and Antunes (2003) propose alternative evaluations. In this study the instability index proposed by Antunes (2003) was used. According to the concept of this parameter, any O_i object is associated to the class of highest membership. Nevertheless it is possible that the same object has also a high membership to another class, indicating a high degree of instability for this object. So the instability index (i_a) is described by the proximity of the degrees of membership of an object between two or more classes (Antunes, 2003 and Antunes & Lingnau 2005). The instability of an object can be determined by the ratio of the difference of the two highest degrees of membership by the highest degree of membership. (i_a) is expressed as $i_a = (b_{c1} - b_{c2}) / b_{c1}$, where
b_{c1} = highest degree of membership for any c1 class;
b_{c2} = second highest degree of membership for any cj class;
c1 is different from cj.

The values from I_a vary between 0 and 1. Value 1 indicates that there is no uncertainty at the association of one object to a defined category, and nil indicates a complete uncertainty. The classification quality can be evaluated from the intervals of occurrence and degrees of instability (Table 2).

I_a – Degree of instability	Quality classes
$I_a = 0$	Unacceptable
0,01 = or < I_a = or < 0,30	Ambiguous
0,31 = or < I_a = or < 0,50	Acceptable
0,51 = or < I_a = or < 0,80	Good
0,81 = or < I_a = or < 1,00	Very Good

Table 2 – Classification quality according to the degree of instability

The quality of classification was evaluated as for the degree of instability to objects and classes. This uncertainty was measured by the degree of instability. The I_a values for all objects of the classification were calculated. Table 3 presents the counting from the number of objects and the evaluation of instability.

	Nr. of objects	%
Non-classified	11,757	2,70
Unacceptable	17,002	3,90
Ambiguous	24,868	5,70
Acceptable	17,987	4,13
Good	57,324	13,15
Very good	306,942	70,42
TOTAL	435,880	100,00

Table 3 – Number of object according to instability classes

After the detailed visual inspection of the classification result, we perceived that the worst levels of instability ("Unacceptable" and "Ambiguous") came from small objects, located in transition areas between two different types of land cover. It is typical for these objects to aggregate pixels from different classes, and thus making its' distinction difficult. The generation of this type of objects is influenced by two factors: 1st the spatial resolution: the higher the resolution, the better defined are the borders of objects and therefore the lower is the probability that such objects are formed, 2nd refers to the characteristics of targets, very small objects that are very close to each other and irregularly arranged, make it difficult to individualize segments, even in very high resolution images like QUICKBIRD. From these observations one can affirm that the behavior of the instability level is related to the quality of object delimitation during the segmentation process.

3. CONCLUSIONS

From the analysis of the object-oriented classification performed, one verifies that this methodology has a very good potential for the classification of land cover in urban areas from high spatial resolution images. The use of multi-resolution segmentation is a new approach, allowing the use information on the relations between objects at different scales. The representation of knowledge in hierarchy nets allows the establishment of heredity relations among classes and also to grouping of classes with distinct physical aspects, but with coherent semantics, such as e.g. roofs of buildings can be grouped in only one class of "Built-up area".

Referring to the characterization of classes, we observed that 3 types of information were of essential importance for the distinction of objects, namely: 1st. Contextual information introduced in some classes, such as e.g. the spatial restrictions imposed to classes Asphalt and Concrete/dark Asbestos, based on the context of object localization, according to the internal or external condition of the blocks; 2nd Spectral attributes (average, standard deviation and others) calculated from IHS channels used to describe several classes, and 3rd the customized attributes that were created to distinguish vegetation (NDVI of the average from objects) and reddish objects from the remaining classes (Ratio 3/1 between the average of objects from bands 3 and 1).

Considering the utility for city planning of data generated from the study described in this paper, several thematic maps of fundamental importance for any Brazilian city can be generated from the information gathered, such as e.g. maps of social-economic inclusion/exclusion, imperviousness, vegetation cover, available/non-available areas for construction/city expansion, areas under environmental protection, etc. to just name a few.

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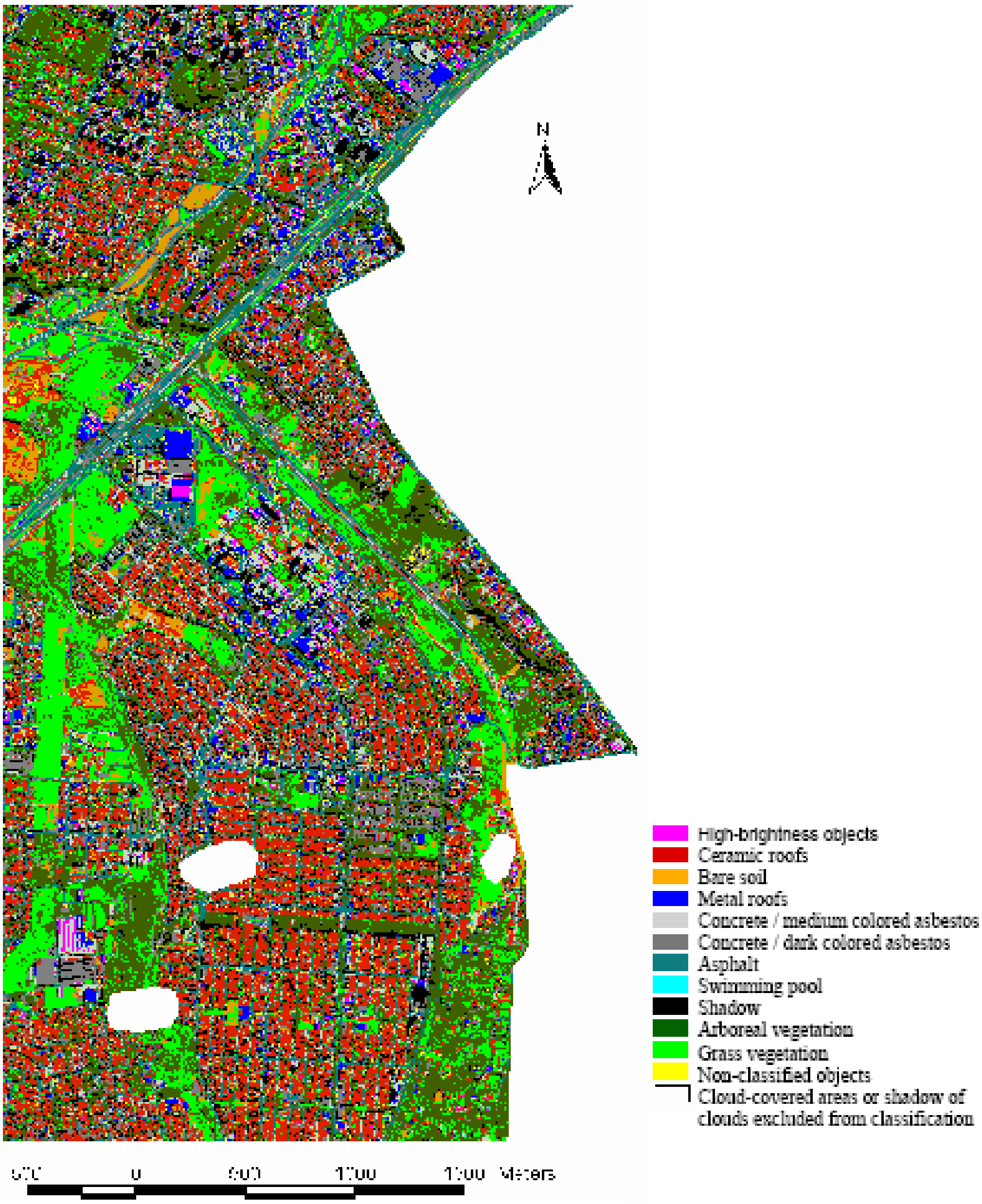

Fig. 2 – Object-oriented classification of a section from São José dos Campos -Brazil