AUTOMATIC CLASSIFICATION OF LAND COVER WITH HIGH RESOLUTION DATA OF THE RIO DE JANEIRO CITY BRAZIL COMPARISON BETWEEN PIXEL AND OBJECT CLASSIFICATION

Luiz Felipe Guanaes Rego[1], Barbara Koch[2]

Abteilung Fernerkundung und Landschaftsinformationssysteme - FELIS
Albert-Ludwigs-Universität Freiburg Forstwissenschaftliche Fakultät
Tennenbacher Strasse 4 * D-79106 Freiburg
Tel.:(49)-761-203 3694 * Fax:(49)-761-203 3701
Regoluiz@felis.uni-freiburg.de

KEY WORD: Brazil, Rio de Janeiro, Land-cover, Automatic Classification, High Resolution, Ikonos

ABSTRACT

This work, using a subset of an orthorectified multi-spectral IKONOS image on part of the Pedra Branca State Park, in the city of Rio de Janeiro, intends to compare two sets of classification techniques, one based on the pixel and the other based on objects as for their potential of automatic extraction of three generic classes: *Vegetation*, *Field* and *Edification*. Accuracy results suggested that the system based on objects had a better classification than the one based on individual pixels in high-resolution images.

1.INTRODUCTION

The city of Rio de Janeiro, with more than 5 million inhabitants, have two big mountains in its centre with natural Atlantic rain forest. The growth of the city around these two mountains puts pressure on this forest. This not only the endangers the remaining Atlantic forest (one of the most endangered forest types of the world) but also causes landslides and mud flows.

The city administration carried out a Land-cover forest classification with visual interpretation using merged LANDSAT and SPOT data. This work produced a compatible thematic map in the scale 1:50,000. It took about 36 months of intensive work and high costs to produce these maps. The scale of these maps permit to have a global vision of the land change cover but unfortunately do not correspond with the geographic information system of the city, which works with a scale of 1:10,000 (Technical Report. SMAC. 2000). The city searched for options to make this work automatically and quickly to get information for planning and to propose solutions.

In order to solve this problem high resolution satellite data and automatic classification of Land-cover classes are needed. Consequently, images as IKONOS (multispectral with four bands and 4 meters) need to be used to produce a classification, with a scale corresponding to the GIS of the city. The automatic classification of Land-cover classes will provide a relatively rapid classification.

High-resolution images have been showing very unsatisfactory results concerning their application on traditional automatic classification systems based on the pixel's spectral value especially in urban areas (Smith, G. M., et al., 2001. Blaschke, T., et al., 2001. Schiewe, J., et al., 2001).

In spite of the works mentioned above there is a certain controversy concerning the Land Cover classification results using the system based on the pixel with conventional supervised classification techniques, especially concerning classes with very differentiated spectral signatures (Bauer, T. & Steinnocher, K., 2001). Therefore, we chose to begin this work by developing a set of experiments that aimed to evaluate the potential of individual pixel classification of high-resolution IKONOS images.

On the other hand, there have been works proving that the potential of classification of high-resolution images using processes that segment the image into objects simplifying the inherent complexity of high-resolution (Hoffmann, P., 2001. Herold, M., et al., 2001). Considering the potential of these techniques, this work developed another set of experiments that applied classification techniques using objects and high-resolution IKONOS images.

Basically two softwares were used to classify IKONOS images in this work: the Erdas Image 8.5 based on the pixel's value and the ecoGnition 2.1 based on objects. Both are state of the art in their categories (Herold, M., et al., 2001).

In short this work intend to compare two classification systems and suggest the best of both to developing the automatic classification of Land-cover classes of the city Hall derived from the IKONOS image.

2.METHODOLOGY

This work was concentrated on part of the Pedra Branca State Park, in the city of Rio de Janeiro, Brazil. The Park was chosen due to the huge environmental problems the park faces, especially because of its insertion within the city of Rio de Janeiro. It was also chosen due to boundary limits such as:

[1] Research of the Department FELIS
[2] Director of the Department FELIS

irregular urban expansion, agricultural areas within the park's limits and constant problems caused by annual fires.

To set up this work, a cloud free IKONOS scene from February 16, 2001 with an 11 bit radiometric resolution was ordered and orthorectified with ER Mapper and Orthowarp software packages.

The orthorectification of the one-meter resolution panchromatic band, based on an existing digital elevation model, has an overall accuracy of less than two pixels. The accuracy of the orthorectification of the four-meter resolution multi-spectral bands of the IKONOS scene is about 0.5 pixels and fits very fine to the rectified panchromatic band. The reference data set for both rectifications was the Mosaic of orthorectified aerial photos of Rio de Janeiro. The map datum is South American Datum 1969; the projection is UTM, zone 23 south.

After the rectification of the satellite scene, the multi-spectral bands of the image were topographic normalised with the C-factor method of the Silvics software package to reduce the effects caused by the high relief energy inside the test area.

One IKONOS sub-set (multi-spectral with four bands and 4 metres) of the western part of the Pedra Branca State Park was used for this study. The area of the subset is of 493 ha and is composed of a mosaic of occupations where there is urban area, scattered vegetation, part of the Pedra Branca State Park, field, non consolidated urban area and slums, which make the subset a simplified expression of the city's spatial complexity. The area's relief is relatively mild with elevations that reach 275 meters intercepted by valleys. Valleys are usually occupied by urban area and the slopes are occupied by field or arboreal vegetation.

Figure 1 offers a 3-D panorama of the subset.The image is based on a digital terrain model (DTM) produced by the Erdas Image software, and functions as a spatial basis for visualisation. The altimetric information used was a City Hall coverage with isolines 25 meters away from one another. The visualization itself was produced by the 3-D module of the Erdas Image software.

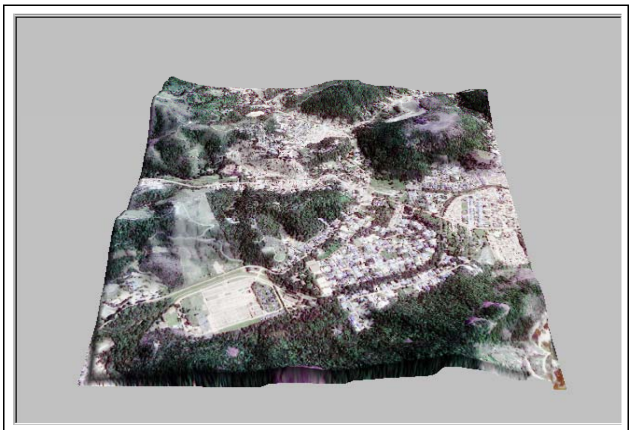


Figure 1. Visualization in 3-D of the subset used in the work.

The classes used in this work were generalizations from the classes used by City Hall in the vegetation coverage mappings produced in 1999, 1996, 1991, 1988 and 1984 by the municipal district's Environmental Department. This way the *Vegetation* class involved the Forest and Altered Forest classes, the *Field* class involved the Anthropic Field and the *Edification* class involved the Urban Area, Non Consolidated Urban Area and Exposed Soil (Technical Report. SMAC. 2000).

Image classification techniques were the main focus of this work. As the study progressed, further classifications came into existence, which were then validated and led to the establishment of techniques, whose effectiveness was then assessed.Each technique was defined as a unit of verification called experiment.

An experiment was defined as a unit of study and evaluation that embodied the study of one or two variables with different values and tried to answer an objective question related to a technique and a result that could be compared to another technique's result. Besides variables, an experiment included certain constants that appeared throughout the whole experiment. In an experiment, a variable could turn into a constant of another experiment and vice versa.

All evaluations or measures of effectiveness of a certain variable in an experiment were performed using reference objects that produced an error matrix, an overall accuracy, a user and a producer accuracy by class. The reference points were acquired directly from the multi-spectral IKONOS image merged with a pan-chromatic 1-meter resolution IKONOS image and orthorectified aerial photos. Much information from the Rio de Janeiro City Hall such as isolines, the 1998 Land-cover and declivity among others were used as support for the chosen points. The set of reference used for the validation of an experiment was equally applied to all of the experiments.

The experiments took place sequentially. The results worked as a basis for the development of the following experiment. This lead to a kind of self-substantiation of the experiments. The codification of the experiments was subdivided into group A, based on the pixel, Erdas Image software, and group B, based on objects, ecoGnition software.

Group A involved three experiments, A1, A2, A3. They included the basic functions of the classification system based on the pixel as shown in Figure 2:

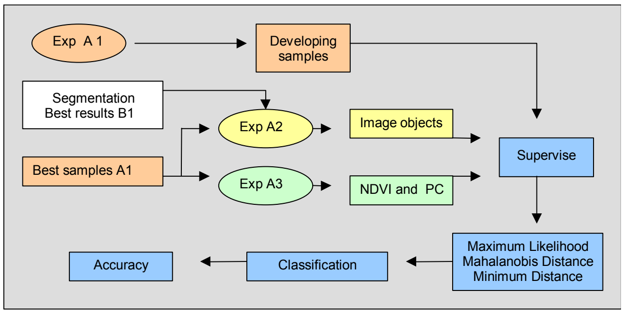


Figure 2. Process developed in experiments of group A.

The first experiment A1 (called Automatic Pixel Based Classification) evaluated the number of samples in the supervised classification process using different algorithms: Maximum Likelihood, Mahanobis Distance and Minimum Distance. Experiment A2 (called Image Objects Classified with Tools for Pixel Classification) produced images with four bands performed using objects produced in the ecoGnition software. The supervised classification with the same three algorithms defined in experiment A1 was applied to these images. Experiment 1A3 (called Automatic Pixel Based Classification Using Indices) classified two images: a NDVI (Normalised Difference Vegetation Index) and a PCA (the Principal

Components Analysis), which was produced by the Erdas Image software with the best classification algorithms from experiment 1A1.

Experiment A1 tested two variables: the number of samples and classification options and it involved two constants, the classes and the multi-spectral IKONOS image. The first variable used eight values and the second, three values, resulting in classifications that were evaluated through the overall accuracy index enabling, consequently, the determination of the best number of samples and the best classifier. Figure 3 describes the procedures that were applied in experiment A1.

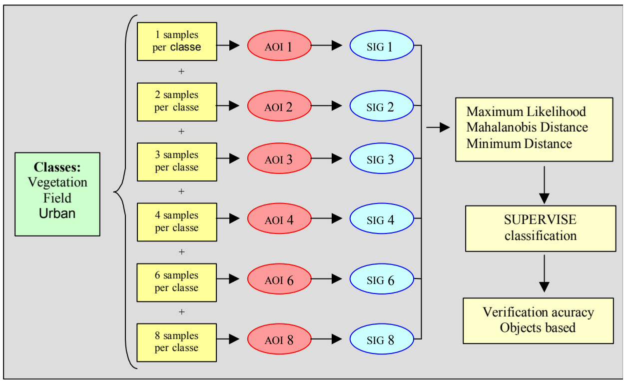


Figure 3. Performed procedures in experiment A1.

Experiment A2 tested two variables: different object images and different classification options; and it involved a constant of classes. The first variable used three values and the second, two values that resulted in six classifications that were evaluated through the overall accuracy index, enabling the determination of the best object image and the best classifier to classify the three classes used in this work. Figure 4 describes the procedures that involved experiment A2

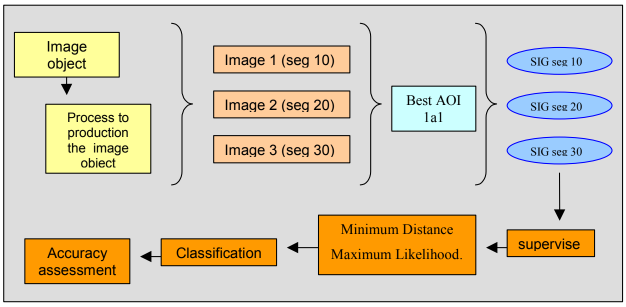


Figure 4. Performed procedures in experiment A2.

The production of an object image, as we may see in Figure 5, involved the ecoGnition software (the blue line) that produced the segmentation of the IKONOS image. The ARCGIS software (the red line) converted the shape file with the segmented objects into the grid format. Finally, the Erdas Image software (the green line) imported these grids and produced the object image with four bands that later may be classified as a normal IKONOS image.

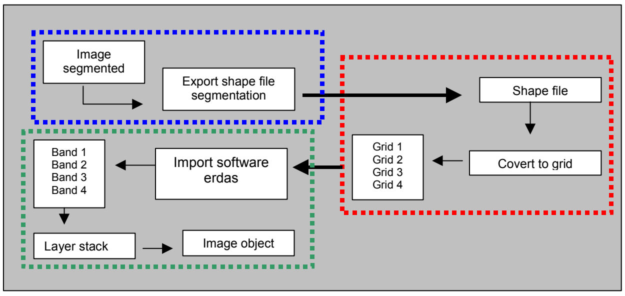


Figure 5. The software used in the production process of object images.

Experiment A3 intended to evaluate the use of images produced through techniques such as NDVI and PCA in the production of supervised classification to categorize three generic classes used in this work. The experiment A3 tested three variables: the first involved three kinds of emphasis, the second, two classification options and the third, four values of samples. The process involved in the experiment may be seen in Figure 6.

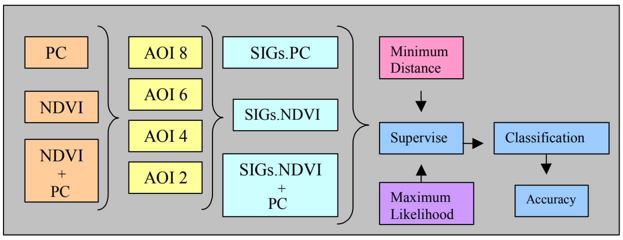


Figure 6. Performed procedures in experiment A3.

Group B involved three experiments, B1, B2, B3, which involved the basic functions of the classification system based on objects as shown in Figure 7:

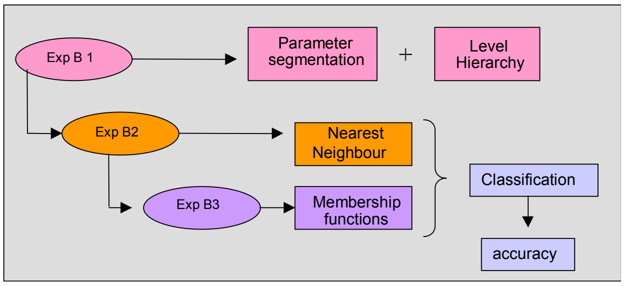


Figure 7. Process developed in experiments of group B.

Experiment B1 (called Segmentations at Different levels and Different Parameters) analyzed different segmentation parameters and different segmentation levels. Experiment B2 (called Nearest Neighbor Classifier) applied the Nearest Neighbor classifier in the classification process. Experiment B3 (called Membership Classifier) applied the Membership classifier in the classification process.

Experiment B1 tested two variables, segmentation parameters (shape and color) and hierarchic networks (scale), and it involved three constants, an IKONOS image, number of samples and the Nearest Neighborhood classifier. Figure 8 describes the procedures used in the experiment.

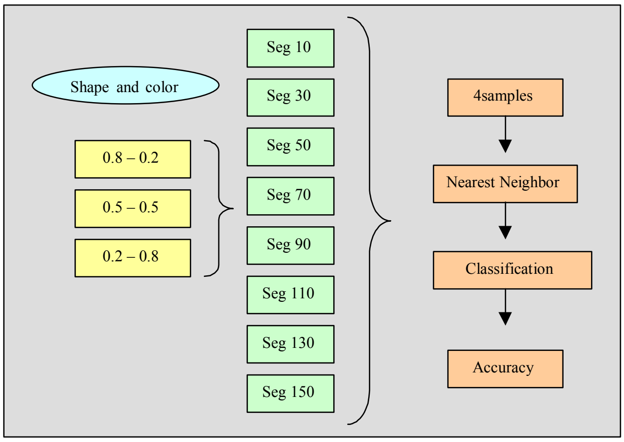


Figure 8. Performed procedures in experiment B1.

Experiment B2 tested two variables, number of samples and hierarchic networks and it involved three constants, segmentation parameters, IKONOS images and the Nearest Neighbor classifier, as we may see in Figure 9.

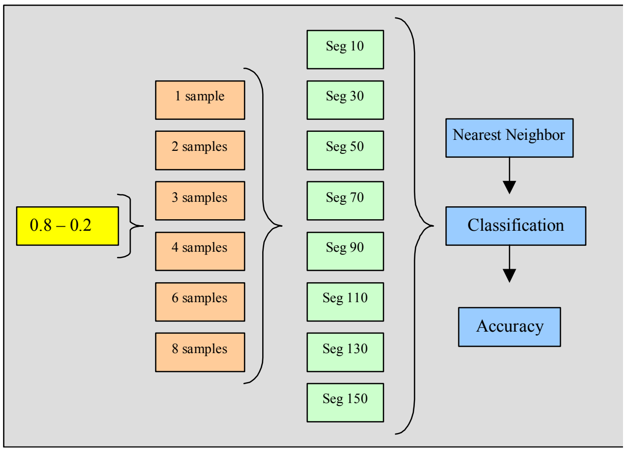


Figure 9. Performed procedures in experiment B2.

Experiment B3 tested one variable (segmentation levels) and involved three constants: segmentation parameters, IKONOS images and the Membership classifier as shown in the Figure 10.

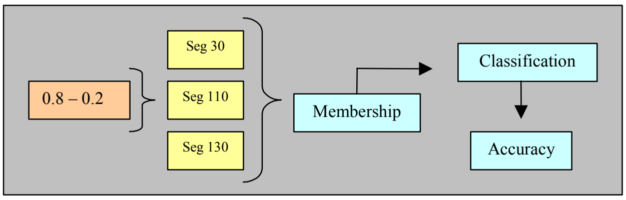
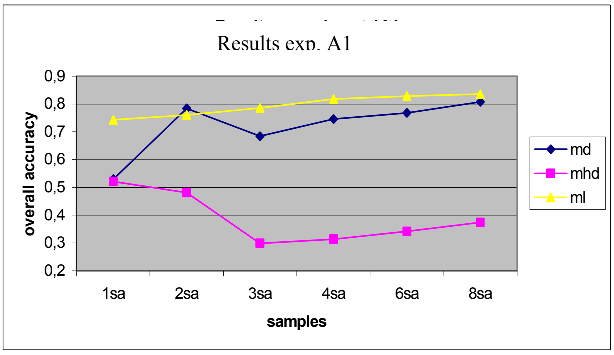


Figure 10. Performed procedures in experiment B3.

3.DISCUSSION AND RESULTS

Experiment A1 produced 18 classifications and the results indicate that with a higher number of samples, the accuracy results increase. The best values were obtained with eight samples per class, and the best classification achieved the value of overall accuracy of 0.835 with the Maximum Likelihood algorithm.

In terms of classification algorithms, Maximum Likelihood (ml) showed the best results, no matter the number of samples. The Minimum Distance (md) algorithm also exhibited very close values, although these were lower than those from Maximum Likelihood.As for the Mahalanobis Distance (mhd) algorithms, these results were significantly lower than the other algorithms. The accuracy of the algorithm also displayed a tendency to decrease as sample size increased, as can be seen in Graph 1.



Graph 1. Results with different numbers of samples and different algorithms.

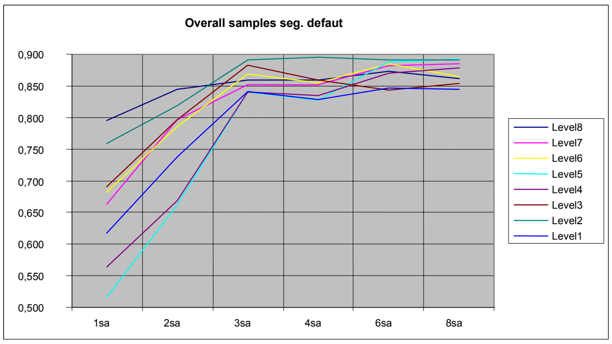
Experiment A2 produced 6 classifications and the best result, with an 88% accuracy, higher than the first experiment's result that had an 83% accuracy, used the Minimum Distance classifier to obtain this result. This contradicts the previous results and the literature itself that indicates the Maximum Likelihood classifier as a better classifier than Minimum Distance classifier.

The results from experiment A2 suggest that when the object images are classified from the Erdas Image software, they obtain higher accuracy values than the ones obtained in experiment A1, based on the pixel. This makes us conclude that the segmentation and, consequently, the formation of objects is a process that really benefits the classification process of high-resolution images, with the IKONOS images, no matter which software was used.

Experiment 1A3 produced 24 classifications and the results obtained were lower than those from the previous experiments. Despite having the best result for an image with two PCA and NDVI bands together, the eight samples using the Maximum Likelihood classifier achieved an overall accuracy of 83%, which was similar to the best result from experiment 1A1 (83.5%). The results obtained for separate images were significantly lower. The best results ranged from 73% to 63% - the former for the NDVI image and the latter for the PCA image. In all cases, as in experiment 1A1, the Maximum Likelihood classifier obtained better accuracy values than the Minimum Distance classifier.

Experiment B1 produced 24 classifications and the results show that the weights in the segmentation parameters no matter their level or scale proved to be more adequate with the parameters of color (0.8) and shape (0.2).

On the other hand, within classifications with parameter 0.8 color and 0.2 shape, defining the best levels of segmentation (scale) proved to be somewhat ambiguous, especially concerning the second, third and fourth best results. The segmentation level 130 reached the best overall accuracy: 0.896. As for levels 30, 50, 110 and 150, they showed very close values, ranging from 0.852 to 0.86, which really makes it harder to define a valuating hierarchy for the performed classifications. Experiment 1B2 produced 40 classifications and the results display little difference among the outcomes. Graph 2 illustrates a summary of all accuracy indices produced using the classifications from experiment 1B2 and clearly indicates that, regardless of scale level, a high accuracy from the classification is heavily dependent on the number of samples. Accuracy appears to stabilise with more than 3 samples per class.



Graph 2. Summary of the overall accuracy among different hierarchic levels and different number of samples.

Experiment B3 produced 3 classifications. The best result was with level 110 and the classifier Ratio band 2. When we compare the best result from the simplified classification Nearest Neighbor, experiment 1B2, with the best overall accuracy result of the Membership classification, the first one proved to be higher, with a value of 0.896, and, the second one with a value of 0.883.

In experiment B3 the Membership function that best classified a certain class at a certain level is described in the table below that is composed of five columns. The first one indicates the level at which the classification was performed. The second one specifies the nomenclature used to name the classes at each hierarchic level. The third one describes per class the classifier that best described the respective class, the fourth, the value itself the class describes and, finally, the fifth one indicates the Slope Function used by each class.

Table 1. Description of the characteristics of the classifiers of the classes use in experiment B3.

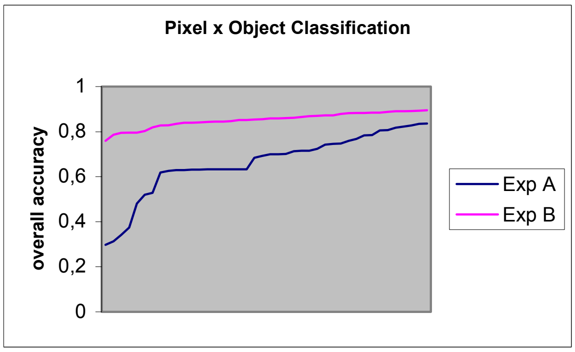
Seg.	Class Name	Membership	Value	Function
	Urban 81	Not Field 8.1	-	-
150	Field 81	Means band 2	265.7	<
	Field 8	Not veg 8	-	-
	Veg 8	Ratio banda 1 X100	44.2	>
	Urban 6.1	Not Field 6.1	-	-
110	Field 6.1	Ratio banda 2 X100	20.1	<
	Field 6	Not veg 6	-	-
	Veg 6	Ratio banda 2 X100	13.2	<
	Urban 2.1	Not Field 2.1	-	-
30	Field 2.1	Ratio banda 2 X100	16.4	<
	Field 2	Not veg 2		
	Veg 2	Ratio banda 2 X100	13.8	<

Table 1 describes how specific and variable the values of the Membership function are at the different hierarchic levels. It used the *Means Band 2* classifier for the same *Field* class at Level 150 and at level 110, the *Ratio Band 2 X100* classifier.

Experiment B3 suggested the Membership classifier that proved to be, despite the large amount of available classifiers, inferior to the Nearest Neighbor classifier using the generic classes of the work.

4.CONCLUSION

This work tested three generic classes, *Field, Vegetation* and *Edification*, and a great number of automatic classification techniques of orbital images. These techniques involved classifications based on the pixel as well as classification techniques based on objects. The results concerning their accuracy showed in more than 100 classifications that the system based on objects had a better classification accuracy results than the one based on the pixel using high-resolution images as it may be seen in Graph 3.



Graph 3. The 40 best results from experiments A (pixel based) and the 40 best results from experiments B (object based)

In short this work suggests that the automatic classification process with high resolution data as IKONOS image should be done in an environment of objects that simplify the complexity of the information in the data and produce a better classification

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ACKNOWLEDGEMENTS

The orthophotos and the coverages used in this work were granted by the Municipal Secretary of Urbanism and by the Secretary of Environment, both from the Rio de Janeiro City Hall. The IKONOS images were granted by the companies K2 Sistemas and Ueffing Umwelt Consult.