APPLICABILITY OF NEURAL NETWORK ARCHITECTURE BY A FUZZY MODEL TO IDENTIFY NATURAL VEGETATION REGROWTH IN BRAZILIAN AMAZONIA

João Roberto dos Santos [1]
Adriano Venturieri [2]
Ricardo José Machado [3]
Frederico dos Santos Liporace [3]

[1] Instituto Nacional de Pesquisas Espaciais - INPE, São José dos Campos, Brasil
jroberto@ltid.inpe.br
[2] Centro de Pesquisa Agroflorestal da Amazônia Oriental-EMBRAPA, Brasil
[3] IBM-Centro Científico Rio, Rio de Janeiro, Brasil

Commission VII, Working Group 3

KEY WORDS: Vegetation, Monitoring, Network, Segmentation, Regrowth, Amazonia.

ABSTRACT

The objective of this study is to present the results of preparation of a neural network trained by a backpropagation algorithm, in order to process TM-Landsat images, used to identify areas under secondary succession, among other landuse classes in Amazonia. Image segmentation techniques by an algorithm of region growth and labelling of these segments by fuzzy-logic were also used for the preparation of the start-up network.The performance of the network to delineate the "initial" and "advanced" regrowth areas, was obtained using both sensitivity and specificity indices and of the MSE (Mean Square Error). Generally, it appears that both spectral, textural (entropy and correlation) and contextual descriptors are effective for the identification of regrowth areas in Amazonia.

1. INTRODUCTION

The changes of the Amazonian landscape due to human interference, have been the basis of discussion by the Brazilian scientific community. The dynamics of land occupation, the degradation of natural resources as well as the private interest to follow the process of ecological succession, they all deserve a research effort with remote sensing techniques, taking into account specially the integration of image segmentation techniques and neural networks, which would contribute to reduce the acquisition time of information.

Information extraction from large areas using an analogic method is based primarily on the experience of visual analysis of images, where a satellite image is classified in homogeneous regions based on spectral, textural, geometric and contextual characteristics. When using conventional digital classification procedures, i.e. the algorithms for supervised and non-supervised classification, an image is stratified by its' spectral values according to a defined statistical concept.

The first step of the method used in this study is the TM-Landsat image segmentation in spectral homogeneous regions, aiming to identify specially those areas under natural regrowth. This image stratification is based on the region growth algorithm. Each segment is labeled in thematic classes, representing the variations of landuse, called "basic categories". The cloud and shadow classes were also identified and named "interfering categories". This labeling, which is made by the analyst and is based also on field information, is defined by a fuzzy-logic approach, with degrees of partial membership that are attributed to each segment. Based on these segments, the start-up network is established (training procedure) by the backpropagation algorithm. While the start-up network is setup - when special features of the training area, such as spectral, textural and geometrical features are detected - the recording procedure is running, and new areas can be classified, to monitor the landscape of a certain region.

2. DESCRIPTION OF THE AREA UNDER STUDY

The area under study is located at SE Pará State, in Amazonia, at the following geographical coordinates: S 3° 30' to S 4° 30' and W 49° 30' to W 50° 30'. This region is close to the Tucuruí Hydroelectric Power Plant, and it has a traditional land occupation pattern along the road Transamazônica. The tropical vegetation is classified as Ombrophilous Dense Forest, over deep soils with medium to highly clay texture. The soils are permeable and present low fertility. This region presents a tropical humid climate with an average annual rainfall of 1,300 to 3,000 mm. The drought period is 3 months long. The area under study is covered by LANDSAT-TM path 224 and row 63.

3. MATERIALS AND METHODS

LANDSAT-TM images of bands 1, 2, 3, 4, 5 and 7 were used. Topographic maps (scale 1:100,000) sheets SA.22-ZC-VI (Tucuruí), SA.22-ZD-IV (Goianésia), SB-22-XA-II (Maracajá) and SB-22-XA-III (Repartimento) were used for georeferencing orbital data. The software packages SITIM and SPRING, developed at INPE, as well as the IBM-developed package NICE (Neural Image Classification Environment) were used. Figure 1 presents a flow diagram that summarizes the methodological procedures, including segmentation and classification by neural networks.

Due to the complexity of land occupation, including as well small agricultural settlements, timber exploration and large pasture areas, the field verification was made in previously selected sample areas. The area under study was stratified as a grid and the sample areas correspond to the UTM geographical coordinates of the topographic maps used. The sample areas (n=138) were randomly defined, taking into account the themes identified at the image. A Global Positional System was used to locate the sampling areas. During field work, the following thematic legend was defined: Forest (F), Advanced (A) and Initial (I) Secondary Succession, Clean Pasture (P), Overgrown Pasture (O), Crops (C), Urban Zone (U), Water (W), Clouds (N) and Shadows (S).

The image segmentation procedure was based on the algorithm for the growth of regions, that generates, according to a pixel (i, j), a region containing (i, j) that includes an average gray level close to that of (i, j). During the segmentation procedure, five values of similarity thresholds (6, 8, 10, 12 and 14) were tested. Each change of the similarity values caused variations of the computer work to process the images, since the similarity degree was defined by the tolerance parameter **t**, represented by the Euclidean Distance among the vectors associated to each segment.

Considering the distance (Ri, Rj) as a defined measure of similarity among regions Ri, Rj, that increase proportionally to the differentiation between Ri and Rj, it was necessary to define the value **A**, a constant that determines the minimum size for each region in the segmentation process (Liporace, 1994). In this case, the smaller region presented a minimum area of 10 pixels. After the segmentation was made, the label of each segment follows the fuzzy-logic, that allows the analyzer to assign to each class, total or partial degrees of membership (Barbosa, et al., 1993). The label of a segment consists of a vector $[0,1]^n$, with a dimension associated to each thematic class. The value 1 indicates total membership of the segment to a certain class. Intermediate values, that correspond to probabilities of 0.75, 0.50 and 0.25, were associated by the interpreter to segments representing partial degrees of membership. As a rule during the procedure of labeling, it was established that the total summation of the weights given to each segment, without interferences such as clouds and shadows, should be equivalent of 1, and that if there are interferences, the segments could have a total summation above 1. The main advantage of the use of fuzzy-logic is that it allows to model transition phenomena (like the stages of secondary vegetation and the conditions of pasture areas), or phenomena at a border position, among pixels of distinct classes, that could have the characteristics of both classes, considering the sensor resolution.

This labeling phase was prepared for "training" of the neural network, in order to establish the knowledge base and to test the neural network, i.e. to monitor its' performance. During the establishment of the start-up network, a backpropagation algorithm was applied for training. At this start-up network both spectral (average of gray values for each band) and textural (variance, correlation and entropy) descriptors were used. During the phase of monitoring of the network, for each thematic class, the mean square error (MSE) and the indices of sensitivity and specificity for a given set of segments were analyzed, within a certain acceptance threshold. After this phase, which was one of the objectives of this study, either the classification can start or the procedure where the network is equalized, in order to have a better performance. From this point on, one has a central network, with the same set of descriptors from the start-up network, including also a neighborhood descriptor, allowing the obtainment of a thematic map.

4. RESULTS

During the segmentation procedure of the Landsat/TM image, among the thresholds tested, that one with value 10 allowed the best discrimination of thematic classes found in the area under study. Lower similarity values (6 and 8) presented an excessive fragmentation, while higher ones (12 and 14) grouped in a same segment, showed spectrally distinct areas. The computational effort spent during the segmentation procedure is directly proportional to the number of TM bands and inversely proportional to the similarity threshold used. For the segmentation of each image module (1025 rows and 763 lines), and considering the 6 optical bands of TM, approximately 45 minutes processing time are needed at a SUN-Sparc 10 workstation (Venturieri, 1996).

The basis of knowledge needed to train the neural network, labeled by fuzzy logic, were 11,697 segments (including totally 322,100 pixels), of which 1,146 belonged to the thematic class Advanced Secondary Succession, found in the area under study. The use of fuzzy-logic allowed several combinations of pertinence for each class, indicating transitions among "neighbor" classes. At the Landsat scene studied, this refers to a transition process of secondary vegetation growth, as well as to a certain spectral non-definition of those pixels that form a certain group of segments. The descriptor that defined certain segments of the advanced succession includes, within its space of spectral attributes, some features of forests and of initial succession (Figure 2). During the analysis of spectral identification of the class "secondary succession", within the context of degrees of membership, TM band 4 (near infrared) allows a better separability. Considering all 10 classes labeled in the area under study, at Figure 3, the percentage of segments, where combinations of membership (total and partial degrees) occur, are presented. One can observe that the classes "overgrown pasture" and "initial and advanced regrowth" present a higher level of combinations, explaining its' transition character. For the labeling procedure of the "test image" of the neural network, 3,300 segments were used, corresponding to 153,000 pixels.

As for the performance of training of the neural network, associated to the 10 thematic classes identified, the Mean Square Error (MSE) was minimized according to its' training time. There is a further reduction of the MSE for the class "Advanced Succession" as compared to "Initial Succession" (Figure 4), which his coherent with the percentage of combinations of the degrees of partial pertinence presented by these classes.

At the present stage of our studies, one can have an idea of the capacity of detection or rejection of each theme by the neural network, taking into account the evolution of the Cartesian distance of classes, associated to the relationship among the indices of sensitivity and specificity (Table 1). In order to monitor this distance, the class "Initial Succession" shows already a better performance of the neural network, while for the case of "Advanced Succession", there is a tendency to minimize this distance, with the increase of sensitivity, during the training.

Table 1 - Neural Network Performance related with the Sensitivity and Specificity indices.

Classes	Sensitivity	Specificity	Distance
Forest	0.5977	0.9964	0.4023
Advanced Regrowth	0.2970	0.9910	0.7030
Initial Regrowth	0.6019	0.9982	0.3931
Clean Pasture	0.5314	0.9977	0.4686
Overgrown Pasture	0.4499	0.9671	0.5511
Crop	0.5833	0.9997	0.4167
Urban Area	0.6884	0.9968	0.3116
Water	0.8725	0.9709	0.1308
Clouds	0.5397	0.9818	0.4607
Shadow	0.8848	0.9880	0.1158

For those cases where the MSE values and sensitivity and specificity measures are not considered satisfactory to perform the classification, it will be necessary to made an equalization of the neural network, creating afterwards a central network, that will use the contextual characteristics of each segment for the thematic classification.

5. CONCLUSION

The use of fuzzy-logic to label image segments allowed the stratification of different levels of secondary succession, where the segmentation approach for the growth of regions is becoming an operational issue for Amazonia. It is expected that those vegetation cover classes that are physiognomically and structurally more complex, such as the succession stages, regarding the different land management practices, will need a longer processing time in order to obtain an adequate performance of the neural network. For the identification of deforested areas in Amazonia, the neural network approach presents already a very high (92%) performance. The aggregation of these landuse classes within the central network is being performed and the previous analysis has shown a large potential use of neural network, even taking into account the complexity of land occupation in Amazonia.

6. REFERENCES

Barbosa, V.C.; Machado, R.J.; Liporace, F.S., 1993. A neural system for deforestation monitoring on Landsat images of the Amazon region. Technical Report CCR-157, IBM, Rio Scientific Center, Brazil. 38p.

Liporace, F.S., 1994. Um sistema neural para monitoração do desflorestamento na região Amazônica utilizando imagens do Landsat. Master's Thesis, Universidade Federal do Rio de Janeiro, Brasil. 123p.

Venturieri, A., 1996. Segmentação de imagens e lógica nebulosa para treinamento de uma rede neural artificial na caracterização do uso da terra na região de Tucuruí (PA). Master's Thesis, Instituto Nacional de Pesquisas Espaciais - INPE, São José dos Campos, Brasil. 116p.

Santos, J.R.; Venturieri, A.; Machado, R.J.; Liporace, F. S., 1995. Monitoring land use in Amazonia based on image segmentation and neural networks. In: International Geoscience and Remote Sensing Symposium, Firenze, Italy. vol. I, pp. 108-111.

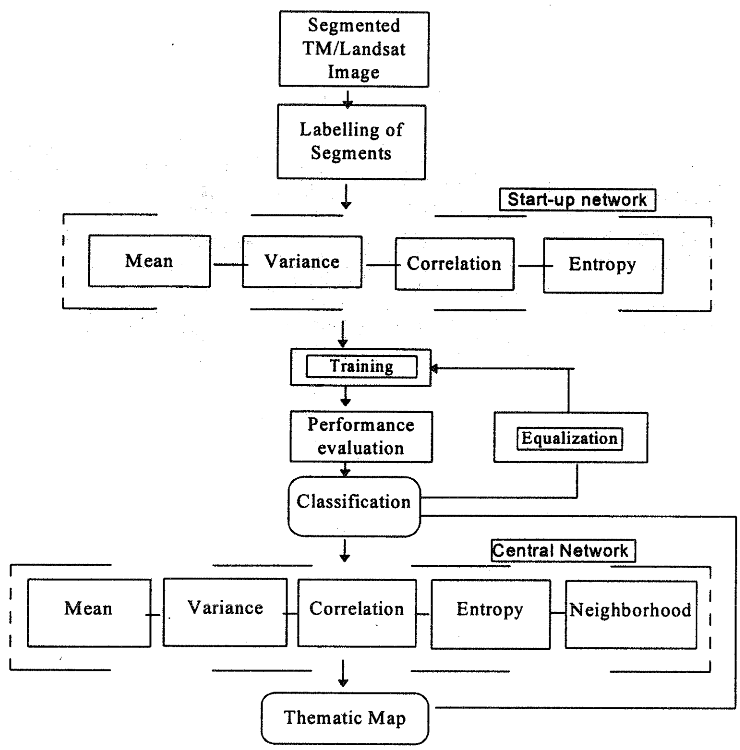

Figure 1 - Flow diagram of the neural network approach.

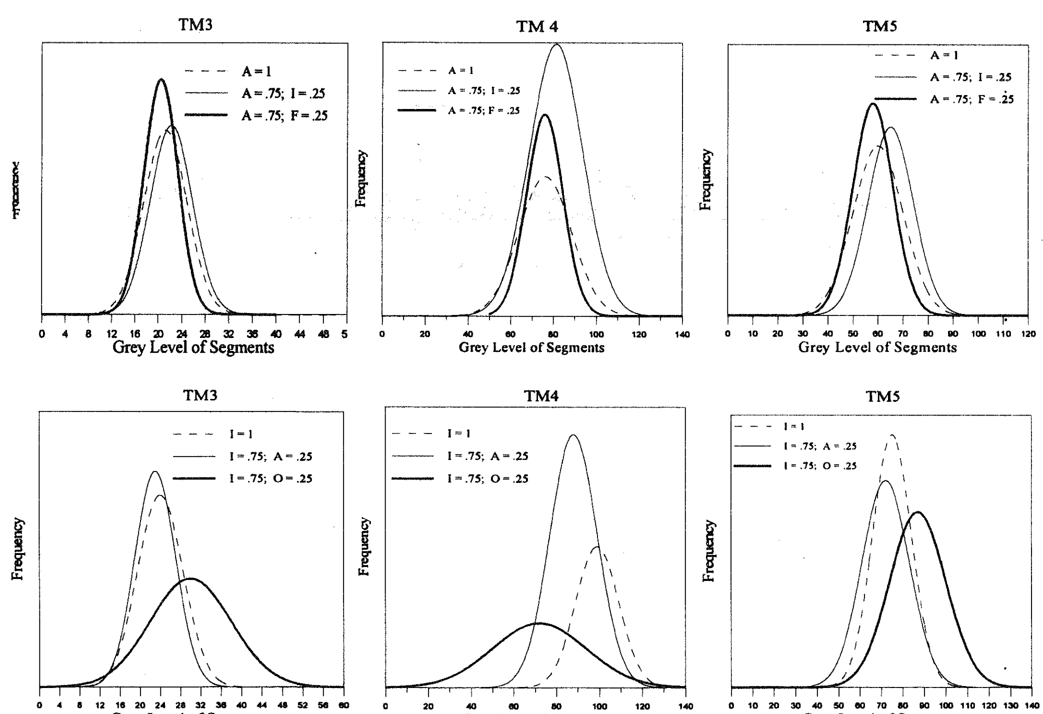

Figure 2 - Frequency of spectral descriptors for "initial and advanced secondary succession" (Santos et al., 1995).

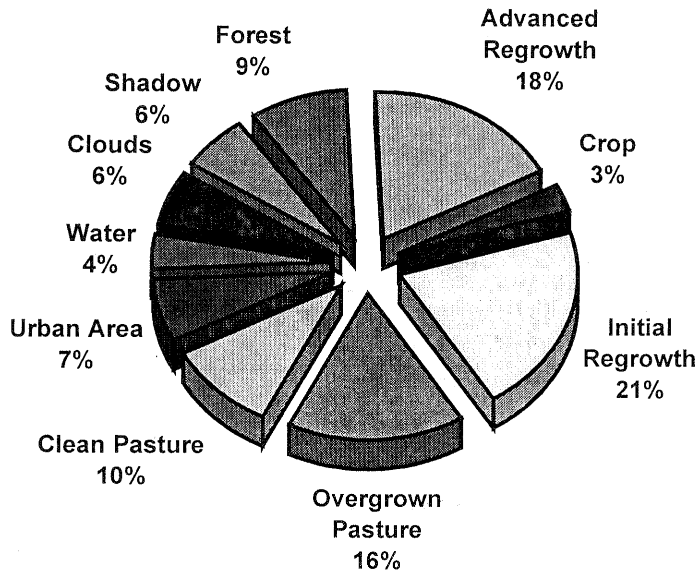

Figure 3 - Combination of membership degree of thematic classes in the Tucurui region.

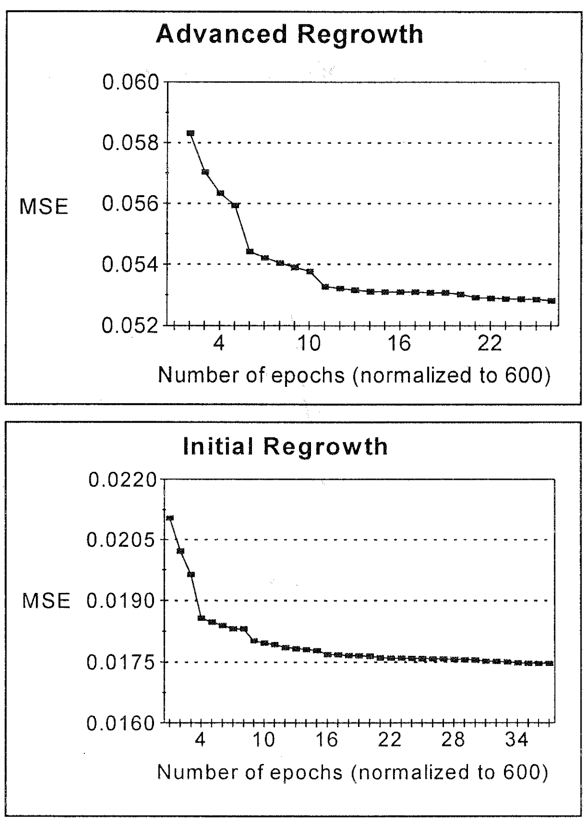

Figure 4 - Minimization of Mean Square Error values for two types of vegetation succession.