A Comparative Study Between Neural Network and Maximum Likelihood in the Satellite Image Classification

Antonio Gabriel Rodrigues[1], Rossana Baptista Queiroz[1] and Arthur Tórgo Gómez[1]

[1] Masters in Computer Applied, Unisinos University, Av. Unisinos 950, São Leopoldo, Rio Grande do Sul, Brazil

Abstract. In this paper it's showed a comparative study between two techniques of satellite image classification. The studied techniques are the Maximum Likelihood statistical method and an Artificial Intelligence technique based in Neural Networks. The analyzed images were scanned by CBERS 1 satellite and supplied by Brazilian National Institute for Space Research (INPE). These images refer to Province of Rondonia area and were obtained by CBERS 1 IR-MSS sensor.

1 Introduction

Nowadays, one of the Remote Sensing techniques more used is the scanning of the Earth surface by satellites. It has application in several areas, since environment application until socioeconomic and managing applications. Some of these applications are: weather forecasting, natural resources monitoring, mapping of areas, census systems and property registering.

The satellite image information can be extracted through classification of these images. There are various classification methods that try through several approaches to identify with accuracy the information of each image pixel, classifying them in categories or classes according to their spectral information. Image classification methods can have different accuracy levels, according their approach and parameters specification. Some of pixel classification methods that are more used by Geographic Information System (GIS) are based in statistical inference. In this context it's checked if the Artificial Intelligence based technique is suitable for image classification.

In this paper it's presented a comparative study between two satellite image classification techniques: the statistical method of Maximum Likelihood and an Artificial Intelligence technique. Maximum Likelihood method is the most used in Remote Sensing into the statistical approach. The Artificial Intelligence technique studied is based in the use of Artificial Neural Networks [9].

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The analyzed images were obtained by the China-Brazil satellite CBERS 1 (China-Brazil Earth Resources Satellite 1) and was supplied by Brazilian National Institute for Space Research (INPE) [9].

2 Image Classification Methods

Image classification in Remote Sensing is one of the most used techniques for extracting of information what makes possible the incorporation of this in a GIS database. Classification can be understood like a space partition according to some criteria [8].

Classification methods, or classifiers, can be divided in classifiers by pixel or classifiers by region and can consider one or more image spectral bands (in the case of multispectral images). Classifiers by pixel use the spectral information of each pixel apart to find homogeneous regions defined such as classes. Classifiers by region consider a set of neighbour pixels (region) information. This technique is also known as contextual classification. [9] The classifiers can also be divided in supervised (in which the classes are defined a priori based in known information) and unsupervised (in which the classes are generated by the classifier) classifiers [2]. For the case of the supervised classification, the classification criterion is based in the definition of spectral signatures for each class in study obtained through training samples.

In this work it's used the classifier based in Maximum Likelihood technique that will be explained in the next item.

2.1 Maximum Likelihood Method

Maximum Likelihood method is the most used in Remote Sensing into the statistical approach. It's a parametrical method, once it involves parameters (mean vector and covariance matrix) of the Multivariate Normal distribution. It's also a supervised method because it estimates its parameters through training samples [3].

This method considers the balance of the distances among the digital level averages of the classes through the use of statistical parameters. The distribution of the reflectance values in a training area is described by a probability density function based in Bayesan statistic. The classifier evaluates the probability of a pixel to belong a category that it has the major probability of association [6].

Maximum Likelihood is implemented in several GISs, but the use of this classifier presents some difficulties in the parameters estimation, specially in the covariance matrix. Moreover, in order to produce good results it's necessary to define with a good precision the training areas, and it requires the selection of a lot of pixels [6]. In high dimensionality data, i.e., many spectral bands information, this estimation becomes extremely problematic due to the size of the available samples that generally in real situations it isn't sufficient.

It was noticed in some research works [1][3] that the growth of the data dimensionality, (i.e., in the spectral bands number) results initially in increment in the accuracy of the resultant classified image. It happens due to increment of the image information available. From a certain point, however, the accuracy begins to decrease with the same training samples due to increase of data dimensionality. This phenomena is known like the Hughes phenomena or "the curse of dimensionality" and occurs because with the increasing of image information is increased also the number of parameters to be estimated, specially the covariance matrix [3].

Moreover, in Maximum Likelihood method the probability density functions of the classes are Gaussian, approximately. McLachlan (1992, p.52) and Tou and Gonzalez (1974, p.119) apude [2] affirms that the normal models for the probability density functions of the classes are important in the theory as in practice, and it's suitable in many practical applications. Haertel and Landgrebe (1999, p.2074) apude [2] say that the distributions of the spectral classes that are present in the image generally can be approached by the Multivariate Normal distribution, once they refers to natural scenes. The supposition of multivariate normality, however, it isn't true for all situations and in this cases, the idea of a classifier that has a capacity to learn becomes appropriate, eliminating the problem of the use of a determined probabilistic distribution [2].

2.2 Artificial Neural Networks

The conventional image classifiers used by GIS software have a difficult parameterization and in many cases they are inadequate for the needs of high accuracy demanded by the users [6]. In order to obtain better results and to facility the parameterization of these tools, it was opted to create a image classifier based in Artificial Neural Networks.

Artificial Neural Networks are algorithms whose its functioning is based in human brain structure [2]. Its processing units are called neurons and they are formed by three basic elements, like are illustrated in Figure 1:

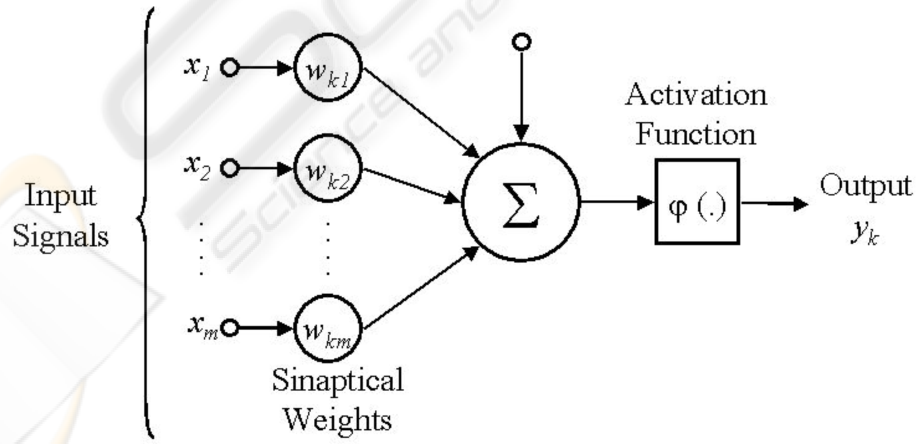


Fig. 1. Neuron Model.

- a set of synapses that are connections where a signal x_j in the input *j* and connected to a neuron *k* are multiplied by the weight w_{kj};
- an adder that adds the input signals, pondered by its own neuron synapses;
- a activation function that restricts the amplitude of output neuron (threshold function).

Neuronal model includes also a *bias* that increase or decrease the activation function input (depending if it is positive or negative) [5].

Each input neuron receives the values of the neuron outputs connected in it. These input signals are multiplied by its respective weights and added generating a activation value. The output value of the neuron is the result of the comparison between its activation value and a determined score threshold defined a priori [10].

In a Neural Network the neurons are arranged in one or more layers and connected by a great number of connections or synapses that are generally unidirectional, in which are associate to weights in the majority of the models [2]. Its basic structure is showed in Figure 2.

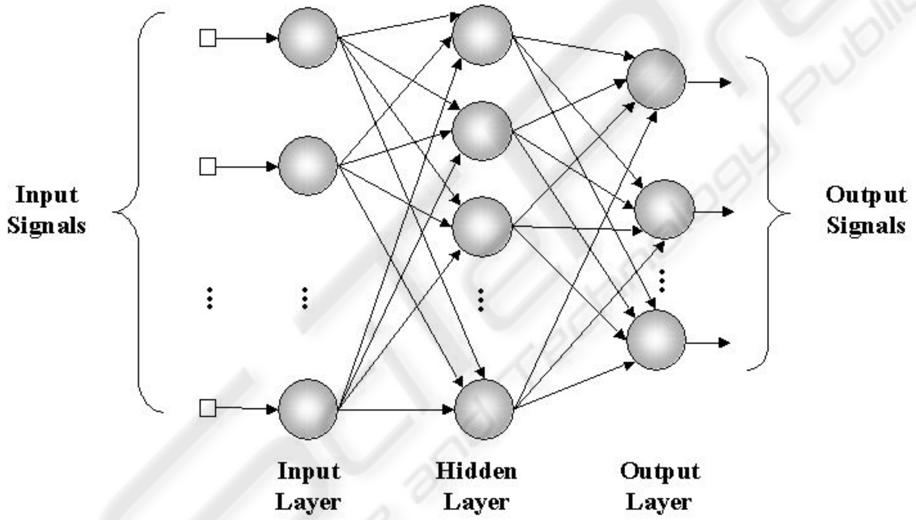


Fig. 2. Neural Network.

The capacity to learn through samples and to generalise the learned information is, doubtless, the principal advantage of the problems solution through Neural Networks [2]. For the learning, the networks are trained using a set of samples organized in a set of database. During this period the synaptic weights are adjusted according to specific mathematic proceedings that determine how the learning of the Neural Networks will be fulfilled. At end of this process, the acquired knowledge of the training set is represented by the set of network weights [10].

There are several types of Neural Networks models such as Recurrent Networks, Perceptron Networks, Multi Layer Perceptron Networks, Constructive Networks, and others [2].

The type of Neural Network that was used in this work was the Cascade Correlation [4] that uses a supervised learning technique to train the networks. It is a Constructive Network that acts on a net initially minimal (with only the input and output layer) and introduces new intermediary units during the training, one by one according to the need of learning. Once a new unit is added to the network, its weights are frozen. So, this unit pass to influence the operations in the network and it is used to detect new attributes in the set of patterns.

The unit to be included in the network can be selected from a pool of candidate units organized as a layer. This layer is connected to the input layer and to the hidden layers, but not in the output layer, once it should not interfere directly in the network result. The selection of the candidate is the correlation that it has with the network output. Therefore, the connection weight among the candidate units and the input layers and intermediary should be defined so that it can maximize the correlation between the candidate unit and the output layer. Thus, the candidate that to present larger correlation will be inserted in the network as a intermediary layer and will be connected to all the other layers [2][4].

The reason that took to opt for this network type is the fact of that is not being necessary the configuration of the number of neurons of the intermediary layer, once if Cascade Correlation is a Constructive Neural Network. This constitutes an advantage, because in works that use other types of Neural Networks, just as Multilayer BackPropagation in [10] they are necessary to do several tests with different numbers of neurons in the intermediary layer, in order to obtain the ideal amount of neurons for better learning of the nets.

3 Experiments

To accomplish the experiments, it was used an image supplied by INPE, orbit 175/point 110 CBERS1 IR-MSS (Infra-Red Multispectral Scanner) sensor, obtained in 2000, July, 29, that covers about 14.400 km^2 of the Porto Velho region in the Province of Rondonia between 07° 50’’ and 09° 03’’ S latitudes and between the 64^0 10” and 62^0 52”O longitudes. In this image was identified and defined 4 classes: native forest, deforestation, “no-forest” (no florestal covering area or *cerrado* vegetation) and water.

To accomplish the classification it was used the Maximum Likelihood technique and Neural Networks. To train the Neural Networks was used the NEUSIM simulator [7] that uses the Cascade Correlation network. It was used the GIS SPRING (*Sistema de Processamento de Informações Geo-referenciadas*) to make the classification with Maximum Likelihood method.

The training and validation of the two methods was made using a set of 240 pixels regarding the classes to be identified (60 pixels per class). Of these, was selected 120 pixels randomly that integrated the train database while the remaining 120 pixels was used to validate the classifiers.

The training process of the Neural Network consisted in to submit the network to learning through the sample basis that was composed of the greyscale of the spectral bands B1, B2 and B3 to each pixel of the analysed image and also the class which this pixel belongs. Each class are represented such as:

Table 1. Classes Representation.

Class	Code
Deforestation	1 0 0 0
Forest	0 1 0 0
No-forest	0 0 1 0
Water	0 0 0 1

This way, the training database of the Neural Networks is organised such as showed below:

Table 2. A Neural Network database sample.

B1	B2	B3	Class
46	33	126	0 0 0 1
57	22	89	0 1 0 0
....	....	....	....

The Neural Network has three neurons in its input layer, each one referring to one spectral band. The output layer has four neurons. When the input signals spread for the network, only one of the neurons of the output layer should be activated. It was used 10.000 epochs in the training.
The Maximum Likelihood classifier was trained with the same 120 pixels used to the construction of de Neural Network training database.
After the training of both methods, the entire image was submitted to classification and the results were plotted, as it will be showed in the next item.

4 Results

Starting from the accomplished experiments with the chosen techniques were generated the confusion matrix and kappa coefficient of concordance for both methods. The confusion matrix shows how much the classifier confuses a class with other. For this, the generated output is compared with the sample database that holds the true results. The diagonal of the matrix shows how much the method got right, i.e., how many pixels were classified correctly according to the true results.

The confusion matrix for both methods are showed below, represented as the legend: (C1) Deforestation, (C2) Forest, (C3) No-forest, (C4) Water.

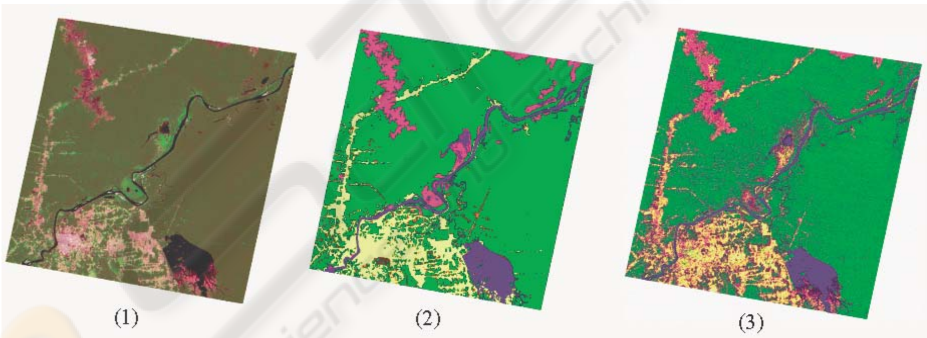
Table 3. Neural Networks confusion matrix.

Class	C1	C2	C3	C4	?
C1	53%	17%	17%	0%	13%
C2	0%	87%	13%	0%	0%
C3	17%	13%	63%	0%	7%
C4	0%	10%	3%	87%	0%

Table 4. Maximum Likelihood confusion matrix.

Class	C1	C2	C3	C4
C1	30%	20%	50%	0%
C2	3%	87%	10%	0%
C3	0%	13%	87%	0%
C4	0%	0%	8%	92%

When the Neural Network activate more than one neuron in the output layer or when its output approaches to zero, these results are counted in “?” column. The classification method of Maximum Likelihood always associates one pixel to one class that it has the major calculated probability, and so it wasn’t count undefined results.
The kappa coefficient obtained by Maximum Likelihood was 0,65 and by Neural Networks, kappa coefficient was 0,64 in these experiments.
The results of classification of the entire image by the two methods are showed in Figure 3.]



Legend: ■ Forest ■ No-forest ■ Deforestation ■ Water ■ ?

Fig. 3. Original Image (1) Maximum Likelihood image classified (2) Neural Networks image classified.

5 Conclusions

In the accomplished experiments, it's noticed that both methods incline to confuse deforestation areas with no-forests areas. It's believed that this is due to the fact that the reflectance values of these two classes are quite near. It's also noticed a high level of success in both methods for the water and native forest classes. The kappa coefficient is considered substantial to both methods.

The classifier based in Neural Networks presented satisfactory results when compared with Maximum Likelihood results, what indicates that this method is appropriate for satellite image classification.

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