Classification of Land Use and Land Cover in the Brazilian Amazon using Fuzzy Multilayer Perceptrons

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ABSTRACT

Here the authors propose the use of Fuzzy Multilayer Perceptrons for classification of land use and land cover patterns in the Brazilian Amazon, using time series of vegetation index, taken from NASA’s MODIS (Moderate Resolution Imaging Spectroradiometer) sensor. In addition to the traditional Multilayer Perceptron (MLP), three fuzzy implementations were investigated. These methods were applied to a study area of approximately 10.5 km² on the east of the state of Mato Grosso in the Brazilian Amazon. For validation purposes, the authors compared the best implementation results with the ones given for the same region by the TerraClass 2010 project. The authors observed that our fuzzy MLP correctly classified 81% of the pixels analyzed.

Keywords: Land Use and Land Cover, Neuro-Fuzzy System, Patterns Classification, Time Series, Vegetation Index

INTRODUCTION

The Amazon forest provides invaluable climatic and ecological services. Covering more than 400 million hectares, it provides habitat for innumerable terrestrial plant and animal species. The Amazon region has also a significant influence on the Earth’s climate, both as carbon sink and as a source of atmospheric carbon dioxide. In spite of its relevance, this ecosystem is under threat, having lost more than 15 million hectares of pristine forests since 2000 (Hansen et al., 2013). The causes of land cover change in the Amazon are complex and variable, and involve, among others, permanent cultivation, livestock development, commercial wood extraction, mining, and the extension of overland energy and transport infrastructure (Nepstad et al., 2002). Tracking and understanding the trends and patterns of these land use changes is

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crucial for the creation and implementation of effective policies for sustainable development and environment protection.

Brazil has the longest tropical forest-monitoring program in the world. Since the late 1980s, Brazil has been collecting remotely sensed information on the Amazon state, and carrying detailed deforestation surveys. Data comes from different sources, including TM/Landsat images and MODIS (Moderate Resolution Imaging Spectroradiometer) products from NASA’s TERRA and ACQUA satellites.

Here we propose the use of Fuzzy Multi-layer Perceptrons (MLP) for classification of land use and land cover patterns in the Brazilian Amazon, using time series of MODIS Normalized Difference Vegetation Index (NDVI) (Freitas et al., 2011). We compare the basic MLP algorithm with three extensions, one involving fuzzy concepts (Pal & Mitra, 1992), another involving the notion of ambiguity (Canuto, 2001) and the last involving both. The study area comprises approximately 10.5 km$^2$ at the east of the state of Mato Grosso, Brazil. Following Maus (2013), we used TerraClass in situ classification data to validate our results.

The multilayer perceptron (MLP), using the backpropagation supervised learning algorithm, is the most common neural network found in the literature (Mehrotra, Mohan, & Ranka, 1996), and has been used in a wide range of applications such as pattern recognition (Dimla & Lister, 2000; Jeong, Kim H., Kim D.S., & Lee, 2000; Zhang, 1999), medical image analysis (Guler, Sankur, Kahya, & Raudys, 1998; Sheppard et al., 1999) and forecasting (Indro, Jiang, Patuwo, & Zhang, 1999). There is a vast literature on the combination of fuzzy set theory (Zadeh, 1965) and the multilayer perceptron (Haykin, 2001; Mehrotra, Mohan, & Ranka, 1996), such as (Stoeva & Nikov, 2000; Pal & Mitra, 1992; Keller & Hunt, 1985).

The use of neural networks and clustering techniques for the classification of temporal patterns in time series has been the subject of recent research. Tsuji, Fukuda, Kaneko and Ito (2000) classified electromyography (EMG) temporal patterns using a neural network that combines the backpropagation algorithm to update weights and a special type of neuron (filter neurons). Kupka and Meloun (2009) used a neural network with radial basis function (RBF) to classify changes in processes of nuclear power plants. Husken and Stagge (2003) used the dynamic behavior of recurrent neural networks to categorize input sequences into predefined classes. Fu, Chung, Ng and Luk (2001) used Self Organizing Maps (SOM) for pattern discovery from time series. In (Keogh, Lin, & Truppel, 2005) the general applicability of clustering in time series is discussed. Wardlow, Egbert and Kastens (2007) investigated the general applicability of the data sets of time series of vegetation index NDVI and EVI, MODIS product, to classification of land use and cover in a region of the state of Kansas, USA. Carvalho et al. (2008) studied the use NDVI MODIS time series and a spectral classification algorithm to identify different Cerrado vegetation types in the Chapada dos Veadeiros National Park in Brazil.

The remainder of this paper is organized as follows. First – after this introduction –, we describe the fuzzy MLPs investigated in this study. Secondly, we present the application of these fuzzy MLPs to time series of vegetation index. The parameters definition is presented in third place, while the results of the work are presented in fourth. The following section presents a parameters sensitivity study and after that we have the description of the validation procedure and corresponding results. Finally we have the conclusion remarks of our work.

**THE FUZZY MULTILAYER PERCEPTRON**

Essentially, the MLP is a multilayer feedforward network that utilizes a supervised learning mechanism that modifies the connection weights of the network in order to minimize the mean square error between the desired and calculated outputs (Rumelhart, Hinton, & Williams, 2002).
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