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Optimization of modular granular neural networks using a hierarchical genetic algorithm based on the database complexity applied to human recognition

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ABSTRACT

In this paper, a new model of a Modular Neural Network (MNN) optimized with hierarchical genetic algorithms is proposed. The model uses a granular approach based on the database complexity. In this case the proposed method is tested with the problem of human recognition based on the face information. The ORL and the ESSEX face databases are used to test the effectiveness of the proposed method. To compare with other related works using the same databases, four cases are established (3 for the Essex Database and 1 for the ORL Database). The results using the proposed method are better than the results achieved by other works, and this affirmation is based on a statistical comparison of results. The main idea is to design the architectures of modular neural networks using a Hierarchical Genetic Algorithm (HGA). The distribution of persons in each granule is determined by an initial analysis, resulting in a grouping of data with the same complexity. The proposed HGA allows the optimization of multiple modular neural networks that use different number of data points for the training phase, which means that in the same evolution multiple results can be obtained.

1. Introduction

Biometric systems used for the authentication of persons have important advantages. These systems use human physiological characteristics, which can be permanent or suffer little change over the life of a person. Some of the most popular biometric measures are ear, iris, fingerprint, and hand geometry [30]. Perhaps, the main advantage that a biometric measure can have is that it cannot be passed to other persons or cannot be stolen, as can happen when cards or passwords have being used [18,27,53].

Although the face is a biometric measure that can suffer changes during the life of a person, since 1970 face recognition has drawn attention in the field of human recognition and many works have been developed [20], where novel methods have been proposed [8,13,22,28] and good results have been achieved [7,10,16,17,32,64]. Some of these methods are; the Digital Curvelet Transform using Support Vector Machine (SVM) [48], the decomposition of images into its curvelet sub-bands and applying PCA (Principal Component Analysis) [49], the Spatially Confined Non-Negative Matrix Factorization (SFNMF) method [36], Modular Neural Networks (MNNs) and their optimization using Genetic Algorithms (GAs) or Parallel Genetic Algorithms (PGAs) [51], the use of fuzzy logic as method to perform the combination of responses of modular neural

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networks [28,31], eigenfaces [64], thermal facial patterns using fuzzy neural network techniques [11] or using the similarity measurement of Gaussian maximum likelihood [25] among other techniques.

In this paper, a new approach for feed-forward back-propagation Modular Granular Neural Networks optimization using a hierarchical genetic algorithm is proposed. The design of the architecture of these modular neural networks is performed in two stages. First, non-optimized trainings are obtained, and an initial analysis is performed where labels and new identification numbers (ID) are assigned to each person using if then rules. Second, the proposed Hierarchical Genetic Algorithm (HGA) is used, using four different elitism methods, the most important of them called external memory. This approach can be used in related applications with the goal of human recognition. In this paper, the proposed approach is tested with the case of human recognition using the face as a biometric measure [29,52]. An analysis of non-optimized trainings is performed a priori, where a granulation approach proposed in previous work [43] is used. In this granulation, a set of persons is divided into sub granules without relation each other. In this paper using the results of the non-optimized trainings, this division is performed based on its complexity, where persons with the same complexity are grouped in the same granule, and the final granulation is performed by the proposed hierarchical genetic algorithm. Some advantages of the proposed method are the optimization of the number of modules for each granule and the use of different number of validations (i.e. different number of data for the training phase) because in other works where modular neural networks are used these parameters are established in a fixed fashion [15,29,31,43,52] and when the optimization of the modular neural networks architectures is performed better results are achieved. This is because it is difficult to find the best architecture when the parameters are randomly established or with a process of trial and error, unless we have already worked on the same database. But if a general method is proposed is important to find the optimal architectures for each different database. In this work the optimization of architecture parameters has an important role because it is already known that the optimization of modules provides better results than using a conventional neural network and that for example the goal error and the number of hidden layers with their respective neurons also have an important role in the final result [43].

The main objectives of this paper are to find optimal architectures of the modular neural networks and allow working with big databases due to the grouping of persons with the same complexity that allows focusing on persons with a higher recognition complexity, because the persons with low recognition complexity can have lower recognition error. The other objective is the optimization of multiple architectures using different number of data for the training phase in the same evolution.

This paper is organized as follows. Basic concepts to understand this work are presented in Section 2. In Section 3, the description of the proposed method is presented. The results obtained using benchmark databases, for testing the proposed method, are explained in Section 4. Statistical comparisons of results are presented in Section 5. Finally, the conclusions are presented in Section 6.

2. Basic concepts

In this section a brief overview of the basic concepts used in this research work is presented.

2.1. Artificial neural networks (ANNs)

Neural networks (NNs) can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques [5,21]. The term of non-optimized trainings is used when the architecture of a conventional neural network, an ensemble neural network or a modular neural network is established randomly or by trial and error, i.e. a method to find an optimal architecture is not used. The parameters of these kinds of neural networks can be the number of hidden layers, the number of neurons for each hidden layer, the learning algorithm, number of epochs, among others [31,32,51]. These kinds of NNs need two phases for their design, which are called the training phase (learning phase) and the testing phase. Of course, depending on the information given in the training phase, the output performance is affected [29].

2.2. Multi-layer feed-forward (MLF) neural networks

Multi-layer feed-forward (MLF) neural networks trained with the back-propagation learning algorithm, are the most popular neural networks [39,47]. A wide variety of applications, such as chemistry problems [65], human recognition [15,17,43], time series prediction [14], among other applications have achieved good results using this neural technique. In this kind of networks, the first layer is called the input layer, and the last layer is called the output layer. The layers between these layers are called the hidden layers.

2.3. Modular Neural Networks (MNNs)

The concept of modularity is an extension of the principle of divide and conquer, which means that the problem is divided into smaller sub problems that are solved by experts (sub modules) and their partial solutions are integrated to produce a final solution [44]. The results of the different applications involving Modular Neural Networks (MNNs) lead to the general