

Use of Multiple Astrocytic Configurations within an Artificial Neuro-Astrocytic Network [†]

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Abstract: The artificial neural networks used in a multitude of fields are achieving good results. However, these systems are inspired in the vision of classical neuroscience where neurons are the only elements that process information in the brain. Advances in neuroscience have shown that there is a type of glial cell called astrocytes that collaborate with neurons to process information. In this work, a connectionist system formed by neurons and artificial astrocytes is presented. The astrocytes can have different configurations to achieve a biologically more realistic behaviour. This work indicates that the use of different artificial astrocytes behaviours is beneficial.

Keywords: astrocyte; artificial neuron-astrocyte network; genetic algorithm; cooperative co-evolutionary genetic algorithm

1. Introduction

It has recently been shown that information processing in the brain is not carried out solely by neurons [1]. Astrocytes from glial system work together with the neurons, using a bidirectional communication called tripartite synapses [1].

From the perspective of artificial intelligence, this finding represents a new approach to connectionist systems (CS) [2]. Most of the CS that are used in tasks such as speech recognition prediction or medical diagnosis, only contain neurons [3]. The implementation of a CS with bidirectional communication between neurons and astrocytes supposes a more biologically realistic system (see Figure 1) that had improved the results obtained by artificial neural networks (ANN).

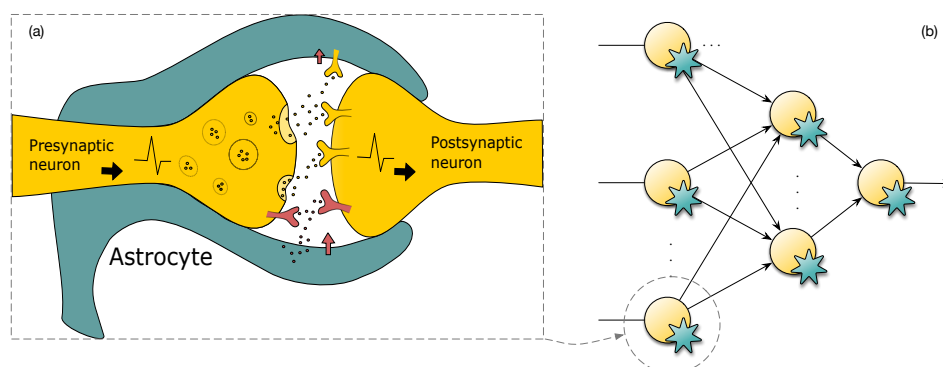


Figure 1. (a) Scheme of tripartite synapse in the brain. (b) ANAN structure, where artificial astrocytes and neurons are represented by green and yellow colors, respectively.

The simulation of astrocyte behaviour is based on biological observation. Unlike neurons that are electrically excitable and their communication is in milliseconds the astrocytes are slower, they communicate by means of calcium waves [4], taking seconds. To represent this behaviour, various algorithms have been implemented that can be seen in [5,6] biological astrocytes can boost or depress the exchange of neurotransmitters in the synaptic space [4]. These properties are collected in artificial astrocytes as hyperparameters [5]. The behaviour of the astrocytes on a different time scale than that of the neurons means that learning techniques based on the gradient cannot be used in the network because the elements of the network have non-smooth and discontinuous functions. This property is not a limitation because techniques such as genetic algorithms (GA) can be used for training because have no restrictions on functions.

The proposed method has been tested using different network architectures with a classification problem extracted from the UCI machine learning repository [7]. The results obtained by the ANAN are superior to those obtained with a classic ANN.

2. Cooperative Co-Evolutionary Genetic Algorithm to Train Networks

ANANs include elements that are non-smooth and discontinuous so gradient based techniques cannot be used to perform the training phase.

For the learning phase it has been decided to use evolutionary learning techniques [8]. The use of canonical genetic algorithms has been ruled out because all the parameters of the ANAN (weights and parameters of the astrocytes) are too variable. It has been decided to use the cooperative co-evolutionary cooperative genetic algorithm (CCGA) because it allows the use of several species with different genotypes. The objective of the species is to work together to thrive.

The way to train ANAN with CCGA is by using two species: the weights of the net and the astrocytic parameters.

3. Proposal

This study aims to determine whether the use of different astrocytic behaviors improves the results obtained by the ANN and also those that can be obtained by an ANAN using a single astrocytic configuration across the entire network.

In order to train the ANAN with the two approaches, two different codings are used. For the approach using the same astrocytic configuration only the parameters of the astrocytes are stored once. The approach which using different astrocytic behaviours stores the astrocytic set-up for each layer.

4. Experiments and Results

The ANN and the ANAN have been compared under the same conditions. The only difference is that the ANN does not have astrocytes and a CCGA is not necessary since it only uses one species and a canonical GA is used instead.

The dataset used is breast cancer which analyzes the presence of cancer using 9 characteristics in 699 patients (9 inputs; a binary output) [9].

To secure independent results, 10cv cross validation was implemented [10]. Thus, 10 different sets were obtained where each of them include: 60% training patterns, 20% validations patterns and 20% test patterns. It was also used 10 different initial genetic populations. This means 100 runs to the cross validation set-up. Wilcoxon signed rand test was used to corroborate statistical significance [11].

As expected, ANAN obtains better results than ANN (see Table 1). ANAN with a different astrocytic configuration in each layer gets the best results when using networks with two and three hidden layers. This suggests that the use of astrocytes is more beneficial with larger networks and that different types of astrocytes are needed to complement each other.

Table 1. Comparative study of the classification accuracy (test values). The values described in the table refer to average performance (100 different runs) and the statistical significance (* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$). The asterisks compare ANAN to ANN. The architecture shows the number of neurons used on each hidden layer.

Architecture	ANN	ANAN	
		Single Astrocytic Configuration	Astrocytic Configuration for Each Layer
1 hidden layer (7)	90.34% $\pm$ 2.34%	90.75% $\pm$ 3.63%	90.43% $\pm$ 3.40%
2 hidden layers (7,3)	90.50% $\pm$ 2.25%	91.25% $\pm$ 3.88% **	91.37% $\pm$ 2.96% ***
3 hidden layers (12,8,3)	90.78% $\pm$ 2.21%	91.28% $\pm$ 4.96% **	92.12% $\pm$ 4.09% ***

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