Artificial NeuroGlial Networks

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INTRODUCTION

More than 50 years ago **connectionist systems** (**CSs**) were created with the purpose to process information in the computers like the human brain (McCulloch & Pitts, 1943). Since that time these systems have advanced considerably and nowadays they allow us to resolve complex problems in many disciplines (classification, clustering, regression, etc.). But this advance is not enough. There are still a lot of limitations when these systems are used (Dorado, 1999). Mostly the improvements were obtained following two different ways. Many researchers have preferred the construction of **artificial neural networks** (**ANNs**) based in mathematic models with diverse equations which lead its functioning (Cortes & Vapnik, 1995; Haykin, 1999). Otherwise other researchers have pretended the most possibly to make alike these systems to human brain (Rabuñal, 1999; Porto, 2004).

The systems included in this article have emerged following the second way of investigation. **CSs** which pretend to imitate the neuroglial nets of the brain are introduced. These systems are named **Artificial NeuroGlial Networks** (**ANGNs**) (Porto, 2004). These **CSs** are not only made of neuron, but also from elements which imitate glial neurons named **astrocytes** (Araque, 1999). These systems, which have hybrid training, have demonstrated efficacy when resolving classification problems with totally connected feed-forward multilayer networks, without backpropagation and lateral connections.

BACKGROUND

The **ANNs** or CSs emulate the biological neural networks in that they do not require the programming of tasks but generalise and learn from experience. Current **ANNs** are composed by a set of very simple processing elements (PEs) that emulate the biological neurons and by a certain number of connections between them.

Until now, researchers that pretend to emulate the brain, have tried to represent in ANNs the importance the neurons have in the Nervous System (NS). However, during the last decades research has advanced remarkably in the Neuroscience field, and increasingly complex neural circuits, as well as the Glial System (GS), are being observed closely. The importance of the functions of the GS leads researchers to think that their participation in the processing of information in the NS is much more relevant than previously assumed. In that case, it may be useful to integrate into the artificial models other elements that are not neurons.

Since the late 80s, the application of innovative and carefully developed cellular and physiological techniques (such as patch-clamp, fluorescent ion-sensible images, confocal microscopy and molecular biology) to glial studies has defied the classic idea that **astrocytes** merely provide a structural and trophic support to neurons and suggests that these elements play more active roles in the physiology of the Central Nervous System.

New discoveries are now unveiling that the glia is intimately linked to the active control of neural activity and takes part in the regulation of synaptic neurotransmission (Perea & Araque, 2007). Abundant evidence has suggested the existence of bidirectional communication between astrocytes and neurons, and the important active role of the astrocytes in the NS's

physiology (Araque et al., 2001; Perea & Araque, 2005). This evidence has led to the proposal of a new concept in synaptic physiology, the tripartite synapse, which consists of three functional elements: the presynaptic and postsynaptic elements and the surrounding astrocytes (Araque et al., 1999). The communication between these three elements has highly complex characteristics, which seem to reflect more reliably the complexity of the **information processing** between the elements of the NS (Martin & Araque, 2005).

So there is no question about the existence of communication between astrocytes and neurons (Perea & Araque, 2002). In order to understand the motives of this reciprocated signalling, we must know the differences and similarities that exist between their properties. Only a decade ago, it would have been absurd to suggest that these two cell types have very similar functions; now we realise that the similarities are striking from the perspective of chemical signalling. Both cell types receive chemical inputs that have an impact on the ionotropic and metabotropic receptors. Following this integration, both cell types send signals to their neighbours through the release of chemical transmittors. Both the neuron-to-neuron signalling and the neuron-to-astrocyte signalling show plastic properties that depend on the activity (Pasti et al., 1997). The main difference between **astrocytes** and neurons is that many neurons extend their axons over large distances and conduct action potentials of short duration at high speed, whereas the **astrocytes** do not exhibit any electric excitability but conduct calcium spikes of long duration (tens of seconds) over short distances and at low speed. The fast signalling, and the input/output functions in the central NS that require speed, seem to belong to the neural domain. But what happens with slower events, such as the induction of memories, and other abstract processes such as thought processes? Does the signalling between astrocytes contribute to their control? As long as there is no answer to these questions, research must continue; the present work offers new ways to advance through the use of Artificial Intelligence (AI) techniques.

Therefore not only it is pretended to improve the **CSs** incorporating elements imitating astrocytes, but it is also intended to benefit Neuroscience with the study of brain circuits since other point of view, the AI.

The most recent works in this area are presented by Porto et al (Porto et al., 2007; Porto et al., 2005; Porto, 2004).

MAIN FOCUS OF THE ARTICLE

All the design possibilities, for the architecture as well as for the training process of an ANN, are basically oriented towards minimising the error level or reducing the system's learning time. As such, it is in the optimisation process of a mechanism, in case the ANN, that we must find the solution for the many parameters of the elements and the connections between them.

Considering possible future improvements that optimize an ANN with respect to minimal error and minimal training time, our models will be the brain circuits, in which the participation of elements of the GS is crucial to process the information. In order to design the integration of these elements into the ANN and elaborate a learning method for the resulting ANGN that allows us to check whether there is an improvement in these systems, we have analysed the main existing training methods that will be used for the elaboration. We have analysed Non-Supervised and Supervised Training methods, and other methods that use or combine some of their characteristics and complete the analysis: Training by Reinforcement, Hybrid Training and Evolutionary Training.

Observed Limitations

Several experiments with ANNs have shown the existence of conflicts between the functioning of the CS and biological neuron networks, due to the use of methods that did not reflect reality. For instance, in the case of a multilayer perceptron, which is a simple CS, the synaptic connections between the PEs have weights that can be excitatory or inhibitory, whereas in the natural NS, are the neurons that seem to represent these functions, not the connections; recent research (Perea & Araque, 2007) indicates that the cells of the GS, more concretely the astrocytes, also play an important role.

Another limitation concerns the learning algorithm known as "Backpropagation", which implies that the change of the connections value requires the backwards transmission of the error signal in the ANN. It was traditionally assumed that this behaviour was impossible in a natural neuron, which, according to the "dynamic polarisation" theory of Ramón y Cajal (1911), is unable to efficiently transmit information inversely through the axon until reaching the cellular soma; new research however has discovered that neurons can send information to presynaptic neurons