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New learning methodology for classifiers based in Fuzzy Cognitive Maps

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Abstract: *Fuzzy Cognitive Maps (FCMs) are a very peculiar type of recurrent neural networks that allow modeling complex systems in terms of concepts and causal relations. While FCMs have proven successful in addressing simulation scenarios, their performance in solving pattern classification problems is quite variable. Nevertheless, the interpretability and transparency attached to these cognitive networks have motivated researchers to improve their performance. On the other hand, some definitions and theorems have been recently introduced to unveil the dynamic behavior in FCMs equipped with sigmoid transfer functions. These analytic tools allow estimating bounds for the activation value of each neuron. In this paper, we present a new learning methodology for FCM-based classifiers, using the estimated bounds of neurons, that leads to high prediction rates. The numerical results show that our neural classifier is able to outperform most algorithms adopted for comparison, while remaining competitive with the most accurate ones.*

Keywords: *Fuzzy Cognitive Maps; Learning; Pattern Classification; Shrinking State Spaces.*

1. Introduction

Perhaps the most well-known problems within the Artificial Intelligence field are those devoted to pattern classification. Researchers in Machine Learning have been primarily focused on computing the best possible prediction rates, but these classifiers behave like black boxes. Fuzzy Cognitive Maps (FCMs) [1] stand as a vehicle to design more transparent classifiers. In principle, these knowledge-based neural networks are capable of expressing the system semantics by using concepts and causal relations. Recently, the key problems arising when constructing FCM-based classifiers were highlighted and was proposed an algorithm to estimate the limit state space of FCMs equipped with sigmoid transfer functions and thus obtaining bounds for every neuron. In this paper, we elaborate on the issues and, using the neuron's bounds, we propose a supervised learning method that takes into account both accuracy and convergence when minimizing the training error. As a second contribution, we compare the performance of our model against 17 state-of-the-art algorithms using 60 benchmark problems.

2. Learning Methodology for FCM-based classifiers

We propose a supervised learning algorithm to compute the parameter set of FCM-based classifiers using a class-per-output architecture. In our proposal, this implies to compute the weight matrix and the slope and offset of the transfer function attached to each neuron. Before defining the learning error to be minimized, we introduce a new definition with the purpose to express the *relative activation value* for neuron i-th at the t-th iteration. The learning error for an FCM-based classifier is computed using the parameters encoded in the candidate solution to be evaluated and the relative activation value to select the output class when inference is completed. Our approach is novel, by means of the new definition to select the decision class together with neuron's bounds given by the limit state space defined by Nápoles et al. [3].

3. Results and discussion

We evaluate the predictive capability of FCM-based classifiers using the proposed methodology by comparing with 17 state-of-the-art classifiers. By doing so, we leaned upon 60 classification datasets taken from the KEEL and UCI Machine Learning [2] repositories. In order to optimize the error function, we adopt a Particle Swarm Optimization algorithm. When analyzing the average Cohen's Kappa coefficient attained by each algorithm, our neural classifier arises as the best-performing algorithm. Also, in order to conduct a more rigorous analysis using more statistical methods, our classifier was able to outperform 11 algorithms, with no significant differences spotted when compared with RF, MLP, LMT, RCE, FRCN and K*.

4. Conclusions

This paper proposed a learning methodology for FCM-based classifiers that comprises three steps, namely: the topology construction, the initialization of neurons and the learning algorithm itself. The simulations have shown that FCM-based classifiers using our learning methodology may be as efficient as black boxes while retaining their capability of explaining the problem domain through meaningful neurons and causal relations.

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