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A flexible enhanced fuzzy min-max neural network for pattern classification

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ABSTRACT

In this paper, the existing enhanced fuzzy min–max (EFMM) neural network is improved with a flexible learning procedure for undertaking pattern classification tasks. Four new contributions are introduced. Firstly, a new training strategy is proposed for avoiding the generation of unnecessary overlapped regions between hyperboxes of different classes. The learning phase is simplified by eliminating the contraction procedure. Secondly, a new flexible expansion procedure is introduced. It eliminates the use of a user-defined parameter (expansion coefficient) to determine the hyperbox sizes. Thirdly, a new overlap test rule is applied during the test phase to identify the containment cases and activate the contraction procedure (if necessary). Fourthly, a new contraction procedure is formulated to overcome the containment cases and avoid the data distortion problem. Both the third and fourth contributions are important for preventing the catastrophic forgetting issue and supporting the stability-plasticity principle pertaining to online learning. The performance of the proposed model is evaluated with benchmark data sets. The results demonstrate its efficiency in handling pattern classification tasks, outperforming other related models in online learning environments.

1. Introduction

The artificial neural network (ANN) is a computational model that is inspired by the biological nervous system. ANNs attempt to mimic the mechanism of the human brain by simulating intelligent behaviors. They have emerged as an important tool for addressing pattern classification problems. ANNs have found applications in several fields, e.g. fault detection(Chow & Yee, 1991), industry(Blanco, Pino-Mejías, Lara, & Rayo, 2013; Salahshoor, Kordestani, & Khoshro, 2010), speech recognition(Hinton et al., 2012; Nedjah, Bonilla, & de Macedo Mourelle, 2023), handwriting recognition(Al Sayaydeh & Bisher, 2015; Gupta & Bag, 2021; Malakar, Sahoo, Chakraborty, Sarkar, & Nasipuri, 2022), texture classification(A. Shamaileh, 2019; A. M. Shamaileh, Rassem, Chuin, & Sayaydeh, 2020), and security(Obaidat & Macchairolo, 1994). Various ANNs for undertaking pattern classification tasks have been constructed, e.g. the radial basis function (RBF) network(Broomhead & Lowe, 1988), multi-layer perceptron(MLP) networks(Rosenblatt, 1958), and the Hopfield network(J. J. Hopfield, 1982; J J Hopfield, 1984). ANNs able to learn, handle large sample sizes, and tackle noisy data collected from real world environments (Al-haimi, Hujainah, Nasir, & Alhroob, 2021). However, several drawbacks have limited their application in practice, which include lack of a formal approach to identifying the optimal network structure, difficulty in tackling imprecise or ambiguous information, and susceptibility to the black-box phenomenon (Thanh Tung Khuat & Gabrys, 2020; Thanh Tung Khuat, Ruta, & Gabrys, 2021; Pourpanah, Lim, & Saleh, 2016; O. N. A. Sayaydeh, Mohammed, Alhroob, Tao, & Lim, 2020). To overcome these shortcomings, researchers have integrated ANNs with fuzzy logic to form fuzzy neural networks (T. T. Khuat & Gabrys, 2023). This integration is able to generate robust classifiers for undertaking real-world problems. e.g., Fuzzy ARTMAP (FAM) (G. A. Carpenter, Grossberg, Markuzon, Reynolds, & Rosen, 1992); and the fuzzy min–max (FMM) neural networks (Simpson, 1992).

The training procedure of an ANN plays a vital role in the overall performance, which is strongly related to presentation of the training patterns (Gail A Carpenter & Grossberg, 1987; G. A. Carpenter et al.,

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