A Review on Pattern Classification Using Multilevel and Other Fuzzy Min Max Neural Network Classifier

Rakesh K. Jambhulkar

Department of Computer Engineering, Savitribai Phule Pune University, India

Abstract: *This paper describes a review on the pattern classification using Multilevel Fuzzy Min Max Neural Network classifier (MLF) and different fuzzy min max domain methods. Multilevel fuzzy min max neural network is a supervised learning method and it uses the concept of fuzzy min max method in a multilevel structure to classify the patterns efficiently. To classify the samples in the overlapping regions MLF uses different classifiers with smaller hyperboxes in different levels. MLF selects the best output among all classifiers as a final output of the network. MLF has the capability of learning overlapped region with a single pass through the data. MLF has the highest performance as well as the lowest sensitivity to expansion parameter in comparison of other fuzzy min max domain methods.*

Keywords: Classification, fuzzy min max, hyperbox, machine learning, neurofuzzy.

1. Introduction

To represent the real life data fuzzy sets are used instead of classical sets for fuzzy hyperbox classification [15]. Because fuzzy sets as well as their operations are more compatible with real world systems and are highly efficient in pattern recognition and machine learning problems. Fuzzy sets represent the complex boundaries between the pattern classes. Due to which it's become possible to describe the degree to which a pattern belongs to one class or another. Neural network is very popular for its computational efficiency hence it is used in computer based pattern recognition. Neural network is based on the structure and function of neurons of the human brain. It is used in various applications such as face recognition, fingerprint identification, flood monitoring system, navigation and surveillance system etc. To take the advantage of fuzzy set and neural network, both are combined to integrate the excellent learning capability of neural network with fuzzy inference system. This combination of neural network and fuzzy inference system is termed as Neurofuzzy.

The Fuzzy Min Max method is special type of neurofuzzy. Its learning phase is single pass through and online adaptive for pattern classification that is done in very short time. During the learning phase hyper-boxes expands till almost the whole pattern space is covered and at the ending of this phase not a single overlapping hyper-box remains that belongs to other classes. The expansion parameter (θ) controls the maximum expansion of these hyper-boxes. Any value can be assigned to θ between 0 and 1.

2. Previous Methods In FMM Domain

Many researchers have done lots of work in fuzzy min max domain. Some most important FMM methods are presented below with their characteristics and limitations.

A. Fuzzy Min Max Classification Neural Network

Professor Simpson had proposed a FMM classification neural network which is a supervised machine learning method [12]. FMM classifier learns just with one pass through the data. Simpson used FMM for classification in 1992 and for clustering in 1993. Hyperboxes were used to cover the pattern which is a convex box and determined by its min point (V) and max point (W). Each class can have one or more hyperboxes and hyperboxes of the same class could overlap each other but hyperboxes from different class should not overlap each other. Each fuzzy set is a union of fuzzy set hyperboxes. In FMM, expansion-contraction process is used for removal of overlapping between hyperboxes. Learning is online adaptive. It learns nonlinear class boundaries with single pass through over the learning samples. FMM acquires the ability to incorporate new and refine existing classes that means no retraining is needed. Simpson gave the clear idea about the classic structure of FMM as shown in fig.1. This structure consisted first layer that takes input samples, second layer represents hyperboxes and third layer represents classes. All hyperboxes are created and adjusted in learning phase.
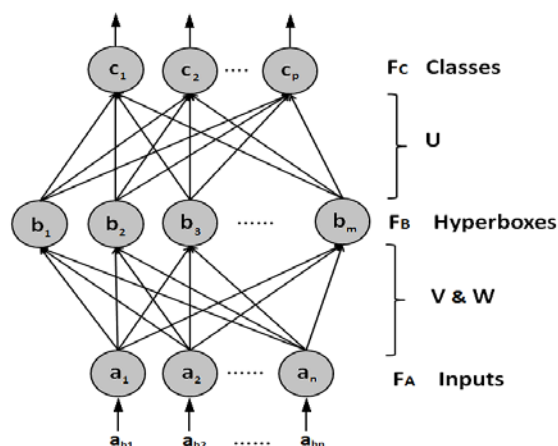

Figure 1: Structure of the classic FMM

B. General Fuzzy Min Max Neural Network

In 2000, Gabrys and Bargiela proposed this method for the improvement of efficiency of FMM method [3]. GFMM combined the supervised and unsupervised learning within a single training algorithm. Learning was completed in a few passes through the data and consisted placing and adjusting the hyperboxes in the pattern space which is referred to as an expansion–contraction process. Retraining for the new added data was not required. The changes were made to FMM method are the fuzzy hyper-box membership function, input patterns, expansion parameter and algorithm. The sensitivity parameter was included which regulates how fast the membership values decrease out of the hyperboxes.

C. Inclusion / Exclusion Fuzzy Hyper-Box Classifier

This supervised machine learning method was proposed by Bargiela et.al in 2003[1]. Some changes were made in the learning process to overcome the overlapping problem. In this method, each class was described by one or more hyperbox defined by their corresponding min and max points as well as their membership function. This method used two types of hyperboxes i) inclusion hyperbox and ii) Exclusion hyperbox. Former type of hyperbox contained input pattern belonging to the same class while later type hyperbox contained patterns belonging to two or more classes.

D. Fuzzy Min Max Neural Network Classifier with Compensatory Neuron Architecture

Prof. Nandedkar and Prof. Biswas proposed this method in 2007[8][9]. FMCN used compensatory nodes to handle the overlapping area problem. CN's are divided into two groups namely overlap compensation neuron (OCN) and containment compensation neuron (CCN). OCN was used for handling simple neurons and CCN was used for handling overlaps where one hyperbox is partially or fully contained in another hyperbox. Fuzzy hyperbox sets were used to represent the pattern classes. The concept pf CN was taken from the reflex system of human brain which takes over the control in hazardous conditions. Neurons handled hyperbox overlap and containment with more efficiently. The contraction process was eliminated from this method and instead that CN's were used. FMCN was less dependent on expansion coefficient i.e. maximum hyperbox size.

E. Data-Core-Based FMM Neural Network

Data-core–based fuzzy min max neural network classifier was proposed by Zhang et.al.in 2011[16]. Like FMCN, this method also used compensatory neurons to handle the overlapping area problem. A novel membership function was introduced to consider characteristic of data as well as the influence of noise. DCFMN retrieves different approach than FMCN such as DCFMN contained two types of neurons (i) classifying neurons (CNs) and (ii) overlapping neurons (OLNs). Another approach was used that the membership function of CNs considered noise, geometric center of hyperbox, and data core. The learning algorithm started the overlap test after the creating and expanding the hyperboxes for all the training data. The drawback of this method is that

either the high percentage of samples located in overlapping area cannot be classified correctly or it cannot classify all learning samples correctly.

3. Multilevel Fuzzy Min Max Neural Network

Recently this method was proposed by Davtalab et.al [2]. MLF is homogeneous classifier [6] and uses the multilevel tree structure. This method always tries to use the smaller hyper-boxes in the boundary regions with more accuracy. The contraction process is no used in MLF. The size of hyperboxes of next levels are smaller than size of the hyperboxes of previous levels. The structure of the network is formed in the training phase and each node of the network is called as subnet which is an independent classifier.

Subnet consists two types of segments (i) HBS i.e. hyperbox segment and (ii) OLS i.e. Overlap box segment. The hyperbox segment contains hyperboxes and overlap box segment contains overlap boxes. Overlap box is like a regular hyperbox with its min and max point and represents part of the overlapped area of pattern space. Both segments are created in the training phase. During the training phase all the hyperboxes are created and are used in test phase. Overlap handling is done after the creation and adjustment of all hyperboxes. The output of subnet is determined by the transaction function of node G. which depends on output of OLS and HBS. Each subnet is trained separately by samples that belong to its region. The maximum size of hyperbox is controlled by expansion parameter θ.

4. Conclusion

Various fuzzy min max neural network methods are studied. The neural network uses multilevel tree structure where all nodes represent the subnet. Each overlap area of the parent nodes is handled by a child node in the next level. In MLF usually child nodes have smaller hyperboxes than those of parent nodes hence the high accuracy can be achieved from the classification in boundary regions. The learning samples can be trained faster as compared to the other FMM methods. In comparison with other methods (FMM, GFMM, EFC, FMCN, DCFMN), MLF is more precise. The recognition rate for training sample is 100% in MLF whereas other FMM-based methods have less recognition rate. The space complexity of the MLF method depends on the area of the boundary region in pattern space because MLF makes the decision in boundary regions. MLF achieves high performance as well as great accuracy due to which it can be used in various applications .MLF especially targets the nonlinear boundaries. MLF can be used in dynamic and real time environment by using its great speed of the training phase.

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