A NEW FUZZY BACK-PROPAGATION LEARNING METHOD BASED ON DERIVATION OF MIN-MAX FUNCTION TUNED WITH GENETIC ALGORITHMS

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To my beloved mother, father and brother

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ABSTRACT

Nowadays, environments are covered by lots of qualitative (inexact) data. Making proper decisions according to this qualitative data is an ultimate aim. Artificial neural networks can be adapted to the quantitative environments, since they have ability of learning. On the other hand, fuzzy logic has the power of dealing with inexact data. To get benefit of advantageous of artificial neural networks and fuzzy logic, *fuzzy artificial neural networks* are proposed. This hybrid soft-computing technique has the ability of learning in qualitative environments. Thus, fuzzy artificial neural networks can make qualitative decisions according to inexact data which are fed to it. Learning process of fuzzy artificial neural networks is one of the most important issues. Thus, many learning methods for feed forward fuzzy artificial neural networks are proposed. Low speed of convergence and accuracy of training have made fuzzy artificial methods inapplicable in most of problems. Thus, efficient learning method for fuzzy artificial neural networks is demandable. In this study a "*genetically tuned fuzzy back propagation method based on derivation of min-max function*" as new learning method has been proposed by author. The proposed learning method has resolved some of the previous shortcomings. Importance of the proposed method is that, three main benefits are reached simultaneously; *it can learn from any kind of convex fuzzy numbers*, *accuracy of training is higher since error function is more realistic comparing to gradient based learning methods*, and *convergence speed is acceptable*.

ABSTRAK

Pada masa kini, kebanyakan keadaan dipengaruhi oleh data-data kualitatif iaitu data yang tidak tepat. Justeru, adalah menjadi keutamaan dalam membuat keputusan yang sesuai berdasarkan data-data kuantitatif. *Artificial neural network* boleh disesuaikan dalam persekitaran kuantitatif memandangkan ia mempunyai kebolehan belajar manakala *fuzzy logic* pula mempunyai kebolehan untuk menguruskan data yang tidak tepat. Untuk mendapatkan manfaat daripada kedua-dua kaedah ini, penggunaan *fuzzy artificial neural networks* dicadangkan. Hasil gabungan kedua-dua teknik tersebut mewujudkan satu kebolehan dalam mempelajari keadaan kuantitatif. Oleh itu, kaedah *fuzzy artificial neural networks* boleh digunakan untuk menentukan data kuantitatif berdasarkan kewujudan data yang kurang tepat. Proses pembelajaran *fuzzy artificial neural networks* adalah satu isu penting yang perlu diambil kira. Sebelum ini, pelbagai kaedah pembelajaran lanjutan *forward fuzzy artificial neural network* telah diusulkan. Namun begitu, penumpuan dan ketepatan latihan yang rendah menjadikan kaedah *fuzzy artificial* tidak sesuai digunakan dalam kebanyakan masalah. Dalam kajian ini, penyelidik telah mengusulkan kaedah *genetically tuned fuzzy back propagation* iaitu hasil terbitan fungsi min-max sebagai satu kaedah pembelajaran yang baru. Kaedah pembelajaran ini juga telah mengatasi beberapa kekurangan yang timbul sebelum ini. Selain itu, kaedah ini juga telah mencapai tiga faedah utama secara serentak iaitu; mempunyai kelebihan belajar daripada pelbagai jenis *convex fuzzy*, memperolehi ketepatan yang tinggi kerana fungsi ralat adalah lebih realistik berbanding kaedah pembelajaran berdasarkan kecerunan serta penumpuan kepantasan yang diterima.

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ANN	-	Artificial Neural Network
BP	-	Back-Propagation
FANN	-	Fuzzy Artificial Neural Network
NN	-	Neural Network
GA	-	Genetic Algorithm

CHAPTER 1

INTRODUCTION

1.1 Overview

Recently, soft computing techniques have been used in many applications. These techniques have shown their vast advantages even if they are used solely, but mostly they are implemented in hybrid ways for better outcomes. Hybrid techniques have better performance since each technique has some drawbacks that can be resolved when hybrid approach is used.

Artificial Neural Networks (ANNs) are one of soft computing techniques. The main aim of ANNs is to find a fitting function. This function fits all the data which are fed as samples to ANNs [1]. Crisp ANNs are just able to approximate fitting functions for crisp data. Nowadays, inexact data which was firstly proposed by Zadeh in 1965, are available in most of environments, and this inexactness has been used in many

applications especially in control systems [2]. Therefore, there is a great need to find a fitting function for given inexact data. Fuzzy artificial neural networks (FANNs) are hybrid soft computing technique that can fit function for given inexact data[3]. The main idea of FANNs is to use fuzzy set theory to generalize ANNs, thus, FANNs are techniques that can learn from fuzzy data [4].

Many learning methods have been proposed since FANNs is introduced such as direct fuzzification [5, 6, 7], learning method for triangular symmetric fuzzy values [8-15], genetic algorithms (GAs) based learning method for FANNs [16, 17], learning method for L-R fuzzy values [18] and recently, fuzzy back-propagation (BP) learning method [19, 20] based on derivation of min-max function.

Evolutionary algorithms such as GAs are good choices for optimization problems [21]. GA finds *almost an optimized* value of a given function with some constraint. In ANNs, we need to find *optimized values* of variables such as weights, biases, learning constant and so on, to approximate a better fitting function. Therefore, a new hybrid technique of GAs learning method [17] and fuzzy BP learning [19] based on derivation of min-max function is developed by the author.

1.2 Background of the Problem

Crisp ANNs refer to any kind of ANNs which can learn from crisp data. These kinds of soft-computing techniques have been used in many domains successfully. Many researches have been done to solve crisp ANNs shortcomings. These can be architectural or learning method defects. One of these deficiencies is that, crisp ANNs

are not able to deal with inexact (fuzzy) data efficiently. Due to the original nature of the environments that are full of inexact information, a need to develop and deal with fuzzy values is very important issue. ANNs can learn from fuzzy data but not efficiently. If one wants to use crisp ANNs to learn from fuzzy data, he or she needs to convert all inexact data to exact data. Then, crisp ANNs can learn from converted exact data. But in this conversion phase, some information will be lost. This defect has led to propose a new kind of ANNs named FANNs [4].

Fuzzy set theory has been brought into the subject of ANNs after the fuzzy associative memory (FAM) was developed. This was followed by a direct fuzzification learning method for ANNs, proposed by Buckley [5]. This method sufferes from mathematical concepts. Fuzzy learning method for symmetric and triangular weights was proposed by Ishibuchi [12]. Aliev [17] proposed learning method for fuzzy neural network with genetic algorithms. In this approach GA is applied to adjust fuzzy weights in different level sets. Qiang [18] improved Ishibuchi's learning method. Improved Ishibuchi's learning method was not restricted to triangular and symmetric fuzzy weights. Recently, Liu [19] proposed a new fuzzy learning method based on derivation of min-max function [22, 23]. Last mentioned learning method is almost the best method that have been proposed so far, due to its merits in learning of any kind of convex fuzzy membership functions (See Table 1.1).

Table 1.1: Leaning methods proposed for fuzzy neural network

Researcher	Approach
Kosko (1987)	Fuzzy associated memory.
Buckley et al. (1993)	Direct fuzzification of neural network
Ishibuchi et al. (1995)	Fuzzy neural network with symmetric and triangular weights
Dunyak et al.(1999)	Practical fuzzy neural network but high time complexity
Aliev et al. (2001)	Learning method of fuzzy neural network with genetic algorithms
Qiang et al. (2003)	Fuzzy neural network with L-R fuzzy weights
Liu et al. (2005)	Learning method of fuzzy neural networks base on derivation of min-max functions.

For simplicity, most learning methods are applied for feed forward FANNs. These learning methods use level sets concept to convert fuzzy weights to their analogous crisp sets, except direct fuzzification method. To have more tuned results, more level sets are needed be used. The proposed learning methods have great trades between their speed of convergence and accuracy of the results after training. Therefore, the study of learning methods for FANNs is still demandable area of research.

1.3 Statement of the Problem

Crisp ANNs are not able to deal with fuzzy data and vague information. Crisp ANNs are just able to find crisp functions which can fit crisp data. Generalized model of ANNs are FANNs which are able to learn from fuzzy data. Therefore, they have the ability to find fuzzy functions which are interpolated from given fuzzy data set. Using fuzzy concept instead of binary logic leads to high time complexity, which is not desirable. Furthermore, FANNs leaning algorithms are not as easy as crisp ANNs to get accurate result after training.

There are many learning methods that have been proposed for FANNs, but most of the proposed techniques have some drawbacks. According to the shortcomings, two categories of learning methods can be defined:

1. Learning methods that can learn from fuzzy data very well, but the speed of learning convergence is extremely low. Fuzzy BP learning method based on derivation of min-max function is an example of this category [20].

2. Learning methods that can learn data with high speed of convergence, but the accuracy of learning are not as good as the first category [12].

It can be said that there is a strong trade off between speed and accuracy of learning. It is clear that in most of applications, learning accuracy is the most important part of any proposed learning method. In addition, if these tools are going to be applied in on-line environment, the learning speed will become another main issue. Therefore, new learning methods are still demandable.

Thus, the hypothesis of this study can be stated as below:

Development of new learning method for feed forward FANNs which has high accuracy of output after training.

1.4 Research Objective

The objectives of the study are defined as follow:

1. To investigate the theoretical mechanism of fuzzy set theory in ANNs as a unique encapsulated unit which is called FANN.
2. To explore theoretical relations of fuzzy BP learning which is based on derivation of min-max function and GA based learning that can work better for FANNs.
3. To develop a new learning method called *genetically tuned fuzzy BP learning based on derivation of min-max function*.
4. To evaluate and simulate the proposed learning method.
5. To compare speed of convergence and accuracy of the proposed technique with fuzzy BP learning method based on derivation of min-max function.

1.5 Scope

- The proposed technique is developed using Microsoft Visual C++ and implemented with Matlab Environment
- The same data which have been used by other researchers will be adopted in this study to validate the proposed learning method.
- The proposed learning method is compared with fuzzy BP learning method based on derivation of min-max function, in terms of learning accuracy after training process.

1.6 Importance of the study

FANNs are widely used in many areas such as system modeling [24], pattern classification [15, 25], system identification [14, 26], process control [27], signal processing [28], communication [28], image processing [29], market predication [30], agriculture [31], fuzzy optimization [32, 33] and so on. Therefore, proposing new learning methods for FANN which can do training task very fast and accurate is requested.

The desired aim is that to develop learning method for FANNs which can be used in on-line applications with high accuracy after training.

1.7 Chapter Summary

The deficiencies of crisp ANNs have been pointed for their. Therefore, FANNs as a tool which can resolve some of those problems is introduced. It has been described that FANNs are able to deal with fuzzy data.

The hybrid of GAs and fuzzy BP method as new learning method for FANNs is proposed by author. The targeted objectives with the scopes for implementation of the proposed algorithm are stated.

Finally, it has been discussed that efficient learning method can be more useful for lots of application areas if faster convergence speed and more accurate result are gained.