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A Parameterized Comparison of Fuzzy Logic, Neural Network and Neuro-Fuzzy System: A Literature

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Abstract- A neuro-fuzzy system is the combined the advance feature of fuzzy logic and neural network, it is simply a fuzzy inference system that is trained by the learning concept of neural network. In NFS learning mechanism fine-tunes the underlying fuzzy inference system. This paper presents fundamental concepts and parameterized comparison in the aspects of fuzzy logic, neural network and neuro-fuzzy systems. The motivation of this paper to represent a precise and clear view in all possible parameter that can affect the outcome of any problem that uses these techniques either combine or stand alone.

Keywords: Neuro-fuzzy System, Fuzzy Logic, Fuzzy Inference System, Neural Network.

I. Introduction

Now a day's technology plays a strong role in day-to-day life of human being to ease their life due to artificial intelligence. An Artificial Intelligence has the many different approaches that imbibe the humane intelligence into machines. A lot of research work has been carried out from the past year done till date that revealed the limitation to solve a problem [1] by stand alone even its application areas also whether it is solved by neural network or fuzzy logic. The methods currently used to solve a complex problems are somewhere incapable to deal with the prediction based future events due to vagueness and mass of the data. Due to unavailability of proper information everything cannot be either solved or represented. [2]

This paper represent the architecture and basic learning of neuro-fuzzy inference system with the comparison of soft computing approaches such as artificial neural network and fuzzy logic. Since they belong to the same family but core domain expertise and the problem solving approaches are different in terms of accuracy, human thinking

and decision making capabilities. The sole purpose of this paper is to represent the analytical comparison in between these techniques, whether to perceive input and give the desired output by processing the data.

The advancement of technology has given a way to use successful modified method, and their acceptance in almost all areas. An emerging class of intelligent machines over traditional methods consists of fuzzy logic and neural networks. Fuzzy logic which provides a mathematical foundation [3] with their membership function to deal with situations full of uncertainties by imbibing human perception to understand linguistic variables while neural networks try to mimic human brain in a way to perform tasks like a human being whether in the data process, learning, thinking and adaptation.

The neuro-fuzzy systems (NFS) is the combination of neural network and fuzzy logic, it uses the advantages of both and leaving behind their limitations. The neuro-fuzzy system is a hybrid model that uses neural network learning algorithms with fuzzy reasoning of fuzzy logic. Each the components of NFS play their own role; neural network determine the values of parameters while if-then rules are handled by fuzzy logic.

Fuzzy logic and [2] neural networks complement each other such as neural networks provide low-level computational structures and can deal with raw data while, fuzzy logic sits on a higher level and uses linguistic information to develop an intelligent system. If consider different point of view, neural network is based on learning so it can learn and adjust according but the fuzzy system lacks the ability to learn. The problem with neural network is it has lots of hidden layers. So by combining these two resultant neuro-fuzzy systems perform parallel computing and adopt learning ability from neural network and fuzzy systems provide the transparent representation with explanation of human-like knowledge.

II. Fuzzy Logic

The concept of Fuzzy set theory,[5] was initially introduced by Lofti Zahed in 1965 which deals with the data that is imprecise and leads to create problem in decision-making of real world applications.

Fuzzy Logic [3] is the logic which deals with the vagueness and it belongs to the family of many-valued logic. Basically it focuses on fixed and approximate reasoning rather than to fixed and exact reasoning. It takes variable value in between 0 and 1 or in between true and false unlike from traditional crisp set which takes either true or false or 0 and 1in. Fuzzy logic provides a way to make definite decisions from on imprecise and ambiguous input data. Fuzzy logic is almost used in every field now days, because it can make faster decision that are closely resembles how a human make decision.

The concept of Fuzzy inference [7] system is to map a given input to an output dataset by using the theory of fuzzy sets. Fuzzy set uses linguistic rules to encode Knowledge which is easily understood by people without any technical knowledge. A fuzzy logic uses If-Then rules to map its input-output. As shown in figure 1, there are three main components of fuzzy logic system:

1. Fuzzification

- a. The Fuzzification process takes crisp value as a input and converted it into fuzzy value
- b. It maps input through membership function

2. Fuzzy inference system(FIS)

- a. FIS is based on rule based reasoning
- b. Membership values are mapped to output through if-then rules
- c. The logical representation of if -then rule is $p \rightarrow q$ where, 'if' part(p) is known as antecedent and 'then' part is known as consequent part

3. Defuzzification

- a. Defuzzification process produces crisp output values by using a fuzzy output membership outputs.

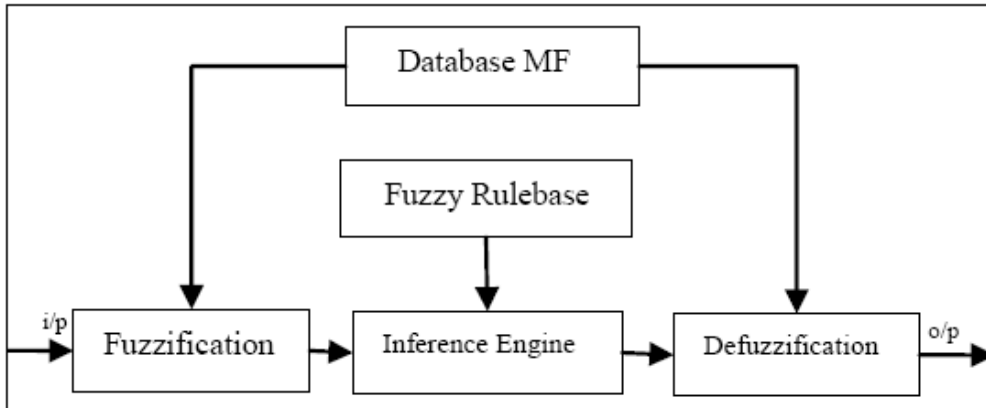


Fig 1: A Framework of Fuzzy Logic System [6]

III. Artificial Neural Network

The motivation behind the artificial neural network (ANN) is try to mimic human brain in which a particular task is performed by humans. The concept [6] of artificial neural networks was introduced in 1943 by Warren McCulloch and Walter Pitts. As neural networks try to do a task in similar manner in a way the human brain does. The network is collection of interconnected neurons that process the given information to solve a problem. Neural network processing is based on learning, it uses training data set to train or learn the system to produce an output. No programming is required to process and for production of result. Traditionally neural network was used to refer as network of biological neurons and now a day's because of mathematical modeling the term ANN is being used.

There are basically four main advantages of artificial neural network:

1. **Adaptive learning**
 - An ability to learn to perform a particular task from a given for training data set.
2. **Self-Organization**
 - An ANN can represent information which it receives during training or learning.
3. **Real Time Operation**
 - To perform a real time operation a parallel computation is being carried out through a special hardware
4. **Fault Tolerance**
 - Network is capable enough to retain or handle the damage.

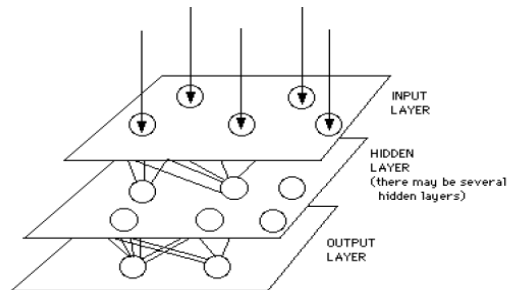


Fig 2: A Simple Neural Network Diagram [6]

As shown in figure 2, there are basic three layer of ANN: the first layer is Input layer which take input data; the second layer is hidden layer which takes output from the input layer and use that output as an input for hidden layer; the last layer is output layer which takes the processed information from second layer and produces output. There can be a multiple layers in hidden layer depending upon the network architecture.

Basically ANN is configured to solve a real world problem such as artificial intelligence without creating real world biological model. There are many application areas of ANN such as speech recognition, image analysis, adaptive control etc.

IV. Neuro-Fuzzy System

The Neuro-fuzzy system is hybridization [4] of artificial neural networks and fuzzy logic. The concept of Neuro-fuzzy system was proposed by J. S. R. Jang. This hybridization gives a hybrid intelligent system that combines the human-like reasoning style of fuzzy systems and the learning of neural networks. Neuro-fuzzy hybridization is known as neuro-Fuzzy System (NFS). In neuro-fuzzy system decision-making capability of fuzzy logic for any uncertainty is used in the decision made by the neural networks.

The benefits of using neuro-fuzzy systems is it involves these two contradictory topic i.e. interpretability versus accuracy of fuzzy modeling. There are following benefits of NFS:

- It tunes the fuzzy parameters with neural network training or learning parameters
- By using fuzzy logic network sizes can be increased
- It Realizes fuzzy membership function with clustering algorithms in unsupervised mode

In NFS, Fuzzy logic allows to make decisions on imprecise or vague or ambiguous data, whereas ANN tries to imbibe human thinking to solve any problems without mathematically modeling them. The detail study of NFS and its type can be found in [9].

V. Parameterize Comparison of Fuzzy logic, Artificial Neural Network and Neuro-Fuzzy System

Although NFS is a combination of neural network and fuzzy logic but there are lots of differences in between them. The comparison is made in between NFS, fuzzy logic and neural network with different parameter s shown in table 1, there are 10 parameters are being considered to make comparison on different point of view.

S.No.	Parameter	Fuzzy logic approach	ANN approach	NFS approach
1.	Variable	Uses linguistic variable	Weighted number	Both initially weighted number and then linguistic
2	Imbibing Human thinking	No, It can not imbibe human thinking	Yes, It can imbibe human thinking	Yes, Since it is the combination of neural network and fuzzy logic so, yes it can imbibe
3	Decision making ability	Yes, It use used to take accurate decision in case of ambiguity	No, It cannot take decision but it can act like human make decision in particular situation	Yes, decision making ability of fuzzy logic included in it
4	Accuracy of result	Yes, It gives accurate result	No, It can classify result	YES
5	uncertainty handling	Yes, it was designed to deal with uncertainty	No , it cannot handle uncertainty	Yes, it can handle

6	Knowledge extraction	Yes, It can extract knowledge	No, It cannot extract knowledge	Absolutely it can extract
7	Interoperability	Yes, through FIS	No, Cannot completely black box	Yes, it can through If-then rules
8	Learning ability	No, Cannot learn use linguistics knowledge	Yes, Can learn from scratch	Yes through Neural network
9	Usability of prior knowledge	Yes, Can be uses	No, Cant not use	Yes, It Can be incorporated
10.	Problem solving approach	Non linear	Non linear	Linear

Table 1: Parametric comparison of fuzzy logic ANN and NFS [1], [9]

VI. Conclusion

By providing the basic structure of neuro-fuzzy inference system with the comparison of soft computing approaches such as artificial neural network and fuzzy logic. Although, by combining fuzzy logic and neural network as a result NFS is generated. But core domain expertise and the problem solving approaches are different in terms of accuracy, human thinking and decision making capabilities, etc are different .As shown in table1, It is clearly visible that the NFS system is strong enough to deal with any kind of problem whether data in vague or in complete information is not given properly than single fuzzy logic or neural network system.

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