ISSN No. 0976-5697

Volume 8, No. 5, May – June 2017

International Journal of Advanced Research in Computer Science

REVIEW ARTICLE

Available Online at www.ijarcs.info

Fuzzy Neural Networks

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Abstract: This article briefly explains the relationship between fuzzy systems and neural networks, which has drawn much attention recently, since both are trainable systems capable of handling uncertainty and imprecision and both have found many successful applications. The combination of fuzzy logic and neural networks has resulted in an extremely powerful computational model known as fuzzy neural network. Representing a linguistic value as a fuzzy set has enabled the system to deal successfully with many expert problems. Neural heuristics further provide the fuzzy network with the capability of learning by self-adaptation and self-organization.

Keywords: Fuzzy Rule, Fuzzy Set, Fuzzy Inference System, Neural Network, Neuron

I. INTRODUCTION

Fuzzy logic and neural networks are complementary technologies. They work at different levels of abstraction and individually provide rich functionality, which when brought together in a cohesive fashion provide us with intelligent systems. A combination of these two technologies endows systems with a twofold advantage. Fuzzy logic provides a high-level framework for approximate reasoning that can appropriately handle both the uncertainty and imprecision in linguistic semantics, model expert heuristics and provide requisite high level organizing principles. Neural networks provide self-organizing substrates for low level representation of information with on-line adaptation capabilities. It therefore seems both plausible and justified to attempt combining both these approaches in the design of intelligent systems [1].

II. NEURAL NETWORKS

The study of the human brain is thousands of years old. With the advent of modern electronics, it was only natural to try to harness this thinking process. The first step toward artificial neural networks came in 1943 when Warren McCulloch, a neurophysiologist, and a young mathematician, Walter Pitts, wrote a paper on how neurons might work. They modeled a simple neural network with electrical circuits. Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A neural network can be thought of as an expert in the category of information it has been given to analyses [3].

Concept of Artificial Neural Network is basically introduced form the subject of biology where neural network plays a important and key role in human body. All the work in our body is done through neural networks which consist of billions of neurons connected to each other that work in parallel. Each neuron receives inputs from other neurons in the form of tiny electrical signals and likewise, it also outputs electrical signals that the neuron does not fire any output unless a certain threshold/bias is reached. These weights can be altered through learning experience. Similar to human brain artificial neural networks consist of artificial neurons called perceptrons that receive numerical value and then after the inputs are weighted and added, the result is then transformed by a transfer function into the output. The transfer function may be anything like Sigmoid, hyperbolic tangent functions [4].

2.1. Correlation between Biological and Artificial Neural Network

As the brain consists of neurons, the Artificial Neural Network consists of Perceptrons that is very similar to the structure of a neuron. The comparison has been provided in following figure [5]. The features of the biological neural network are attributed to its structure and function. The fundamental unit of the network is called a neuron of a neuron or nerve cell. The structure of neuron consists of a cell body or soma where the cell nucleus is located. Tree like nerve fibers called dendrites are associated with the cell body. These dendrites receive signals from other neurons. Extending from the cell body is a single long fibre called the axon, which eventually branches into strands and sub strands connecting too many other neurons at the synaptic junctions or synapses. The receiving ends of these junctions on other cells can be found both in the dendrites and in the cell bodies themselves. The axon of a typical neuron leads to a few thousand synapses associated with other neurons [6].

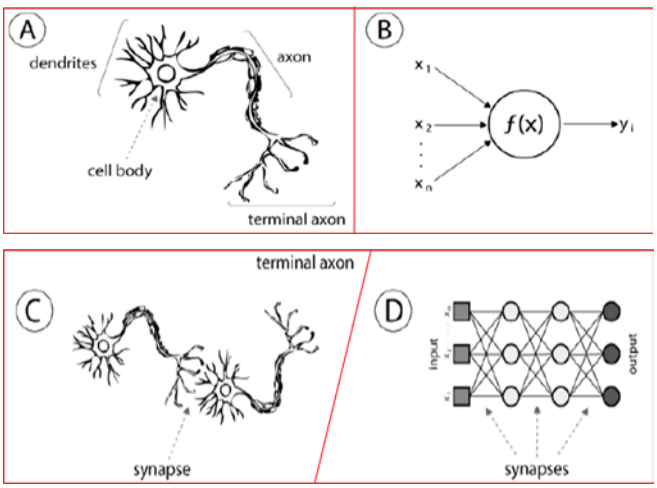

Fig.1. Correlation between Biological and Artificial Neural Network

The neural network contains three types of layers input, hidden and output. The layer of input neurons receives the data either from input files or directly from electronic sensors in real-time applications. The output layer sends information directly to the outside world, to a secondary computer process, or to other devices such as mechanical control system. Between these two layers can be many hidden layers. These internal layers contain many of the neurons in various interconnected structures. The inputs and outputs of each of these hidden neurons simply go to other neurons.

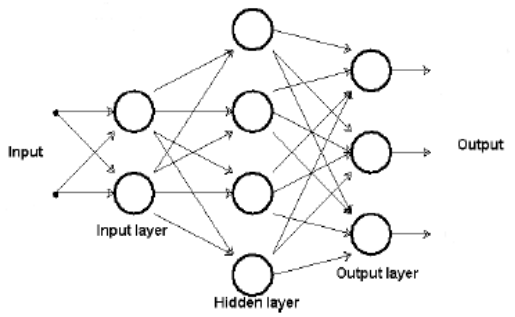

Fig.2. Neural Network Architecture

Hidden layer receives the signals from all of the neuron in a layer above it, typically an input layer. After a neuron performs its function it passes its output to all of the neurons in the layer below it. Once a network has been structured for a particular application, that network is ready to be trained. There are two approaches to training supervise and unsupervised. The vast bulk of networks utilize supervised training. Unsupervised training is where the network has to make sense of the input without outside help [3].

III. FUZZY LOGIC AND NEURAL NETWORKS

Based on Zadeh's fuzzy set theory, fuzzy logic views each predicates as a fuzzy set. Pao and Kosko have suggested their complementary roles. Bezdek has collected recent work on this subject. In this section, we focus on a major development along this line, namely, how to integrate the basic elements of fuzzy set theory into neural networks to yield computational structures known as fuzzy neural networks [2].

3.1. Fuzzy Neural Networks (or) Neuro Fuzzy System

Neural network and Fuzzy logic are many times applied together for solving engineering problems. They neuro-fuzzy term was bron by the fusing of these two techniques. Each researcher combines these two tools in different ways. Such systems show two distinct ways of behavior. In a first phase, called learning phase, it behaves like neural networks that learns its internal parameters off-line. Later, in the execution phase, it behaves like a fuzzy logic system [7]. Nidhi and Jatinder presented a definition for neuro-fuzzy "Fuzzy logic provides a mathematical foundation for dealing with situations full of uncertainties by simulating human perception for understanding linguistic attributes while neural network mimics human beings in the process of learning, thinking and adaptation. This combination of these two techniques called neuro-fuzzy system. Fuzzy logic and neural networks complement each other in developing intelligent systems. Neural networks were form low-level computational structures and deal with raw data while, fuzzy logic sits on a higher level and uses linguistic informations [8].

As it is still an ongoing research topic, the fuzzy neural network may have different implementations. Despite this fact, a general approach can be identified. Assume that fuzzy knowledge is represented as set of fuzzy rules. Fuzzy neural networks are well known for their ability to handle the fuzzy (inexact) nature of inference involving symbols (symbolic inference). In fuzzy logic, a linguistic variable like "size" can have several linguistic values like 'small, medium or large'. Each linguistic value is viewed as a fuzzy set associated with a membership function, which can be triangular, bell-shaped or of another form. The degree of membership can be interpreted as the degree of possibility, which evades the requirement of satisfying the probability axioms [2].

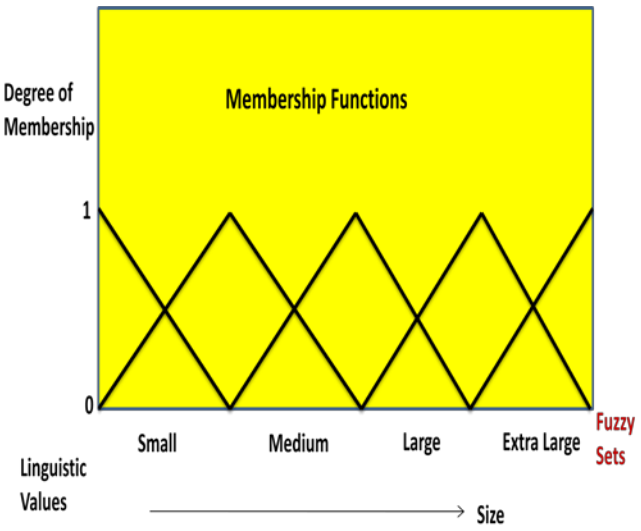

Fig.3. Membership function associated with the linguistic variable "size".

3.2. Fuzzy Rules

For fuzzy rules, additional layers are used to store fuzzy set units. It would be reasonable to use connections of five layers to implement one-level fuzzy rules, as illustrated in following figure.2. Lin and Lee also suggest a similar approach. We call these five layers as: Input layer, Input fuzzy layer, Conjunction layer, Output fuzzy layer, output layer. The activation level of an input unit is the value of a certain input variable in the given instance. Now, the output fuzzy set unit will collect information from one or more conjunction units. There exist variations at his point. An output fuzzy set unit may take the maximum or sum of its inputs or may employ the CF-based combination function. The last alternative ensures the combined value in the range from 0 to 1. Then, the output unit generates the result by integrating the information from the output fuzzy se units. How the output unit calculates its activation level depends on the defuzzification scheme adopted [2].

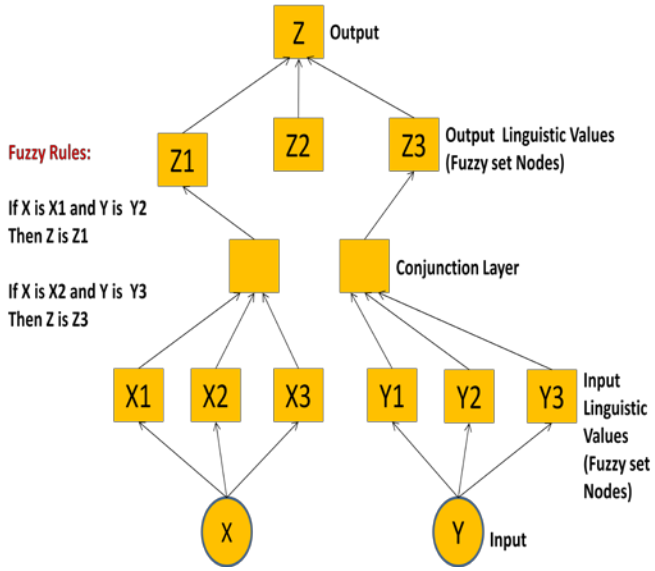

Fig.4. A fuzzy neural network based on fuzzy rules.

3.3. Structure of fuzzy rule

In [7], Jose, Fernando and Alexandre proposed that the fuzzy system propose a mathematic calculus to translate the subjective human knowledge of the real processes. This is a way to manipulate practical knowledge with some level of uncertainty. The fuzzy sets theory was initiated by Lofti Zadeh in 1965. The behaviour of such systems is described through a set of fuzzy rules, like:

IF <premise> THEN <consequent>

A fuzzy rule is the basic unit for capturing knowledge in many fuzzy systems. A fuzzy rule has two components: an if-part (also referred to as the premise or antecedent) and a then-part (also referred to as the consequent). The antecedent describes a conclusion that can be drawn when the condition holds. Among all the techniques developed using fuzzy sets, fuzzy if-then rules are by far the most visible due to their wide range of successful applications. Fuzzy if-then rules have been applied to many disciplines such as control systems, decision making, and pattern recognitions [12].

There are two types of fuzzy rules: fuzzy mapping rules, fuzzy implication rules. A fuzzy mapping rule describes a functional mapping relationship between inputs and an output using linguistic terms, while a fuzzy implication rule describes a generalized logic implication relationship between two logic formulas involving linguistic variables and imprecise linguistic terms [12].

In [10] Ajith proposed that with crisp inputs and outputs, fuzzy inference system implements a nonlinear mapping from its input space to output space by a number of if-then rules. The basic fuzzy inference system consists of three conceptual components: a rule base, which characterized the rule in the form of if-then rules in which preconditions and consequents involve linguistic variables. The collection of these fuzzy rules forms the rule based for the fuzzy logic system. Aggregation is the combining of fuzzy relations, representing fuzzy rules, into a single fuzzy relation.

In [11] Ciaramella and their team designed a fuzzy neural network based in a fuzzy relational if-then reasoning scheme. And also showed how the fuzzy relational neural network (FRNN) was designed with the consisting of fuzzy rules throughout their article. The difficulty in extracting if-then rules in NEFCLASS approach is discussed. FRNN model was compared with ANFIS and NEFPROX system to extract rules in a simple way.

3.4. Classification of Neuro-Fuzzy Systems

Each authors approaches on the combination of neural network and fuzzy logic techniques and the structure representation of these can be differ. Jose Vieira and his colleagues in his paper they given three main types of fuzzy techniques namely; Cooperative Neuro-Fuzzy system, Concurrent Neuro-Fuzzy system and Hybrid Neuro-Fuzzy system. Cooperative neuro-fuzzy system used in initial phase where as Concurrent model work together with fuzzy system [7].

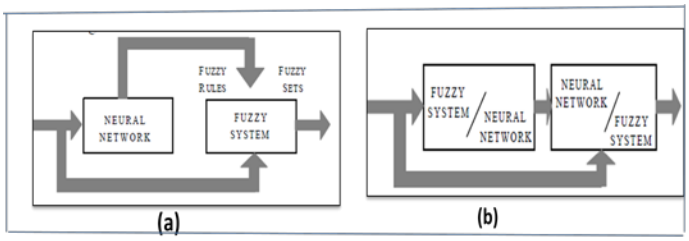

Fig.5.(a)Cooperative Neuro-Fuzzy system, (b)Concurrent Neuro-Fuzzy system (Source [7])

In Hybrid Neuro-fuzzy system nearly nine types of hybrid neuro-fuzzy were given by the authors Jose and their colleagues namely: Fuzzy Adaptive Learning Control Network (FALCON), Adaptive Network based Fuzzy Inference System (ANFIS), Generalized Approximate Reasoning based Intelligence Control (GARIC), Neural Fuzzy Controller (NEFCON), Fuzzy Inference and Neural Network in Fuzzy Inference Software (FINEST), Fuzzy Net (FUN), Self Constructing Neural Fuzzy Inference Network (SONFIN), Fuzzy Neural Network (NFN), Dynamic/Evolving Fuzzy Neural Network (EFuNN and dmEFuNN) [7].

Author Ajith Abraham in his paper “It’s time to Fuzzify Neural Networks!” he has given three types of Neuro-fuzzy techniques, but the only different is instead of Hybrid he has named Fused Neuro-fuzzy system. In the order of cooperative and concurrent neuro-fuzzy system it’s consider as preprocessor and postprocessor.

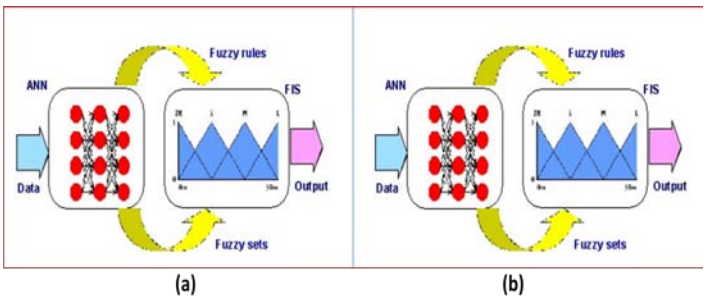

Fig.6.(a)Cooperative Neuro-Fuzzy system, (b)Concurrent Neuro-Fuzzy system (Source [10])

The implementations of neuro-fuzzy system on Mamdani and Takagi, Sugeno were illustrated. The difference between neural network and Fuzzy inference system are also discussed [10].

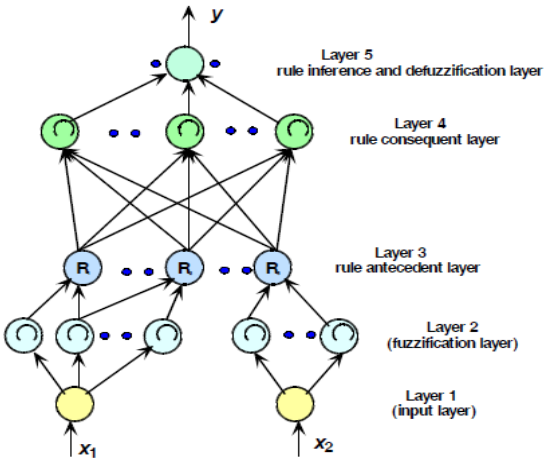

Fig.7. Mamdani Neuro-Fuzzy system (Source [10])

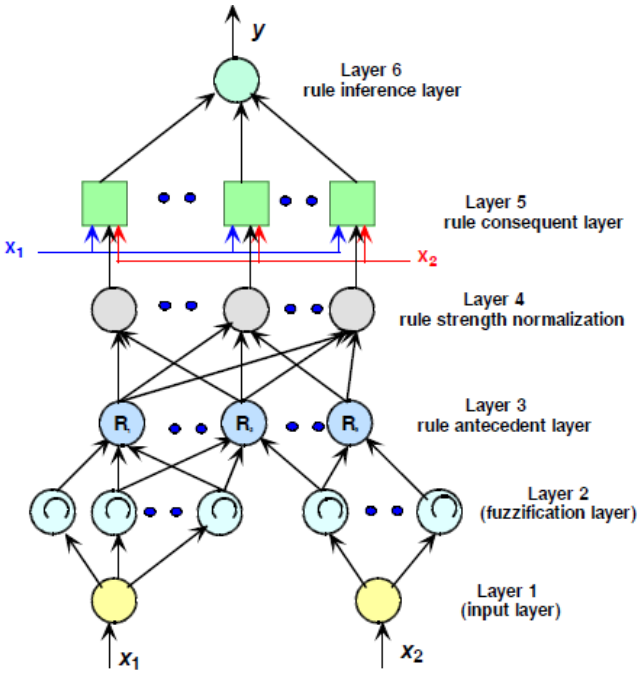

Fig.8.Takagi Sugeno Neuro-Fuzzy system (Source [10])

In Fused Neuro-fuzzy system nearly eight types of neuro-fuzzy systems were given by the author Ajith, namely: GARIC, FALCON, ANFIS, NEFCON, FUN, SONFIN, FINEST, EFuNN, dmEFuNN [10].

3.5. Fuzzy Inference System (FIS)

Mohamed .A.H. as approached the fuzzy inference system (FIS) in a different way as; in fuzzy systems the evaluation of the output is performed by a computing framework called the fuzzy inference system. A fuzzy inference system is a function/model that takes a fuzzy set as an input and performs a composition to arrive at the output based on the concepts of fuzzy set theory, fuzzy if-then rules and fuzzy reasoning. Fuzzy inference involves the fuzzification of the input variables, evaluation of rules, aggregation of the rule outputs and finally the defuzzification of the result. There are two popular types of fuzzy models: the Mamdani model and the Takagi-sugeno model. The Takagi sugeno model is popular when it comes to data driven identification [9].

In recent development on neuro fuzzy system, Ajith Abraham (2001) presented a comparative structure between Mamdani and Takagi in following figures [10].

In Mamdani Fuzzy Inference System, the rule antecedents and consequence is defined by fuzzy sets and has the following structure:

$$if\ x\ is\ A1\ and\ y\ is\ B1\ then\ f\ =\ c$$

Where, A_1 and B_1 are input fuzzy sets and C the output fuzzy set respectively.

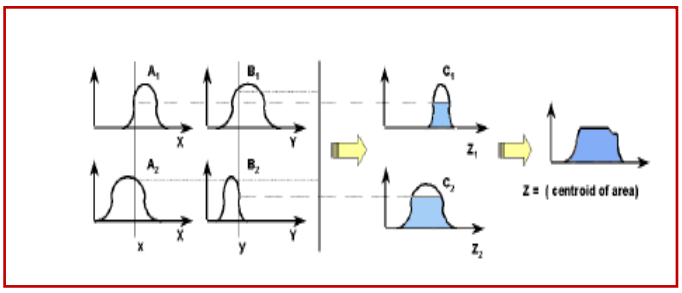

Fig.9. Mamdani Fuzzy inference system

Takagi, Sugeno and Kang (TSK) proposed an inference scheme in which the conclusion of a fuzzy rule is constituted by a weighted linear combination of the crisp inputs rather than a fuzzy set. A1 and B1 are input fuzzy sets and p1, q1 and r are linear parameters re[presenting the output in perms of input variables.

$$if\ x\ is\ A1\ and\ y\ is\ B1\ then\ f\ =\ p1x + q1y + r$$

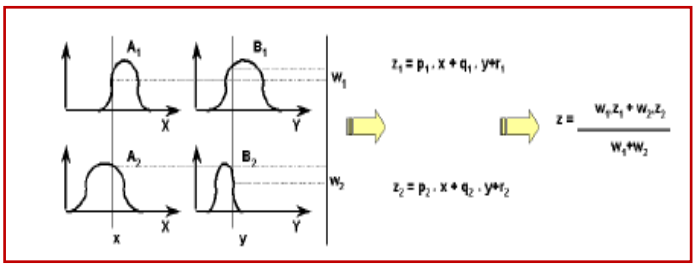

Fig.10. Takagi, Sugeno and Kang (TSK) Fuzzy inference system

A comparison between Artificial neural network (ANN) and Fuzzy inference systems (FIS) were given by Ajith Abraham was given below

Neural Networks	Fuzzy Inference System
Prior rule-based knowledge cannot be used	Prior rule-based can be incorporated
Learning from scratch	Cannot learn (use linguistic knowledge)
Black box	Interpretable (*if-then* rules)
Complicated learning algorithms	Simple interpretation and implementation
Difficult to extract knowledge	Knowledge must be available

Table.1 Comparison table between ANN and FIS

IV. RELATED WORKS

A. Ciaramella et al. (2006) in the paper, “Fuzzy relational neural network” proposed the main features of neuro-fuzzy system and a hybrid-learning algorithm based on a Backpropagation approach and a pseudo inverse matrix technique. The fuzzy relation IF_THEN reasoning scheme is builded, based on fuzzy neural network design. T-norms and t-

conorms have used to define the structure of the system. The main feature of the fuzzy relational neural network (FRNN) based on IF-THEN model is to show and prove, that the results have reached in better approximation/prediction and classification tasks. The results have compared with NEFCLASS multilayer Perceptron and radial basis functions. The FRNN model has compared with ANFIS model and NEFPROX system and Mackey-class chaotic time series [11].

Jose Vieira et al. (2004) in their paper "Neural Fuzzy-Systems: A Survey" mainly describing the general vision of area which are all explaining the most known hybrid neuro fuzzy techniques with its advantages and disadvantages. Authors of this article has gave a definition for neuro fuzzy systems, where, the type if system characterized for a similar structure of a fuzzy controller. Fuzzy sets and rules are adjusted using neural network tuning techniques in an iterative way with data vectors. The fist life of fuzzy neuro system and its types are defined with appropriate diagram. Types of neuro fuzzy systems have described briefly to examine the characteristics efficient and architecture of neuro fuzzy system [7].

Mohamed.A.H. (2014) in his paper "A Fuzzy Neural Network Fault Diagnostic System" as reviewed neural network and fuzzy logic control as a complex device and it is widely used for the diagnostic devices. The concept of proposed system introducing a new diagnostic system and its used to diagnose the production line of the radiated surgery tool with two main function acquiring fault information real time online and determine the causes of faults automatically. The drawback of this system overcomes by integrating the fuzzy logic and neural network. Handling imprecise information by fuzzy logic elaborately has described by fuzzy inference system, because imprecise and vague information has not handled by neural network. The proposed system has applied into two steps and two-function: extraction of fault symptoms and feeding the normalization data to sub neural network. The fault produced by the proposed system (nearly 42 kinds of fault) was summarized (sensor fault, actuator faults, control unit faults and so on) and compared with two traditional fuzzy neural network diagnostic systems [9].

Nidhi Arora and Jatinder Kumar (2014) in their paper "A Literature review on recent advances in Neuro fuzzy applications" has gave an elaborate description of fuzzy logic and neural network. The complements between fuzzy and neural networks has described in different point of view. They presented a list of recent neuro-fuzzy applications and their contributors. According to them new finding on the combination of neuro fuzzy are mentioned. This paper attempted to review current advancements in business using neuro fuzzy hybridized approach. A comprehensive review of applications, combining neural network and fuzzy logic in business has presented and reviewed some articles published from 2011 to 2014 [8].

Ajith Abraham (2001) in his paper "It is time to Fuzzify neural networks" he attempts to describe the fundamental concept of artificial neural network, fuzzy inference system and neuro fuzzy systems. The functioning of Mamdani and Takagi-Sugeno fuzzy inference system has detailed briefly based on layered structured. Box Jenkins gas furnace time series benchmark has used to evaluate the performance of fuzzy neuro system [10].

V.CONCLUSION

In this paper, different definition of neuro fuzzy systems has been discussed where different approach in fuzzy inference system and various previous related works were under discussed. A comparison on biological and artificial neuron and its network were given in short. Implementing neuro fuzzy system on Takagi and Sugeno, Mamdani to get accurate results were discussed. So, this paper concludes that the combination of neural network and fuzzy logic together will produce number of successful applications and has bright future.

VI. ACKNOWLEDGEMENT

I would like to thank my parents and my brother for their support for completing this journal. Last, and most obvious but not least, I thank the IJARCS for their valuable guidance to scrutinize mistakes in my article.

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