Comparison of Fuzzy Logic and NEURO Fuzzy Algorithms for Load Sensor

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Abstract — Load sensor is developed using fuzzy logic as well as neuro-fuzzy method. It is two inputs and one output sensor. Both fuzzy logic and neuro-fuzzy algorithms are simulated using MATLAB fuzzy logic toolbox. This paper outlines the basic difference between the results of fuzzy logic and neuro-fuzzy algorithms and provides the better algorithm for load sensor.

Index Terms —fuzzy logic, load sensor, neuro-fuzzy, optical fiber, rule base.

I. INTRODUCTION

A Load sensor is a sensor that converts a load or force acting on it into an electronic signal. This electronic signal can be a voltage change, current change or frequency change depending on the type of load cell and circuitry used [1]. Load sensors can be simulated by neuro fuzzy model .Load sensors are being used in different type of structures for e.g. bridges, wind mills, roofs of sport centers, blades of helicopters, airplane wings etc through the use of embedded or surface bonded sensors [2].

In the case of wind mill blades, optical fiber sensors based on fiber brag grating is embedded in composite material(GFRP & CFRP) used in wind mill blade to monitor the load on wind mill blade[2]. Data acquired using load sensors are typically not directly usable as they suffer from three problems: a) noise because of inaccuracy in hardware sensing and transmission and unfavorable environmental The conditions and limited battery power further exacerbates this problem; b) missing values usually occur due to packet loss and node failure; c) Incompleteness, since sample sensors have continuous physical phenomena at discrete time intervals. All these problems seriously impact the quality of data obtained from such sensors. The aim of the industry, indeed, is to manufacture tiny, cheap sensors that can be deployed everywhere and disposed when depleted. Consequently, noise, imprecision and inaccuracies are inevitable in these cheap sensors. It is extremely important that data from these sensors be reliable since actions are usually taken based on their readings [1].

Nowadays, optical fiber sensors have been commercialized. Optical fiber sensors have certain advantages such as immunity to electromagnetic interference, lightweight, small size, high sensitivity, large bandwidth, and easy in implementing multiplexed or distributed sensors. Strain, temperature and pressure are the most widely studied measured and the fiber grating sensor represents the most widely studied technology for optical fiber sensors. Fiber-optic gyroscopes and fiber-optic current sensors are good examples of rather mature and commercialized optical fiber sensor technologies. Today, some success has been found in the commercialization of optic technology [3].

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Fuzzy logic was first proposed by Lotfi A, Zadeh of the University of California at Barkley in 1965 paper and the idea was elaborated in 1973 paper that introduced the concept of Fuzzy set [4].Fuzzy logic techniques represent a means of both collecting human knowledge and expertise and dealing with uncertainties in the process of control [5].

A simple fuzzy system consists of four blocks:

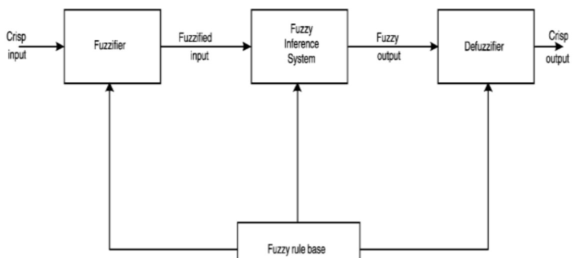

Figure 1: A simple fuzzy system [6]

A Fuzzifier, defuzzifier, inference engine and fuzzy rule knowledge base. The fuzzy set theory describes vague or incomplete concepts that are difficult to formulate mathematically. The centre point of fuzzy system is rule based that contains IF-THEN-ELSE rules. The Fuzzifier maps the crisp input to fuzzy sets, defined by their membership functions, whereas the defuzzifier maps the output fuzzy sets to crisp the output values [6]. One of the major problems of the fuzzy logic control is the difficulty of choice and membership functions for a given problem [7].

A combination of neural networks and fuzzy logic offers the possibility of solving tuning problems and design difficulties of fuzzy logic [7]. Neuro-fuzzy system combines the learning capabilities of the neural networks and the control capabilities of a fuzzy logic system [8]. It is a system that uses a learning algorithm to determine its parameters by processing data samples. Fig. 2 shows architecture of neuro-fuzzy system. First layer of neurons represent the input variables, second layer represents the input membership functions, third layer represents the rule base, fourth layer represents the output membership functions and fifth layer represents the output variables [7].

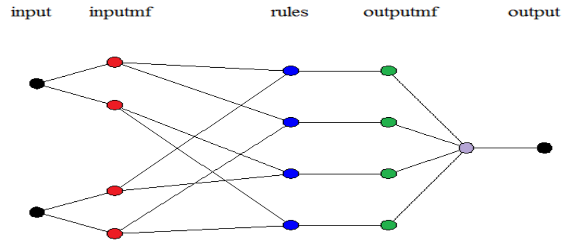

Fig. 2 architecture of neuro fuzzy system [7]

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The affectivity of the fuzzy models representing the non linear input-output relationships depends on the fuzzy partition of the input output spaces. Therefore, the tuning of the membership functions becomes an important issue in fuzzy modeling. Since this tuning task can be viewed as an optimization problem, neural networks offer a possibility to solve this problem. A neuro-fuzzy system is a fuzzy system that uses a learning algorithm derived from or inspired by neural network theory to determine its parameters by processing data samples.

The rest of the paper is organized as follows: Section 2 gives the fuzzy logic algorithm and Section 3 represents neuro-fuzzy algorithm for load sensor. Section 4 provides the results. Section 5 is Conclusion.

II. FUZZY LOGIC ALGORITHM

Fuzzy logic algorithm for load sensor consists of two inputs namely load and displacement. Output named as voltage is generated. The load and displacement are taken to be in ranges from 1162 to 1960 gm and 95 to 107 mm respectively. Each of these inputs has four triangular membership functions as shown in Fig. 3 and 4. The output have four membership functions namely "low", "medium", "high", "maximum" with a constant value(0-1). Membership functions of voltage are shown in Table I and Rule base for the design is shown in Table II.

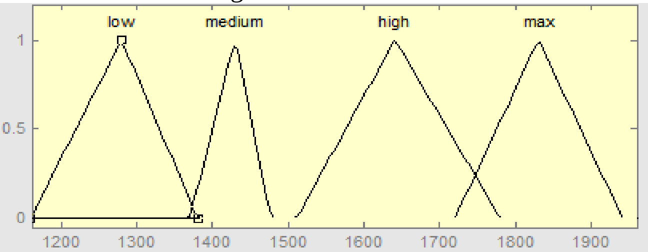

Fig. 3 Load membership functions

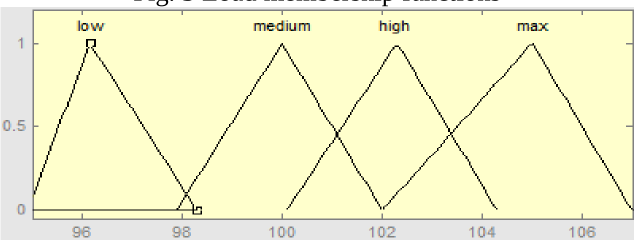

Fig. 4 Displacement membership functions

Table I. Membership functions of Voltage

voltage	Constant value
Low	0
Medium	0.33
High	0.66
Max	1

TABLE II
FUZZY RULE BASE FOR THE LOAD SENSOR

Rules	Load	Displacement	Voltage
1	Low	Maximum	Maximum
2	Medium	High	Maximum
3	Low	High	Maximum
4	High	Low	Low
5	Medium	Maximum	Low
6	Maximum	Low	Low
7	High	Low	Medium
8	Medium	Medium	High

III. NEURO-FUZZY ALGORITHM

The design proposed for load sensor using fuzzy logic then can be trained using the learning algorithms of neural networks to make it adaptive. Fuzzy logic for load sensor system is trained using ANFIS Toolbox of MATLAB for a data set which was gathered from technical expertise. On training the given fuzzy inference system, the input load takes the name "Input1" and is changed to the range from 1200 to 1800 gm with membership functions as shown in Fig.5. Similarly, input displacement takes the name "Input2" and has membership functions in the range of 0 to 100mm as shown in Fig.6. The rule base for the system also changes accordingly as shown in Table III .The Fuzzy system structure in form of neural networks formed by ANFIS is shown in Fig.7.

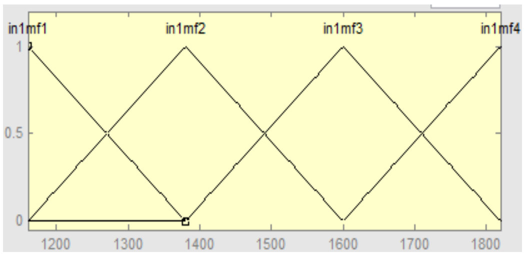

Fig.5 Input1 membership functions

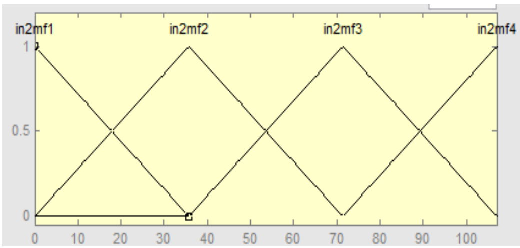

Fig. 6 Input2 membership functions

TABLE III
NEURO-FUZZY RULE BASE FOR THE DESIGN

Rules	Input1	Input2	Output
1	In1mf1	In2mf1	Out1mf1
2	In1mf1	In2mf2	Out1mf2
3	In1mf1	In2mf3	Out 1mf3
4	In1mf1	In2mf4	Out 1mf4
5	In1mf2	In2mf1	Out 1mf5
6	In1mf2	In2mf2	Out 1mf6
7	In1mf2	In2mf3	Out 1mf7
8	In1mf2	In2mf4	Out 1mf8
9	In1mf3	In2mf1	Out 1mf9
10	In1mf3	In2mf2	Out 1mf10
11	In1mf3	In2mf3	Out 1mf11
12	In1mf3	In2mf4	Out 1mf12
13	In1mf4	In2mf1	Out 1mf13
14	In1mf4	In2mf2	Out 1mf14

15	In1mf4	In2mf3	Out 1mf15
16	In1mf4	In2mf4	Out 1mf16

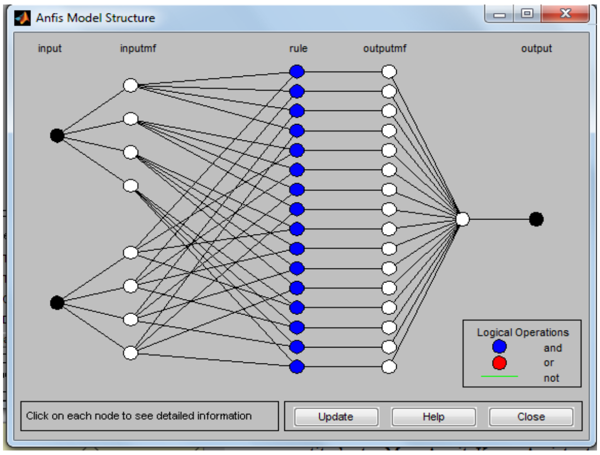

Fig. 7 ANFIS Structure

IV. EXPERIMENTAL RESULTS

Following are the curves obtained after simulation of fuzzy based load sensor using MATLAB (as shown in Figs. 8, 9, 10).

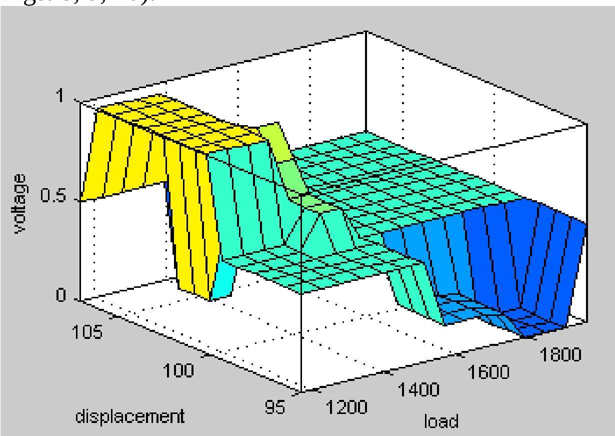

Fig. 8 Surface view using fuzzy logic algorithm

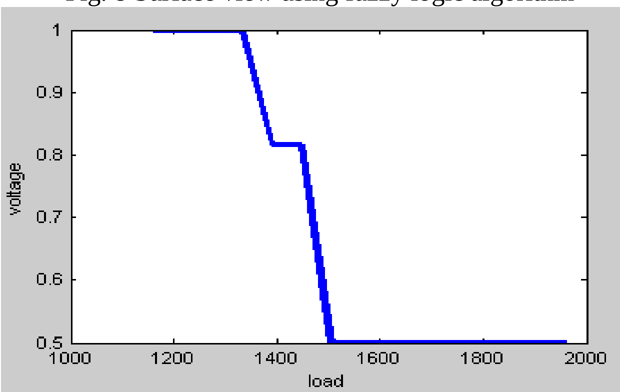

Fig. 9 voltage with load

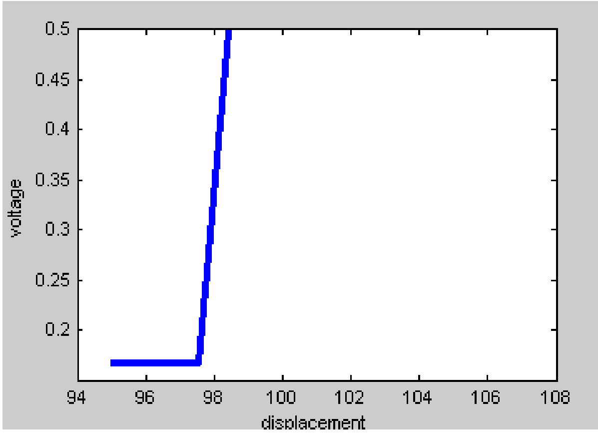

Fig. 10 voltage with displacement

Figs. 11, 12, 13 shows the result obtained using neuro fuzzy algorithm of load sensor system:

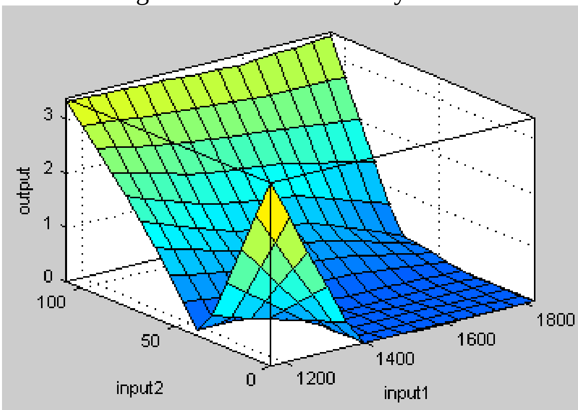

Fig. 11 Surface view using neuro fuzzy algorithm

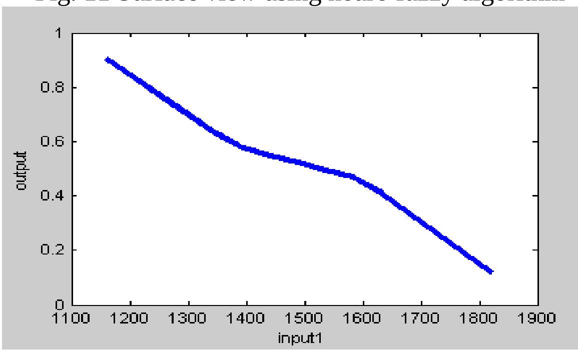

Fig. 12 Voltage with Load

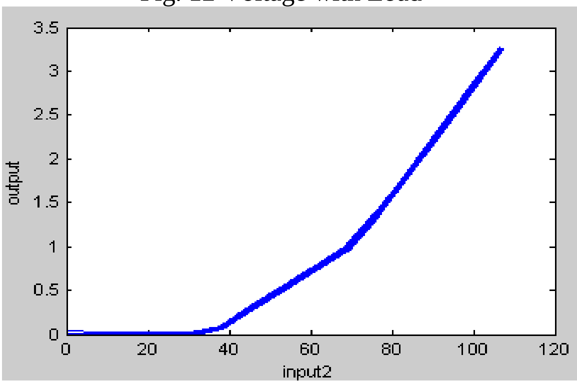

Fig. 13 Voltage with Displacement

The surface viewers indicates that how an output is being changed with the change in input for the load sensor. It has been shown that output voltage is decreasing as load on the sensor is increased and as displacement is increased; voltage is also increased in both fuzzy logic and neuro-fuzzy system. But the results obtained in the neuro-fuzzy algorithm provide better results than fuzzy logic algorithm for load sensor. As shown in the fig .9, voltage in fuzzy logic algorithm becomes constant after 1500 of load whereas in fig.12, voltage in neuro-fuzzy algorithm is continuously decreasing with the increase in load hence it is a linear in nature. Also, in fig.10, the graph of displacement is better in ANFIS as compared to fuzzy logic system. Therefore, ANFIS is much better than fuzzy logic system.

V. CONCLUSION

As evident from the results, neuro-fuzzy model is a better choice than fuzzy logic model for load sensor. It can be concluded from the simulations that neuro-fuzzy model provides better loading capability than fuzzy logic model it inherits adaptability and learning. Neuro-fuzzy algorithm is superior to fuzzy logic algorithm for load sensor. The performance of neuro fuzzy model can still be improved by training the neural networks with more number of input and output combinations.

VI. ACKNOWLEDGMENT

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