Comparison of Constant SUGENO-Type and MAMDANI-Type Fuzzy Inference System for Load Sensor

Vandna Kamboj, Amrit Kaur

Abstract* — *Load sensor is developed using mamdani fuzzy inference system and sugeno fuzzy inference system. It is two input and one output sensor. Both mamdani-type fuzzy inference system and sugeno-type fuzzy inference system are simulated using MATLAB fuzzy logic toolbox. This paper outlines the basic difference between these two fuzzy inference system and their simulated results are compared.

Index Terms* — *Fiber Bragg Grating sensor, fuzzy inference system (FIS), fuzzy logic, mamdani, sugeno, windmill blades.

I. INTRODUCTION

Fuzzy logic was first proposed in 1965 as a way to imprecise data by Lofti Zadeh, professor at University of California. After being mostly viewed as a controversial technology for two decades, fuzzy logic has finally been accepted as an emerging technology since the late 1980s. This is largely due to a wide array of successful applications ranging from consumer products, to industrial process control, to automotive applications [1]. This is largely due to a wide array of successful applications ranging from consumer products, to industrial process control, to automotive applications [1]. Fuzzy logic is closer in spirit to human thinking and natural language than conventional logical systems [2]. Fuzzy logic is methodology to represent and implement human's knowledge about how to control a system [1]. In fuzzy logic, knowledge can be captured in terms of rules and linguistic variables [3]. Fuzzy systems are extremely versatile because, by appropriate tuning of their configuration parameters, they can approximate with arbitrary precision any nonlinear input output mapping. Fuzzy inference process, i.e. the numerical interpretation of the linguistic information, requires a very small computation effort [4].

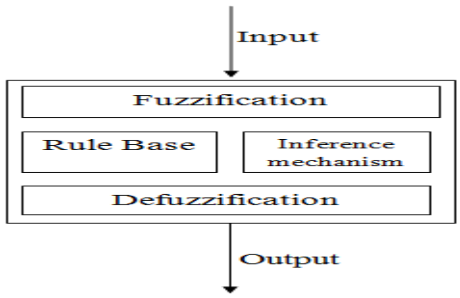

Fig. 1 Basic building block of fuzzy logic system [5]

Fuzzy logic system is shown in Fig. 1. It has four main parts: (i) Fuzzification interface simply modifies and converts inputs into suitable linguistic values so that can be compared to the rules in the rule base. (ii) Rule base, holds the knowledge in the form of a set of rule. (iii) Inference mechanism, evaluates which rules are relevant at current time and then decides what the output should be. (iv) Defuzzification interface, converts the conclusions reached by the inference mechanism into crisp ones [6].

In recent years, there have been efforts for developing load-bearing structures that include health-monitoring systems. These systems represent an important aspect in the maintenance of different types of structures (e.g., bridges, roofs of sport centers, blades of helicopters or of wind power plants, airplane wings, etc.) through the use of embedded or surface bonded sensors [7]. Now days, more and more fiber reinforced composites are used in manufacture of structures [8]. Fiber-optic sensors used for sensing a device offer many advantages over their electrical counterparts—these include their electromagnetic immunity, light weight and minimal intrusiveness when embedded in load-bearing structures. Fiber optic sensor based on Fiber Bragg Grating technology is found to be more suitable for strain sensing because FBG sensors, owe to small size, good repeatability, stable performance in product quality, have become the focus of research of fiber intelligent sensors [8][9]. In comparison with conventional strain gauges, the FBG sensors are unsusceptible to EMI and have no EM emission. They are intrinsically safe and have unique optical multiplexing potential [4]. Fiber Bragg Grating sensors(FBG) are very compatible with new structural materials like glass and carbon fiber reinforced composites used in highly stressed construction e.g. in airplanes and in wind power plants etc. The heavy load bearing structures undergoes a lot of strain on it. Due to this, structure suffers from cracks and delimitation leading to weakening in its strength and degrading its load bearing capacity. Hence to avoid this condition, we need to monitor the health of structure.

Recently, there has been a growing interest in wind energy as it has outstanding advantages: ample, renewable, wide distribution, cheap, reducing toxic gas emission. The wind turbine systems with larger blades are preferred to harvest more energy as the size of the wind turbine blades is directly related to their capacity of energy generation, and cost efficiency. Thus, the blade has become larger and slender [9]. In this paper, we use fuzzy logic to implement algorithm for load sensor with two inputs load and displacement and one output voltage. The input load is taken from Fiber Bragg Grating sensor embedded on the wind mill blades.

Manuscript Received on May, 2013.

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II. MAMDANI-TYPE FIS VS. SUGENO-TYPE FIS

The most fundamental difference between Mamdani type FIS and Sugeno type FIS is the way the crisp output is generated from the fuzzy inputs. While Mamdani FIS uses the technique of defuzzification of a fuzzy output, Sugeno FIS uses weighted average to compute the crisp output. Therefore in Sugeno FIS the defuzzification process is bypassed [10]. Other difference is that Mamdani FIS has output membership functions whereas Sugeno FIS has no output membership functions. Mamdani FIS is less flexible in system design in comparison to Sugeno FIS as latter can be integrated with ANFIS tool to optimize the outputs.

Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type FIS entails a substantial computational burden. On the other hand, Sugeno method is computationally efficient and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic non linear systems. These adaptive techniques can be used to customize the membership functions so that fuzzy system best models the data [11].

III. DEVELOPMENT OF MAMDANI-TYPE FIS

Load sensor is first developed using Mamdani fuzzy model. It consists of two inputs as load and displacement from sensor. Based on these inputs, output voltage is generated. The load and displacement are taken to be in ranges of 1162-1960 gm and 95-107 mm respectively. Each of these inputs has four triangular membership functions as shown in Fig. 2 and 3. The output i.e. voltage is taken in range of 2.2- 3.4 V and have four triangular membership functions as shown in Fig.4. The rules base for the system is described in TABLE I.

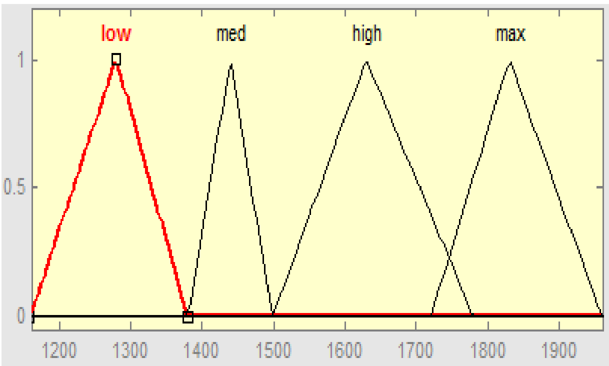

Fig. 2 Load membership functions

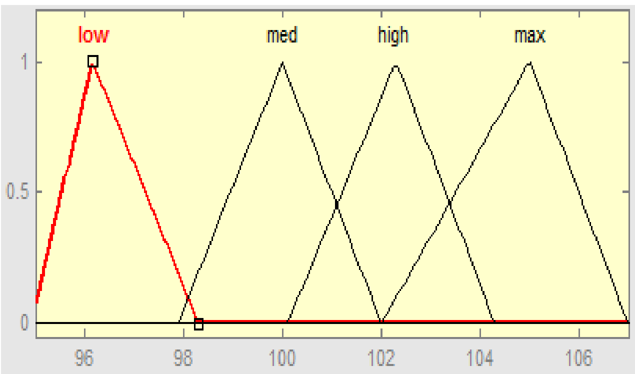

Fig. 3 Displacement membership functions

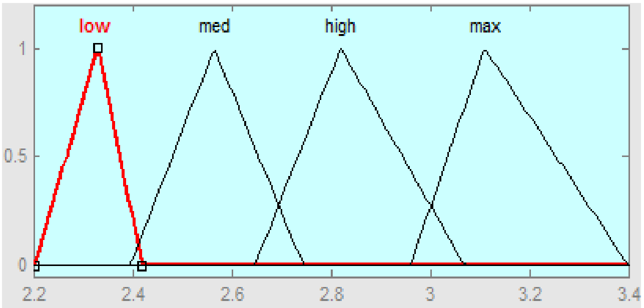

Fig. 4 Voltage membership functions

TABLE I
MAMDANI RULE BASE FOR THE SENSOR

Sr. No.	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

IV. DEVELOPMENT OF CONSTANT SUGENO-TYPE FIS

For development of load sensor using constant sugeno fuzzy inference system, initial steps are same as mamdani fuzzy inference system. It also consists of two inputs load and displacement from sensor and output is voltage. The load and displacement are taken to be in ranges of 1162-1960 gm and 95-107 mm respectively (as shown in fig. 2 and fig. 3) and has four triangular membership functions. The output voltage can only be either constant or linear, so four triangular membership functions for output are “low”, “medium”, “high” and “maximum” which are constant and shown in TABLE II. The output in sugeno-type FIS only be in range 0-1. The rule base for sugeno-type FIS is same as for mamdani-type FIS as shown in TABLE I.

TABLE II. Voltage membership functions

Voltage	Constant value
Low	0
Medium	0.3333
High	0.6667
Maximum	1

V. RESULT AND DISCUSSIONS

Following are the plots obtained after simulating the mamdani-type FIS for load sensor using MATLAB GUI toolbox (as shown in Figs 5,6,7).

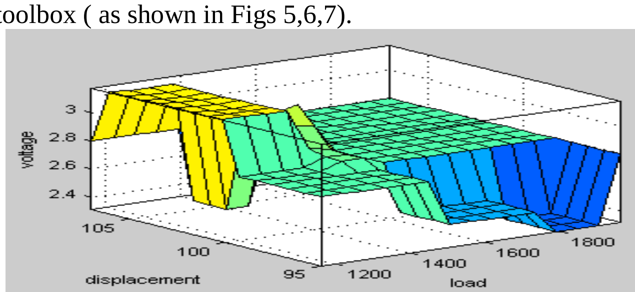

Fig. 5 Surface view using mamdani fuzzy logic algorithm

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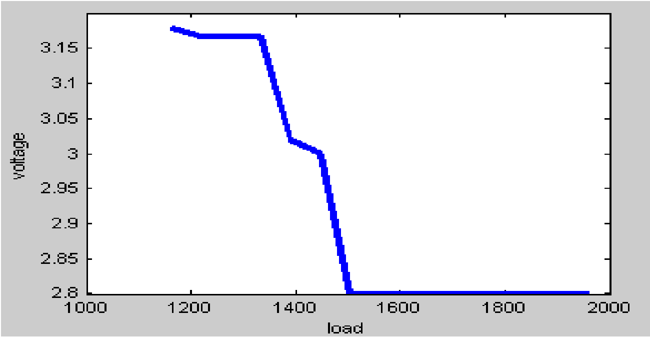

Fig. 6 Voltage with load

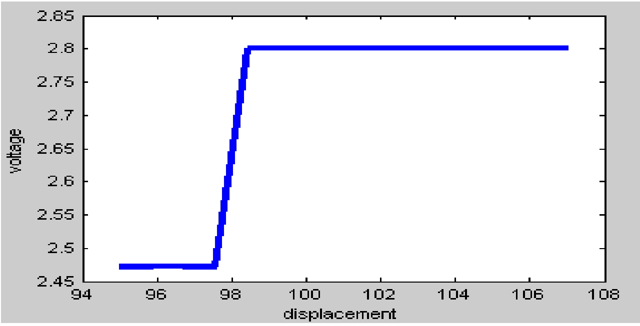

Fig. 7 Voltage with displacement

The plot obtained after simulation of sugeno type fuzzy inference system (FIS) based load sensor using MATLAB GUI toolbox (as shown in Figs. 8, 9,10).

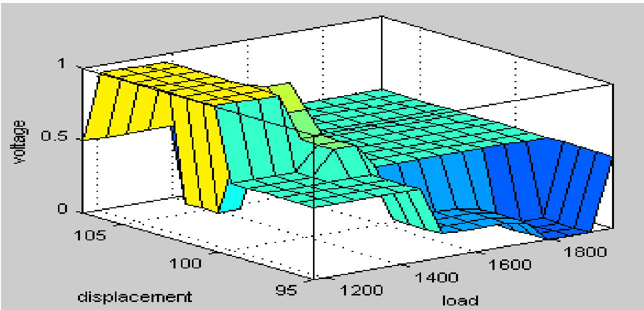

Fig. 8 Surface view of sugeno type FIS

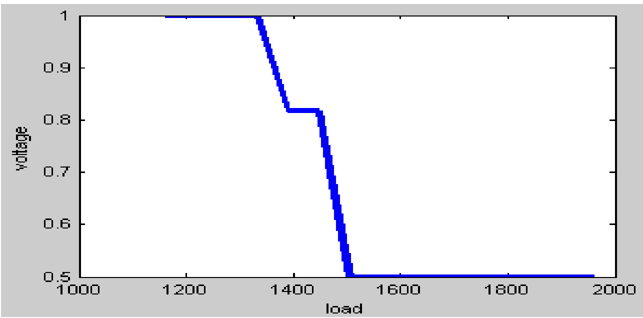

Fig. 9 Voltage with load

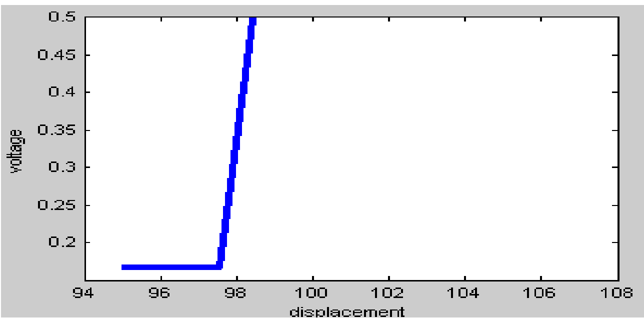

Fig. 10 Voltage with displacement

From these simulation results, it is evident that both Mamdani fuzzy algorithm and Sugeno fuzzy algorithm gives almost same result for the load sensor as surface viewers for both the model are same. Both give the same loading capability for load sensor. The only differences between Mamdani type FIS and Sugeno type FIS are: 1. the way the crisp output is generated from the fuzzy inputs. 2. Mamdani FIS has output membership functions whereas Sugeno FIS has no output membership functions. The Sugeno fuzzy logic model has advantage over Mamdani fuzzy logic model as Sugeno fuzzy logic model inherits learning capability as it integrated with ANFIS tool.

VI. CONCLUSION

It has been concluded from this paper that for the given application of load sensor, Mamdani-type FIS and Sugeno-type FIS works similarly. Membership functions and rules are same for both the FIS, only difference is that output membership functions for sugeno-type FIS can only be either constant or linear and also the crisp output is generated in different ways for both the FIS. Sugeno-type FIS is superior to Mamani-type FIS as it can integrated with neural networks and genetic algorithm or other optimization techniques so that sensor can adapt to individual user, environment and weather. Both the models are simulated using 8 rules. So there is scope for the improvement of rule-base and membership functions for the load sensor. Here, only one output is used for simplification, instead of one output model can be extended to multiple outputs. Genetic algorithm which is one of the optimization technique can also be used for tuning the membership functions.

VII. ACKNOWLEDGMENT

Vandna Kamboj Author wishes to express her sincere gratitude to Mrs. Amrit Kaur, Assistant Professor, University College of Engineering, Punjabi University, Patiala for valuable guidance throughout the current research work.

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