FUZZY LOGIC-BASED AUTOMATIC DOOR CONTROL SYSTEM

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Abstract*: In this paper, fuzzy logic based an automatic door control system is designed to provide for heat energy savings. The heat energy loss usually occurs in where outomotic doors are used. Designed fuzzy logic system's Input statuses (WS: Walking Speed and DD: Distance Door) and the output status (DOS: Door Opening Speed) is determined. According to these cases, rule base (25 rules) is created; the rules are processed by a fuzzy logic and by appyled to control of an automatic door. An interface program is prepared by using Matlab Graphical User Interface (GUI) programming language and some sample results are checked on Matlab using fuzzy logic toolbox. Designed fuzzy logic controller is tested at different speed cases and the results are plotted. As a result; in this study, we have obtained very good results in control of an automatic door with fuzzy logic. The results of analyses have indicated that the controls performed with fuzzy logic provided heat energy savings, less heat energy loss and reliable, consistent controls and that are feasible to in real.*

1. INTRODUCTION

Fuzzy logic is a set of mathematical foundations for knowledge representation based on degrees of membership. Fuzzy logic is use in solving a wide variety of the problems relative to mathematic and engineering. A. Zadeh has developed the mathematical method to produce many complex probing solutions in medical areas [1]. Fuzzy logic has been applied in many areas of engineering and medical. [2-4]. But, it is actually gained a popularity when it was applied to industrial problems [5].

There are a lot of methods to control of automatic doors, such as Field Programmable Gate Array (FPGA) [6], Peripheral Interface Controller (PIC) microcontroller [7], Arduino

[8], Programmable Logic Controller (PLC) [9] etc. Normally; in classical systems, an electronic sensor (Passive Infrared sensor (PIR) sensor) is placed in front of an automatic door and the door opens or closes according to the information from PIR. But the opening speed of the door is fixed and when someone approaches the door, the door starts opening at a constant speed (please attention that detection time is important). However, our used method is considerably remarkable to the control of automatic doors. In our method, the door speed is adjusted to open as required range. People do not wait in front of the door when come. There is less hot air to out from the inside (because of the door don't opened until the end and the door range decreased). Thus saving energy would be provided, *figure 1*.

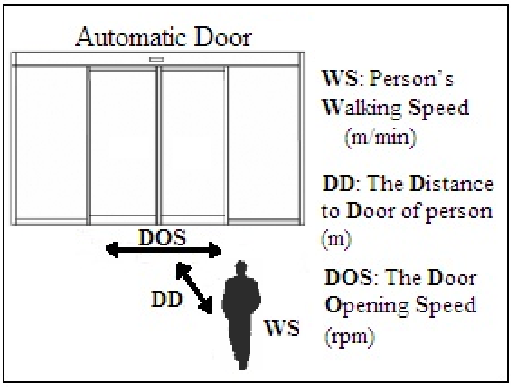

Fig. 1. Working principle of the designed system.

2. FUZZY SYSTEM CONTROLLER DESIGN

Fuzzy logic controller is recently one of the developing popular methods in control systems. The main idea behind the fuzzy logic controller is to write the rules that operating the controller in heuristic manner, mainly in "*If A Then B*" format. Fuzzy systems generally consist of two units; Knowledge-Base and Inference Engine. Knowledge-Base involves real information previously validated. Inference Engine determines answers to the chosen questions by using the information in the database that that composed of rules [10]. The Fuzzy system structure used in this study is given in *figure 2*.

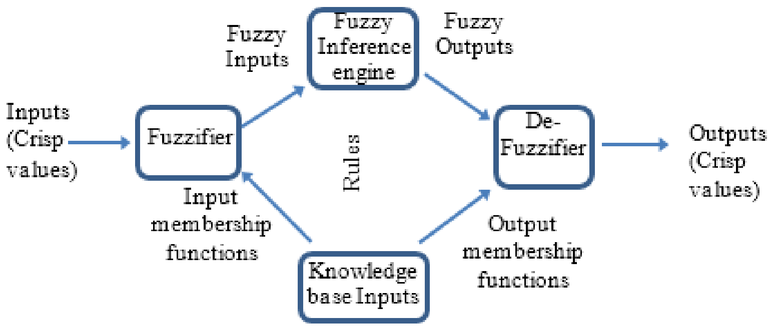

Fig. 2.The structure of fuzzy logic controller [11].

Fuzzy System components are described briefly below;

- *Fuzzifier:* This block transforms input information to fuzzy logic data format that can express with linguistic. The blurred variables obtained are called as linguistic.
- *Inference Engine:* This engine generates blurred results by applying the inputs coming from fuzzifier on the knowledge base rules. The most commonly used inference method is mamdani, so in this study it was chosen. Another interface model is the method developed by Takagi and Sugeno and there is no need for defuzzification [12]
- *Knowladge Base:* The knowledge base accumulates the sets of regulations of conclusions that are used in reaching a decision. Most of these systems use IF-THEN programming condition codes to put in practice the knowledge. Knowledge base consists of data base and rule base. The rules may be of the following structure [10]:

IF (condition (one or more)) THEN (action)

- *Defuzzifier:* This unit generates nonfuzzy result according to blurred inputs from the fuzzy decision and the actual value that will be used in practice. Decision algorithms can be summarized like; fuzzy [13, 14], Neuro Network [15], Adaptive Neuro fuzzy [16], machine learning [17] etc.

While the fuzzy based controller designing, firstly fuzzy rules were defined as two input variables and one output variable. Figure 3 shows the inputs, the output variables and fuzy control system editor.

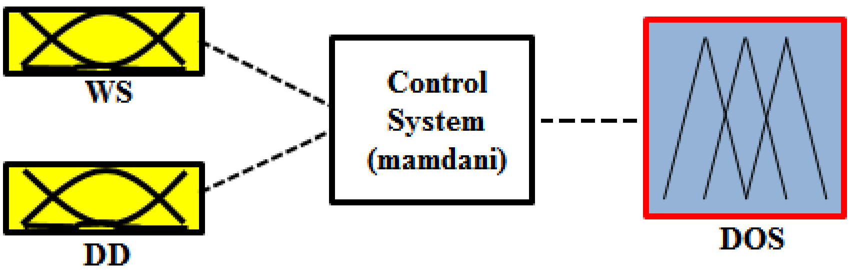

Fig. 3. Fuzzy Editor.

1.1. Input and Output Variables

In the designed system, two input variables were defined, namely as the person's Walking Speed (WS) and Distance to Door of person (DD). The input variables were sent to the fuzzy expert system, the most appropriate result was found among the defined rules system and state of automatic door was transferred to the output variable as The Door Opening Speed (DOS). Limit values for each fuzzy expression were given below. These parameters were linguistically classified. Input parameters, output parameters, degree of the membership function and linguistic expressions of designed fuzzy controller were defined as shown in the Table 1.

1.1.1. Input Variables:

WS: Person's Walking Speed [0-50 m/min].

WS= VS (Very Slow) – S (Slow) – M (Medium) – F (Fast) – VF (Very Fast)

DD: The Distance to Door of person [0-6 m].

DD= VC (Very Close) – C (Close) – M (Medium) – A (Away) – TA (Too Away)

1.1.2. Output Variables:

DOS: The Door Opening Speed [0-500 rpm].

WS= VS (Very Slow) – S (Slow) – M (Medium) – F(Fast) – VF(Very Fast)

Table 1. Input parameters, output parameters, degree of the membership function and linguistic expressions of designed fuzzy controller.

Input variables		***Output variables***
WS(m/min)	***DD (m)***	***DOS (rpm)***
VS [0-12,5]	*VC [0-1,5]*	*VS [0-150]*
S [0-25]	*C [0-3]*	*S [0-250]*
M [12,5-37,5]	*M [1,5-4,5]*	*M [125-375]*
F [25-50]	*A [3-6]*	*F [250-500]*
VF [37,5-50]	*TA [4,5-6]*	*VF [375-500]*

1.2. Rule Base

The fuzzy controller decides according to the rules contained in the rule base that created with the help of an expert. Essentially, the rules structures consist of statements as "if-then" that are intuitive and easy to understand. The rules used in this study are created with the help of an expert. In this study, 25 rules are created by using membership functions. Some rules from prepared rule base are shown in the Table 2.

Table 2. The sets of rule.

Rule No:	*Rule structure*	***Input variables***		*Rule structure*	***Output variables***
	condition	*WS*	*DD*	*action*	*DOS*
1	***if***	*VS*	*TA*	***then***	*VS*
2		*VS*	*D*		*VS*
...		...	...		...
13		*M*	*M*		*M*
14		*M*	*C*		*F*
...		...	...		...
24		*VF*	*C*		*VF*
25		*VF*	*VC*		*VF*

Membership degrees of the output variable are shown in the Table 3.

Table 3. Rule table for problem.

WS	***DD***					
	TA	*A*	*M*	*C*	*VC*	
VS	*VS*	*VS*	*S*	*S*	*M*	***DOS***
S	*VS*	*S*	*S*	*M*	*F*	
M	*S*	*S*	*M*	*F*	*F*	
F	*S*	*M*	*F*	*F*	*VF*	
VF	*M*	*F*	*F*	*VF*	*VF*	

These rules have been shown as membership functions in *figures 4, 5* and *6*.

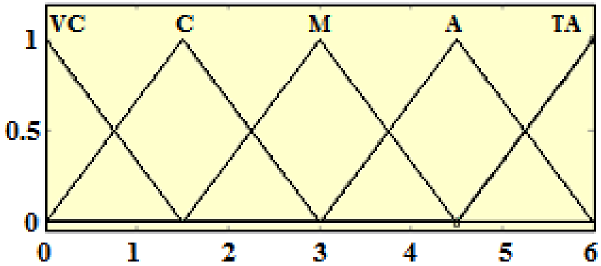

Fig. 4. Membership functions for DD.

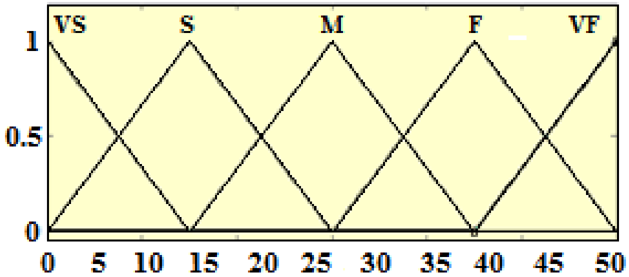

Fig. 5. Membership functions for WS.

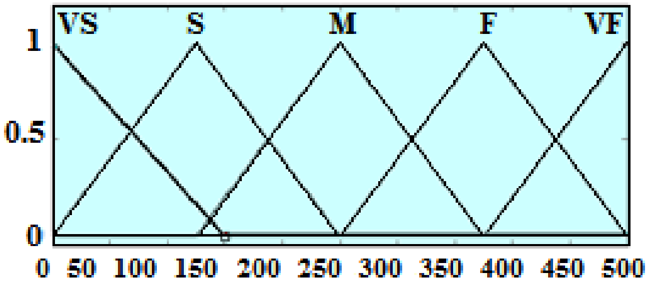

Fig. 6. Membership functions for DOS.

1.3. Defuzzification Method

In this study, we used the center-of-gravity/area (centroid) defuzzification method, cause it is the most preferred method in litertature. In this method, the output of each membership functions and the corresponding maximum membership value (z*) are calculated by the formula given below (1). $\bar{z}$ is the distance to the centroid of the respective membership functions [5].

$$z^* = \frac{\sum \mu_c(\bar{z}).\bar{z}}{\sum \mu_c(\bar{z})} \tag{1}$$

3. RESULTS

The sensors sense the input variables using the above model. After the inputs are fuzzyfied, the output fuzzy function DOS (Door Opening Speed) is obtained by using simple if-else rules and other simple fuzzy set operations. *figure 7* shows the response surface of the input-output relations as determined by Fuzzy Interface Unit (FIU).

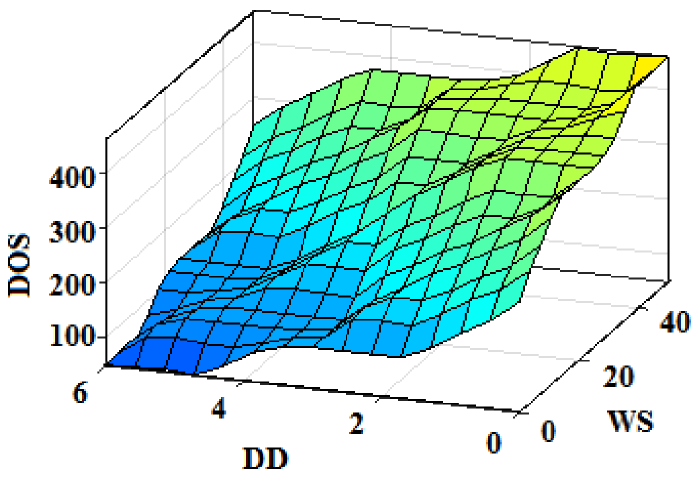

Fig. 7. Input/output response surface wiever

Values of each membership functions of fuzzy sets which are formed according to the method are taken weighted average by multiplying each one with its maximum membership degree. The results shows the way the automatic door will response in different conditions. For example, if we take WS= 29.6 and DD= 3.19, DOS which the model output is equivalent to 278 RPM. This is quite convincing and appropriate that as a linguistic ' M (Medium) '. This operation is demonstrated in *figure 8*.

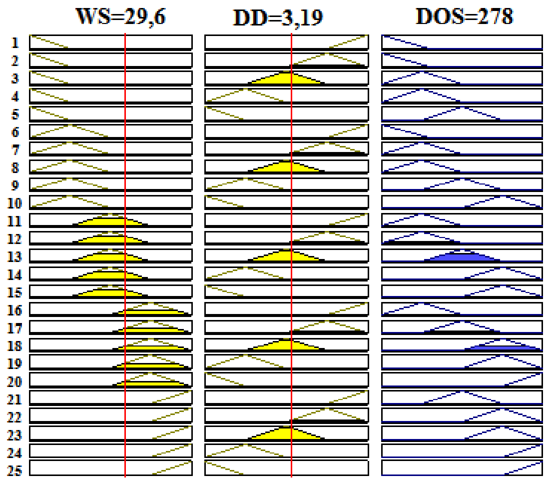

Fig. 8. Detection of DOS.

An interface program was developed and prepared by using Matlab Graphical User Interface (GUI) (version R2015b (8.6.0.267246)) programming language to some sample results were checked on Matlab using fuzzy logic toolbox. Then the program calculated degree of DOS as 278 as given in *figure 9*.

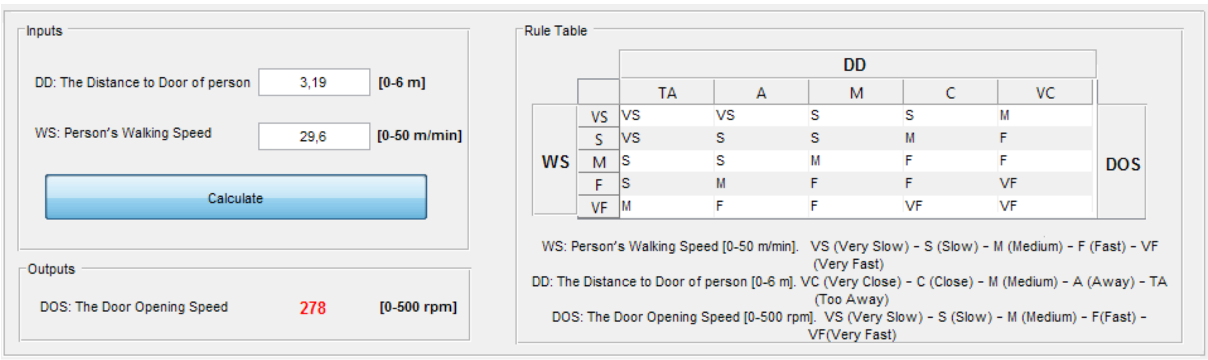

Fig. 9. Interface program (prepared by using Matlab GUI programming language commands)

4. CONCLUSION

In this paper, an application of fuzzy algorithms in the controller of the automatic door has been investigated.

Opening speed of the automatic door (0-500 rpm) was obtain for different speed of walking (0-50 m/min) and different distance of door (0-6 m) by using a fuzzy logic controller.

In classical systems, the person's distance to the door and the walking speed of the person have no effect on the opening speed of the door. The door do not open until the point in where the person perceives by the sensor and the person may have to wait in front of the door for a while. At that point, the door opens at constant speed. In our control system, as the person's walking speed increases, the opening speed of the door also increases. Variation of door opening speed according to person's walking speed and distance to door is shown in *figure 10*.

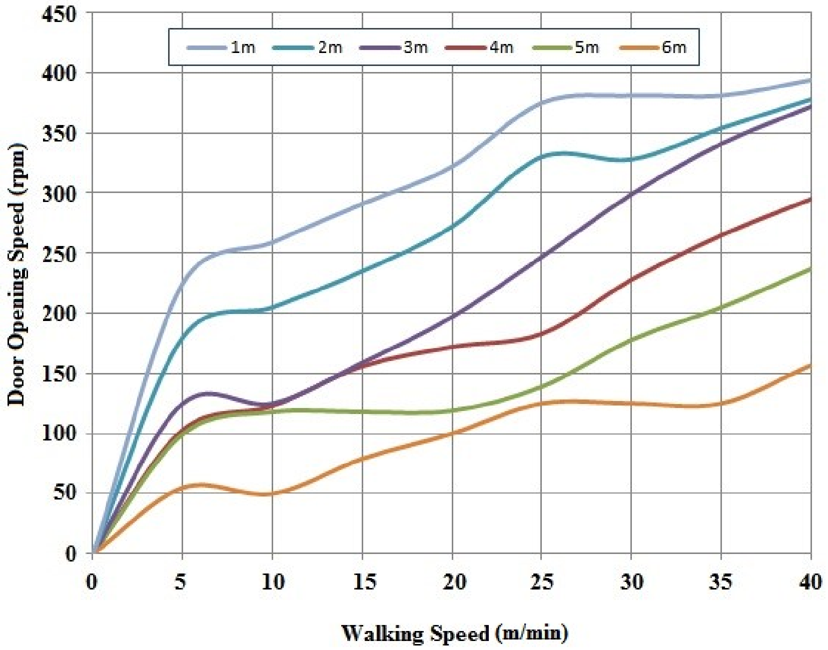

Fig. 10. Variation of Door opening speed according to the person's walking speed and distance to door.

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