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Intelligent Control System of Automobile Window using Fuzzy Logic

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Abstract

It has been attempted to develop an intelligent control system based on fuzzy logic to regulate height of automobile windows in this paper. An ATMega32 microcontroller is responsible for the system of fuzzy control programmed by Bascom AVR software. The control system involves two manual and automatic modes. In the automatic mode, there is no need to keep switch pressed for complete up and down functions of the window. Meanwhile, using the designed system is both convenient and accurate with the possibility to regulate position of the window after turning off the car. Another feature of this system is its sensitivity to carbon monoxide and carbon dioxide gasses. Whenever the extent of CO or CO_2 gasses exceeds an allowable limit, the windows will automatically come down in order to prevent asphyxiation of passengers. Simulation was implemented by MATLAB using fuzzy logic and the obtained results were compared with those from fuzzy linear regression method.

Keywords: regulating height of automobile window, sensitivity to CO and CO_2, fuzzy linear regression, MATLAB fuzzy logic.

1. Introduction.

Taking into account the worldwide growth of science and technology especially in field of automobile, developing intelligent systems will be accounted for substantial technologies in this industry. Therefore, it is of great importance to make systems fuzzy. The early cars used to have hinged windows which made it

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impossible to choose different opening levels. Subsequent window regulator made windows movable manually. A lever handle was cranked to drive a gear and move the window through a guiding rail, so it was eventually made possible to control up and down movement of the window. Using such equipment is both time consuming and harassing. This mechanism had a great friction such that the lever handles were failed or the windows were locked due to difficult cranking of both levers and gears [1]. Some of the expenditures of any industrial company is devoted to create comfort and to satisfy welfare needs of their customers. Therefore, economic methods must be used to reduce costs of the conventional window regulator in addition to make them accessible. Some modern automobiles today have the option to remove this mechanism and thus regulating the windows will be no longer controlled by driver [2]. Some more advanced cars are equipped with a switch to control windows automatically. These models of window regulator suffer from numerous disadvantages including impossible adjustment of the desired height of window or need to press the switch continually for complete open/close. Moreover, the designs were unable to control height of the windows accurately and continuously with the windows being locked once the car is turned off. Furthermore, hundreds of people die due to breathing carbon monoxide or carbon dioxide gasses annually. Since the gas leaked into automobile has no distinctive sign, no one can feel it. Thus, some initiatives must be taken to solve this problem and to provide safety for passengers.
To the best of our knowledge, window control system of automobile based on fuzzy logic is not considered so far. High accuracy of the system and continuity in its output as well as the ability to comprehend commands using time phasing are other characteristics of such a system.
An intelligent system has been designed and developed here to regulate windows of automobiles, which is able to comprehend the received commands and automatically transmit the required commands to the operators. The appropriate command will be addressed taking into account time and direction a switch is pressed. If the small indicator is pressed, the system will regulate windows automatically and if the switch is pressed for more than one second, height of the window will alter according to this time. The longer a switch is pressed, the more it will move in that desired direction. This system is equipped with a smoke sensor (CO_2-CO) which will move the windows automatically down in order to prevent asphyxiation of the passengers. A detector of CO and CO_2 gasses would be used to notify the least amount of leaked gas inside automobile, while an infrared sensor is devised to determine position and height of the windows.

2. Fuzzy Inference System (FIS)

A Mamdani Fuzzy Inference System (FIS) is adopted for the simulations, which is known as one of the earliest fuzzy theories in controlling systems. This method was invented by Ebrahim Mamdani in 1975 to control a steam engine. Fuzzy inference is a calculational structure working based on Fuzzy Set Theory (FST), if-then rules and fuzzy logic [4]. This logic has the power to be executed in hardware, software or a combination of these two. In fact, fuzzy logic provides a simple way to reach a decisive and definite result on the basis of incomplete, obscure and ambiguous input information [5]. Two inference systems have been used in this simulation. Meanwhile, pressed time of the switches and height of the windows have been chosen as input and output variables, respectively, because the existing systems of window regulator have small flexibility. Moreover, changing height of windows is rather large in each step and they lack the automatic option to actuate complete up/down movement of the window in currently used systems. These changes could be made smoother and more precise once the accuracy of circuit is further enhanced [3]. However, the other system is programmed with inputs of CO/CO_2 detector and outputs of window height controller.

2.1. Software

The main task of software is to implement fuzzy control having the following features:

a) discover commands of user regarding the direction and time of pressing the switch.
b) precise and continuous performance at proper speed which will lead to continuous operation of the system.

Controller of such a system is a stepper motor, whose position will determine height of the windows.

2.2. Formation of Fuzzy Rules

Fuzzy rules represent various experiences and experiments, which can have the following structure:

" IF X is A and Y is B, Then H is W."

Where, X is A and Y is B, provide the conditions and H is W gives the result of this rule. The number of fuzzy rules depends on input, output and accuracy of the system [5]. This logic has the power to be executed in hardware, software or a combination of these two. In fact, fuzzy logic provides a simple way to reach a decisive and definite result on the basis of incomplete, obscure and ambiguous input information. Mamdani inference operator is then put in FIS tool. Significance of the linguistic values has been summarized in table (1).

Table1. Values of linguistic variables

Linguistic Value (label in the FIS)	Rate of Linguistic Values (described in words)
VL	Very Low
L	Low
N	Normal
H	High
VH	Very High

Table2. Fuzzy rules for inputs of CO and CO_2

OUTPUT (High)		INPUT (CO)				
		VL	L	N	H	VH
INPUT (CO_2)	VL	VL	VL	VL	L	N
	L	VL	VL	L	N	H
	N	VL	L	N	H	VH
	H	L	N	H	VH	VH
	VH	N	H	VH	VH	VH

Table2. Fuzzy rules for inputs of CO and CO_2

IF	THEN
Δt is t_1	motor is h_1
Δt is t_2	motor is h_2
Δt is t_3	motor is h_3
Δt is t_4	motor is h_4
Δt is t_5	motor is h_5
Δt is t_6	motor is h_6
Δt is t_7	motor is h_7
Δt is t_8	motor is h_8
Δt is t_9	motor is h_9

2.3. Input-Output Membership Functions

Membership functions have been designed on the basis of knowledge and experienced. They are shown in the following figures respectively. Input of a system which is time of pressing the switch has been divided into 9 fuzzy sets addressed with the membership functions. Their design is such that the operator will experience smooth and steady changes during running all commands. Triangular functions and trapezoidal functions (for definition of steady state) have been applied. The following functions cover time ranges of pressing the switches including t_1 to t_9, where t_1 is the shortest time and t_9 is the longest time of pressing the switch.

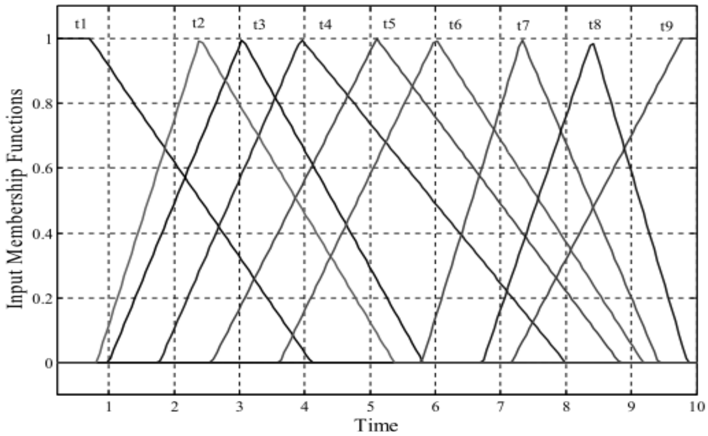

Fig.1. Input membership functions of times the switch is pressed

Furthermore, output of the system which is height of the window has been categorized by definition of the following membership functions. These membership functions have been defined according to the tasks of operators in various time ranges. They involve h_1 to h_9, where h_1 and h_2 are the lowest and highest positions of the window.

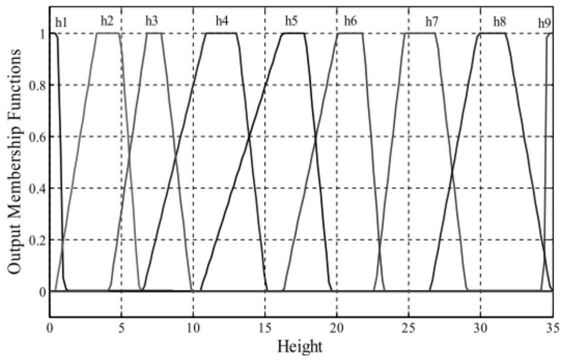

Fig.2. Output membership functions of window's height for times the switch is pressed

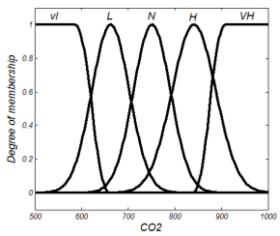

Fig.3. Input membership functions of CO_2 content

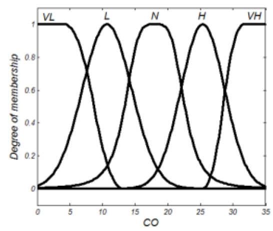

Fig.4. Input membership functions of CO content

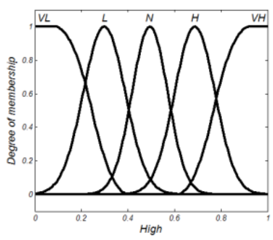

Fig.5. Output membership functions of window height for inputs of CO_2 and CO contents

2.4. Output vs. Input Diagram

As a result of implementing fuzzy rules among input and output functions, one would be directed to figures 6 and 7. Looking at these diagrams is advantageous to regulate and correct input/output functions more simply and also to modify fuzzy rules once needed. As can be seen, they do demonstrate a relatively smooth behavior instead of a sharp rise.

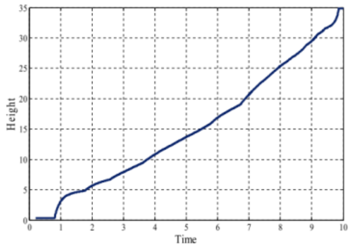

Fig.6. Output height control of window vs. input pressing time of switch

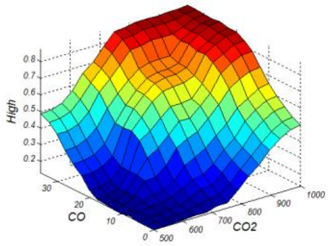

Fig.7. 3D surface of CO_2 and CO inputs

3. Linear Fuzzy Regression

Regression analysis is used by modeling the relation between dependent and independent variables. In this analysis, the dependent variable (y) is a function of independent variables with the degree of membership or the role of each independent variable at output (dependent variable) being stated by coefficients of the variables. The difference between values observed and values predicted by the model in common regression methods, is attributed to the error of prediction in comparison with observations and it is thus assumed as a random variable. The possibility of output value is investigated by the amounts of input variables in fuzzy regression. The coefficients of variables are taken as fuzzy numbers in a general fuzzy regression model having the form below:

$Y = f(x,A) = A_1x_1 + A_2x_2 + \ldots + A_ix_i$

Where, A_i is the fuzzy number of i^{th} coefficient.

Linear regression equations are being attended due to many reasons. They easily enter mathematical operations and usually provide acceptable approximations for complex equations.

The linear fuzzy regression equation obtained for CO_2 and CO inputs is given below:

$$f(x,y) = 41.28 - 0.3034x + y + 0.0008873x_2 - 0.005978xy - 0.004115y_2 - 1.285e\text{-}006x_3 + 1.3e\text{-}005x_2y + 3.981e\text{-}006xy_2 + 0.0003056y_3 + 9.203e\text{-}010x_4 - 1.22e\text{-}008x_3y + 1.433e\text{-}08x_2y_2 - 7.665e\text{-}007xy_3 - 1.126e\text{-}006y_4 - 2.597e\text{-}013x_5 + 4.163e\text{-}12x_4y - 7.901e\text{-}012x_3y_2 + 1.104e\text{-}010x_2y_3 + 8.282e\text{-}009xy_4 - 4.599e\text{-}008y_5$$

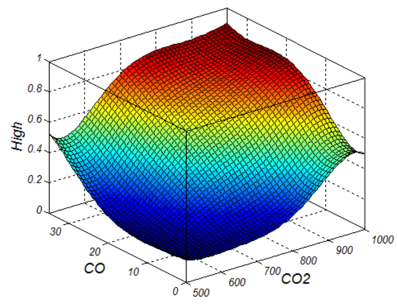

Fig.8. 3D surface of linear fuzzy regression for CO_2 and CO inputs

Measure of mean squared error has been utilized in order to calculate the amount of output error produced from the functions of obtained equation and the desired fuzzy controller. The amount of mean squared error reveals a small error of just 0.992.

4. Hardware

The infrared sensor of H9700 has been used to address current position of the motor. This sensor is composed of two parts: one to transmit infrared waves and the other to receive them. It comes in a package of two infrared sensors (transmitter and receiver). The sensor package has been used for a better performance of the system rather than two separate infrared sensors. Meanwhile, a variable has been defined in program of the sensor which adds one to the variable per each encoder pulse (Equation (1)).

$$350 \text{ pulses} \geq \text{total received pulses} \geq 0 \text{ pulse} \qquad (1)$$

With respect to the number of SHABLON grooves installed on the stepper motor, each pulse of the sensor will be equal to 1.8°. The maximum rotation includes 350 pulses in one direction, while each pulse has been calculated and defined as 1 mm considering the radius of its relevant SHABLON and gear. The longest and the shortest times of up/down operations of the window are from 0 to 7.35 s. Indeed, the window must be moved up/down for 35 cm during this time (Equation (2)).

$$350 \text{ mm} \geq [(\text{number of clockwise pulses})+(\text{number of counterclockwise pulses})]\times 1\text{mm} \geq 0 \text{ mm} \qquad (2)$$

Position of the stepper motors are easily controlled, so that each pulse can rotate the rotor for one step. A regulator 7805 has been utilized for power supply of the motor. MQ7 sensor is used in this circuit for detection of CO and CO_2 gasses, which is sensitive to various toxic gasses with affordable price and acceptable performance. The sensing action of gas is done by a filament devised inside the sensor and the window is moved down according to the gas sensed by this system. In order to drive the stepper motor, a ULN2803 IC has been used. Micro cannot be connected to the motor directly and its function is just to command. This IC is the buffer of current amplification and the output signals of this IC are amplified by ULN2803A. One LCD (2X16) is used to display the information namely: height of window, pressing time of switch, and amount of up/down movement of window. Fuzzy hearth of the system is ATMega32 microcontroller which reads the input values and transmits required commands to the output based on the fuzzy control programmed(fig10). Moreover, controlling the height of windows is done in a Crisp nature by it considering the amount of toxic gasses detected [6]. A block diagram of the circuit performance has been depicted in figure 9.

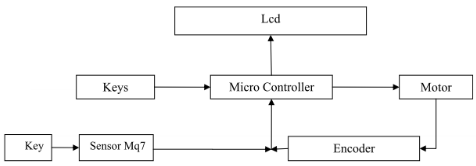

Fig.9. Block diagram of circuit performance

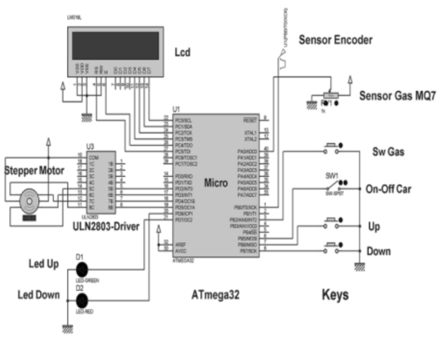

Fig.10. Schematic view of circuit

Programming of the AVR microcontrollers was launched using Bascom AVR software. Board and control of equipments used in this study has been illustrated in figure 11 in brief. Components of the board were: (1) ATMega32 microcontroller, (2) optical sensor, (3) smoke sensor, (4) stepper motor, (5) driver, (6) display.

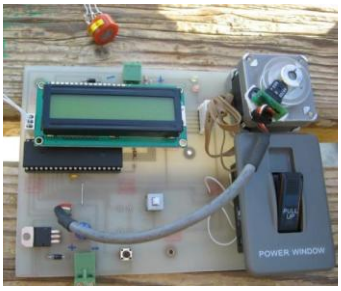

Fig.11. Board of equipments used

Functions of the hardware are listed below:

a) data acquisition: this is done by sensors and definitions obtained in the micro from pressing the switches or amount of gasses.
b) data processing and analysis: the microcontroller checks the outputs with respect to fuzzy rules and previous commands to finally put the system in a steady and favorite state.
c) display data of system performance to user: operator observes the control procedure and alters them when necessary.

5. Advantages

The developed intelligent control system of automobile window benefits from numerous advantages some of which have been summarized below:

- ability to control the system after turning of the automobile.
- proper speed and optimized accuracy.
- further flexibility in regulating height of automobile windows.
- ability to prevent asphyxiation of passengers.
- displaying information on its LCD.
- simple installation on door of automobiles.
- smooth and steady control of window position.
- minimum requirements of a switch (three state switch).
- no need to keep the switch pressed until complete up/down movement of the window (instant touch in the desired direction-automatic mode).
- paying more attention to driving (hand of the driver will not be busy for a long time).
- ability to regulate position of the window accurately (by keeping the switch until reaching the desired position-manual mode).
- removing mechanical handles of window regulator.
- being inexpensive.

6. Conclusion

Taking into account the growth of science and technology all over the world especially in the field of automobiles, it seems necessary to propose solutions for further safety of the passengers. Some developed countries like Japan have taken effective initiations and numerous efforts have been launched in Iran. Development of intelligent control system of windows is an example which has been designed for the first time in the world and works based on fuzzy logic. This invention involves technical fields in both control and electronic. One applied, the height of windows would be controlled with the up/down operations being done by fuzzy control and completely intelligent. The algorithm of such a system is designed by modern and advanced fuzzy logic and it runs using common microcontrollers.

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