SMART WIPER SYSTEM FOR SKYSCRAPERS

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Abstract - *Cleaning glasses and windows in skyscrapers has become a challenging task for which wiper systems could be employed. Window cleaning is also considered one of the toughest jobs and the fatality rate of window cleaners is 10 per second in the United States. Currently only robots are used to clean buildings and this is an expensive and difficult solution. Wiper systems also play a key role in assuring the driver's safety in vehicles during any form of precipitation. Existing standard wiper systems require the driver's constant attention in adjusting the wiper speed and the intermittent wiper interval because the intensity of rain on the windshield constantly varies according to time and vehicular speed. Thus the proposed fuzzy controlled wiper system is extended to skyscraper windows and aims to prevent such accidents at low cost, by automatically changing the speed and time interval of the wipers, based on the intensity of rain.*

***Key Words*: Wiper, Fuzzy Sets, De-fuzzification, Motor, Pulse Width Modulation, ANFIS.**

1. INTRODUCTION

Rain has always been the problem for the automobile transport as it can cause the drivers to lose attention in driving. Hence there is a need for a smart wiper system which will clean the windshield automatically in the presence of rain. In the existing wiper systems, there are various speed levels which require constant attention of the driver which causes the driver to lose attention on the road. Apart from automobiles, high rise buildings with glass windows, airplanes, skyscrapers and speed motorboats also require smart wiper system. To clean the windows of high rise buildings robots are being used which are expensive .Further the existing automatic wiper systems do not provide the required accuracy and hence a smart, low cost fuzzy based wiper system is presented in this paper.

Fuzzy logic helps to avoid the damage of wipers by providing the appropriate speeds for the appropriate rain intensities. It helps in providing a smooth transition from one level to another thereby preventing excessive speed during lower rain or lower speed during excessive rain.

1.1 LITERATURE SURVEY

In [1], B.S. Hsu and S.F. Ling have presented the design of a basic windshield wiper system for vehicle design. In [2], S.S. Patil, P. Bhaskar and L. Shreemanth Sudheer have presented the design and implementation of an integrated fuzzy logic controller for a MIMO system. In [3], Jyh-Shing Roger Jang, Chuen-Tsai Sun and Eiji Mizutani have described a Neuro Fuzzy and Soft Computing approach to Learning and Machine Intelligence. In [4], Songkran Kantawong and Nontawat Janepumisart have presented the design of a Single wiper blade mechanism design using Fuzzy-PID control system. In [5], Marcelo Costa de Oliveira and Marco Antonio Rocha Facury have described the conversion of Fuzzy Rules directly into C++ source code.

This paper is organized as follows: In Section 2, the operation of the Wiper is explained. The concepts of Fuzzy logic are discussed in Section 3. Section 4 describes the proposed model and its Fuzzy logic implementation. Section 5 describes the hardware implementation of the proposed model. Section 6 provides the results and discussion. In Section 7, we provide the conclusions and the scope of future work.

2. WIPER SYSTEM

Wiper Mechanism:

The wipers combine two mechanical technologies to perform their task[1]:

- A combination of an electric motor and worm gear reduction provides power to the wipers.
- A neat linkage converts the rotational output of the motor into the back-and-forth motion of the wipers.

Motor and Gear Reduction:

It takes a lot of force to accelerate the wiper blades back and forth across the windshield so quickly. In order to generate this type of force, a worm gear is used on the output of a small electric motor.

Linkage:

A short cam is attached to the output shaft of the gear reduction[4].This cam spins around as the wiper motor turns. The cam is connected to a long rod; as the cam spins, it moves the rod back and forth.

DC Motor:

In a DC motor, an armature rotates inside a magnetic field. Basic working principle of DC motor is based on the fact that whenever a current carrying conductor is placed inside a magnetic field, there will be mechanical force experienced by that conductor. In permanent magnet DC motor the field poles of this motor are essentially made of permanent magnet[9].

3. FUZZY SYSTEM

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth values may range between completely true and completely false[3].

Process:

- Fuzzify all input values into fuzzy membership functions.
- Execute all applicable rules in the rule base to compute the fuzzy output functions.
- De-fuzzify the fuzzy output functions to get "crisp" output values.

Membership Functions:

The simplest membership functions are formed using straight lines. Of these, the simplest is the triangular membership function, and it has the function name trimf. The trapezoidal membership function trapmf, has a flat top and really is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity.

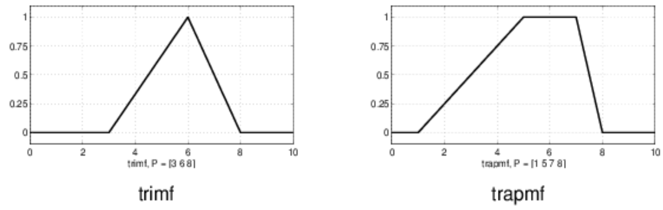

Fig -1: Membership Functions

Fuzzy logic operators:

Fuzzy logic works with membership values in a way that mimics Boolean logic. To this end, replacements for basic operators AND, OR, NOT must be available. There are several ways to this. A common replacement is called the Zadeh operators as mentioned in the table below.

Table -1: ZADEH OPERATORS

Boolean	**Fuzzy**
AND(x,y)	MIN(x,y)
OR(x,y)	MAX(x,y)
NOT(x,y)	1-x

Fuzzy rule:

A fuzzy rule is defined as a conditional statement in the form:

IF x is A

THEN y is B

Where x and y are linguistic variables; A and B are linguistic values determined by fuzzy sets on the universe of discourse X and Y respectively.

Defuzzification:

Defuzzification is the process of producing a quantifiable result in Crisp logic, given fuzzy sets and corresponding membership degrees. It is the process that maps a fuzzy set to a crisp set. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets[3].

4. PROPOSED SYSTEM

The proposed model requires additional rain sensors and fuzzy logic controller to provide automatic change in speed of the wipers based on the speed and intensity with which the rain droplets fall on the glass or the windshield of the vehicle or the window[6].The system is much more complex than the traditional system but it has the following advantages:

•Due to automatic speed control of the wipers, the driver does not need to worry about the rain intensity and can focus on the driving[8].

•When rain keeps varying for skyscrapers then the windows can be cleaned without using any additional water.

Sensor values are processed in the microcontroller and fuzzified values are obtained[7].These values are defuzzified which are pulse width modulated and speed control of the motor is done which in turn runs the wiper. Thus, based on the intensity of the rain the speed of the wiper changes.

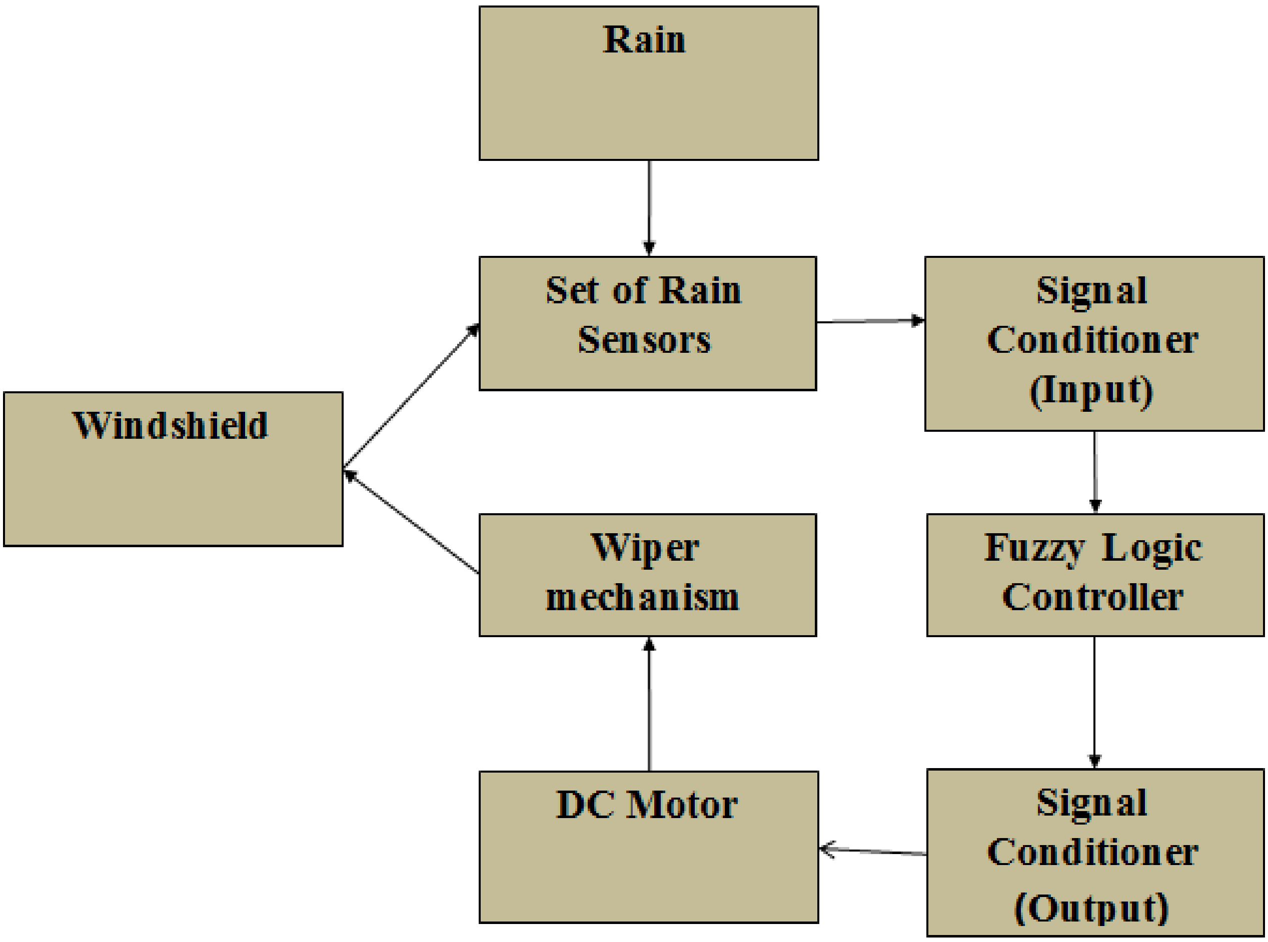

Fig –2: Proposed Model

4.1 DESIGN OF FUZZY LOGIC ALGORITHM

Fuzzy logic algorithm was developed by using the fuzzy logic toolbox in MATLAB. The fuzzy system consists of two inputs which are rain and intensity and two outputs which are speed and interval. Twelve test cases were designed overall based on the membership functions. Sensors were used to provide input for the rain and intensity. The speed and interval were used to control the wiper motor using pulse width modulation and microcontroller. Three levels were chosen for both the inputs and for both the outputs and 9 rules were defined for the fuzzy systems[5].

A mamdani system was developed in order to obtain crisp values for comparing the various algorithms. Rules are based on IF-THEN conditions. Defuzzification was performed using the centroid method.

Table -2: RULE-BASE

Antecedent	Consequence
Rule1:If rain is dry and intensity is light	Then speed is stop and interval is long
Rule2:If rain is dry and intensity is medium	Then speed is stop and interval is short
Rule3:If rain is dry and intensity is heavy	Then speed is stop and interval is zero
Rule4:If rain is drizzle and intensity is light	Then speed is slow and interval is long
Rule5:If rain is drizzle and intensity is medium	Then speed is slow and interval is short
Rule6:If rain is drizzle and intensity is heavy	Then speed is slow and interval is zero
Rule7:If rain is wet and intensity is light	Then speed is fast and interval is long
Rule8:If rain is wet and intensity is medium	Then speed is fast and interval is short
Rule9:If rain is wet and intensity is heavy	Then speed is fast and interval is zero

In setting up the fuzzy logic rules, Rain and Intensity have been defined as the Input Fuzzy Variables; Speed and Interval as the Output Fuzzy Variables[2]. Each of these fuzzy variables is associated with descriptors or labels such as Dry, Drizzle, Wet, Light, Medium, Heavy, Stop, Slow, Fast, Zero, Short, and Long, which are the Fuzzy Sets.

Table -3: SHAPES OF FUZZY VARIABLES

Test Case	Rain (Shape of Input1)	Intensity (Shape of Input2)	Speed (Shape of Output1)	Interval (Shape of Output2)
Case 1	Trap	Trap	Trap	Trap
Case 2	Tri	Tri	Tri	Tri
Case 3	Trap	Trap	Tri	Tri
Case 4	Tri	Tri	Trap	Trap
Case 5	Tri	Trap	Trap	Trap
Case 6	Trap	Tri	Trap	Trap
Case 7	Trap	Trap	Tri	Trap
Case 8	Trap	Trap	Trap	Tri
Case 9	Trap	Tri	Tri	Tri
Case 10	Tri	Trap	Tri	Tri
Case 11	Tri	Tri	Trap	Tri
Case 12	Tri	Tri	Tri	Trap

CHOOSING A TEST CASE:

Algorithm is to be selected from the 12 algorithms designed based on the above table. The efficiency of the algorithm is considered greater when

- Speed of wiper is high
- Interval of wiper is low

To choose the best test case , random values were chosen for each of the 9 rules and the best test case was found corresponding to the above conditions.

Table -4: COUNT OF BEST SPEED AND INTERVAL FOR EACH TEST CASE

Case No	Best Speed	Best Interval	Total
1	0	5	5
2	2	0	2
3	5	0	5
4	1	2	3
5	2	5	7
6	2	5	7
7	2	5	7
8	2	1	3
9	1	1	2
10	0	0	0
11	2	0	2
12	2	5	7

As seen above, test case numbers 5, 6, 7 and 12 were the most efficient test cases, with each having a count of 7, that is the largest number of best speed and interval. To select the most suitable test case, neuro- fuzzy training was performed and the test case with the least testing error was obtained.

4.2 ANFIS TRAINING AND TESTING

An adaptive neuro-fuzzy inference system or adaptive network-based fuzzy inference system (ANFIS) is a kind of artificial neural network that is based on Takagi–Sugeno fuzzy inference system[3].

To perform ANFIS training, the training data set must be loaded that contains the desired input/output data of the system to be modelled. The data was taken from the rule viewer and the data was arranged as columns and stored in an array.FIS must be loaded and this is done by converting the Mamdani FIS into Sugeno type.

Hybrid method of training was used, with 3 epochs and 0 error tolerance. An epoch is a measure of the number of times all of the training vectors are used once to update the weights while error tolerance used to create a training stopping criterion.

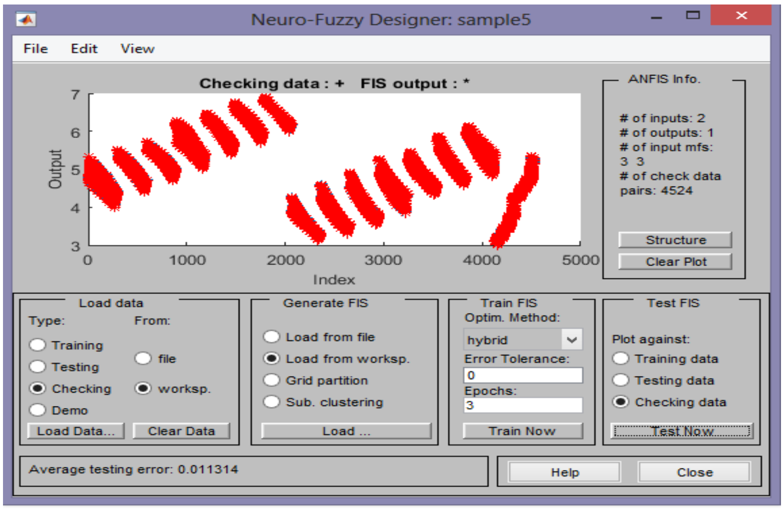

Fig -3: ANFIS testing for case 5

Once the system has been trained, the system has to be tested by providing the testing data and plotting it on the graph against the testing error and finding out the training errors.

TABLE -5: PERCENTAGE ERROR OF ANFIS TESTING

TEST CASE	PERCENTAGE ERROR (%)
CASE 12	15.6
CASE 7	16.6
CASE 6	1.2
CASE 5	1.1

Comparing the test cases and tabulating them based on the percentage error, we get case 5 with (Rain-Triangle; Intensity, Speed, Interval-Trapezium) as the test case with the least error and hence it was considered as the most efficient test case for hardware implementation.

5. HARDWARE IMPLEMENTATION

The case 5 was found out to be most efficient and was used for implementation. The flow diagram of implementation is as follows:

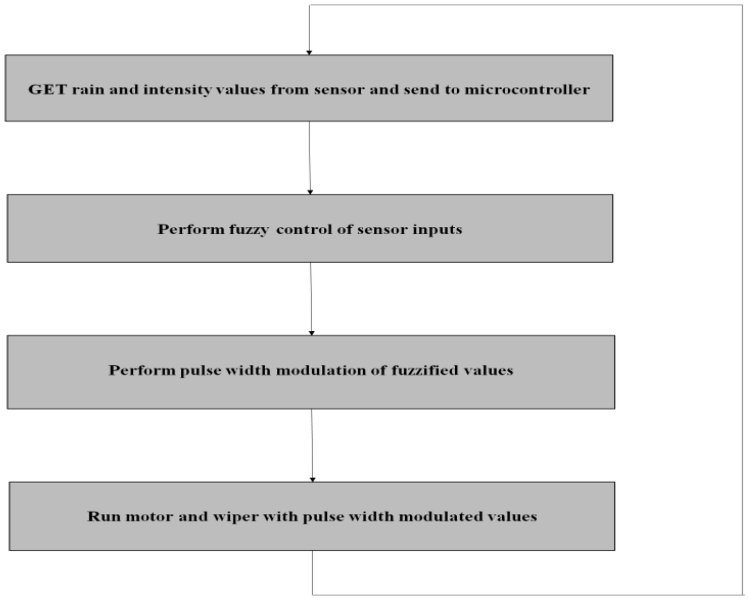

Fig -4: Flow diagram

The following components are used for the implementation of the system:

MICROCONTROLLER: Arduino Uno R3 which has the ATMEGA328p is used for implementation of the hardware.

MOTOR DRIVER: A motor driver is a little current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.L298N was used for implementation.

RAIN SENSOR: Rain sensors are used in the detection of water beyond what a humidity sensor can detect. The rain sensor detects water that completes the circuits on its sensor boards' printed leads.

FORCE SENSOR: FSRs are sensors that allow you to detect physical pressure, squeezing and weight.

5.2 CIRCUITRY

The individual connections are as follows:

Arduino

Analog Pin0 (A0)→ Sensor1

Pin Analog1 (A1)→Sensor 2

Ground→Battery Source negative (-)

Motor Driver (L298N)

Motor Output1 (Pin 1)→ Motor Terminal 1

Motor Output1 (Pin 2)→Motor Terminal 2

Vcc (Pin 4) →Battery Source Positive (+)

Connection between Arduino and motor driver is as below:

TABLE -6: CONNECTION BETWEEN ARDUINO AND L298N

ARDUINO	**L298N**
Digital output 1(Pin 6)	input 1 (Pin 8)
Digital output 2 (Pin 7)	input 2 (Pin 9)
PWM (Pin 9)	Enable1 (Pin 7)
Ground	Ground (Pin 5)
VIN	5V output (Pin 6)

WIPER SYSTEM

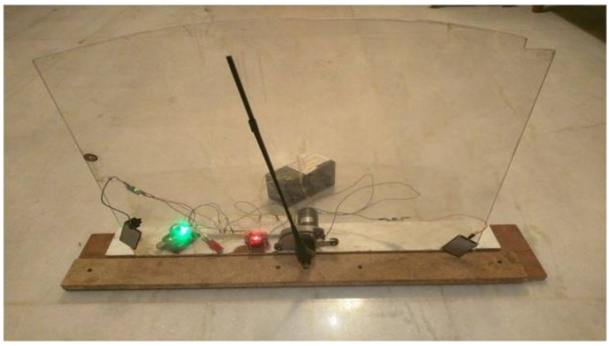

Fig -5: Wiper System

6. RESULTS AND DISCUSSION

To test the working of the wiper system, the intensity of the water droplets were varied and the following were obtained and tabulated

- Number of wiper movements in 30 seconds.
- Interval between wiper movements.
- Speed of wiper movements.

The number of wiper movements was obtained by counting the number of movements while the interval was obtained by using a timer.

However, to find the speed the following had to be done:

Initially the distance covered by the wiper had to be calculated. To obtain the distance the radius of the wiper (r) and the angle between the wipers (θ) had to be found.

r=48cm

θ=140°

distance (d) =(θ/360)*2*π*r

= (140/360)*2*π*48=117.22 cm

Using the above distance the corresponding speed was obtained as:

Speed=distance/interval (cm/s)

The values are tabulated below.

TABLE -7: RESULTS

Rain(Droplets)	No.of Wiper Movements (30 seconds)	Interval (seconds)	Speed (cm/s)
0	0	0	0
1	5	6	19.5
3	10	3	39.07
10	13	2.3	50.95
15	16	1.9	58.2
20	20	1.5	78.3
25	22	1.36	86.16

The following graphs were plotted taking the number of rain droplets in x axis and the remaining parameters in the y axis.

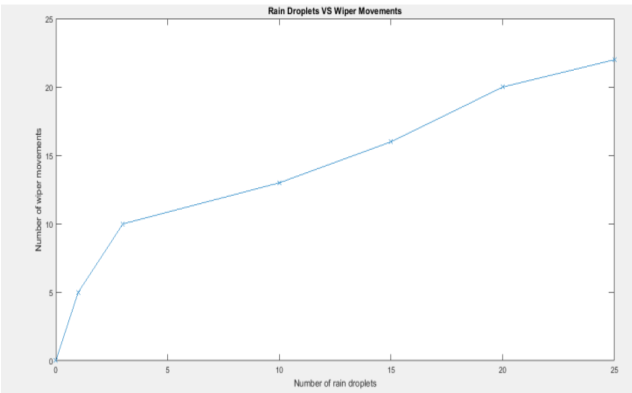

Chart -1: Rain Droplets Vs Wiper Movements

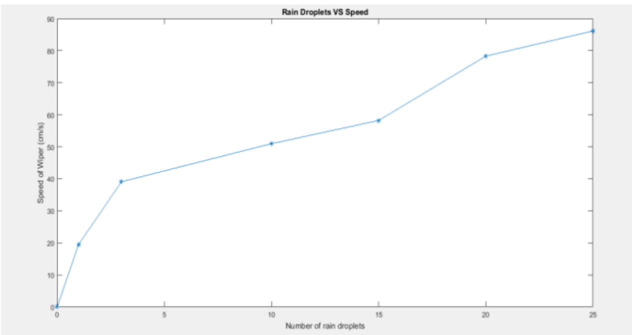

Chart -2: Rain Droplets Vs Speed

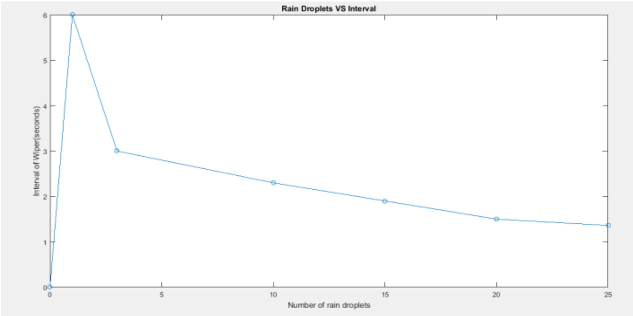

Chart -3: Rain Droplets Vs Interval

7. CONCLUSIONS AND FUTURE WORK

The following conclusions can be drawn from the implemented wiper system:

The wiper motor is off when there is no rain.

Then in a fuzzy sense,

- Operates at full speed with zero delay interval when the rain is heavy
- Operates at full speed with long delay interval when the rain is light.
- Operates at low speed with zero delay interval when the drizzle is heavy.
- Operates at low speed with long delay interval when the drizzle is light.

Hence the wiper system implemented is quite satisfactory as the system follows the rules mentioned in the rule base. The precision of the system can be improved by determining the rain droplets using the amount of reflection along with the current rain sensors.

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