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Design and development of smart automatic windshield wiper system: fuzzy logic approach

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Abstract:*Windshield wipers play a key role in assuring the driver's safety during precipitation. The traditional wiper systems, however, requires driver's constant attention in adjusting the wiper speed and the intermittent wiper interval because the amount of precipitation on the windshield constantly varies according to time and vehicle's speed. The manual adjustment of the wiper distracts driver's attention, which may be a direct cause of traffic accidents. The project is an endeavor towards an effective design and development of an automatic windshield wiper system, based on intensity of rain. The system comprises of PIC (Peripheral Interface Controller), grid sensor and a D.C. motor to actuate the windshield wiper. Next, the grid sensor is used to detect the rain intensity which is based on the simple principle that, as wetness increases sensor output voltage decreases, when the sensor is a part of voltage divider circuit. The proposed system has ability to change the wiper speed automatically with the change in rain intensity. But the system is not able to measure the rain intensity. Hence to tackle this problem the Matlab 7.0 fuzzy logic toolbox is used to predict the intensity of rain (High rain, Medium rain, Drizzle).*

***Keywords*:** Fuzzy Logic, Fuzzy logic Matlab toolbox, Grid sensor, PIC 16F877, PWM.

I. Introduction

Automated windshield wiper system is used to detect rainfall and activate automobile windshield wipers without driver interaction. The system is developed to mitigate driving distractions and allow drivers to focus on their primary task of driving. The distraction eliminated with the development of this product is the manual adjustment of windshield wipers when driving in precipitation. The few seconds that a driver takes their attention off the road to adjust a knob while driving in poor weather conditions could potentially lead to car accidents.

The National Highway and Transportation Safety Association reports that twenty-six percent of all car accidents are caused by distractions due to talking on cell phones, eating while driving, and other similar distractions that take a driver's focus off the road. The distraction considered in this project is the adjustment of wiper speed based on the intensity of precipitation falling. The number of accidents caused by distraction can be slightly reduced by eliminating the need for drivers to adjust wiper speed.

A control circuit for a windshield wiper motor is developed in which the wiper motor is made automatically responsive to the presence of moisture droplets on the grid sensor causing the wiper blades to sweep back and forth at a rate dependent upon the level of precipitation encountered. In this project, design and working of Windshield wiper speed control will be discussed taking into account the recent challenges in the windshield assembly. The system uses a grid sensor to detect rain and its intensity. The ADC in the controller detects the sensor input and gives the signal to the driver circuit. The motor driver actuates the motor to run at high speed or low speed based on the amount of rain detected.

The microcontroller used for the design is PIC16f877A. Here the discussion has been confined towards automatic windshield wiper which has a lot of advantages over the basic technology that is used normally in today's world. The low-cost solution proposed by the design will most importantly satisfy the safety and performance requirements needed for the driver at a more reasonable price. The windshield wiper system will manage to do this by the performance of an inexpensive grid sensor.

II. Objective

The project is an endeavor towards an effective design and development of an automatic windshield wiper system, based on intensity of rain.

The following are the main objective

1. To design hardware for the system using PIC 16F877A microcontroller.
2. To develop an experimental setup.
3. The simulation is done in MATLAB using Fuzzy approach to check possible additional feature of system i.e. to predict the intensity of rain.

III. System Description

The following Fig. 1[1] shows block diagram of working of automatic smart windshield Wiper. The grid rain sensor is used to detect the amount of the rain and its intensity. This gives the signal to the microcontroller. The ADC in the controller detects the grid sensor output and gives the signal to the PIC microcontroller. A PIC16F877A has an in-built Capture/Compare /PWM (CCP1) module for which the I/O pin is served by RC2 (Pin No. 17).

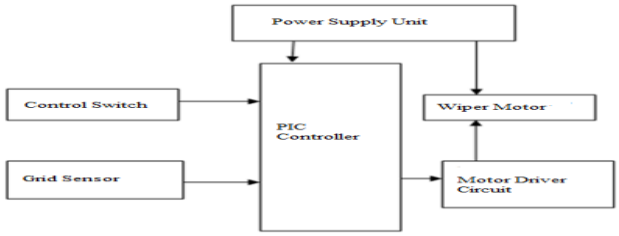


Fig. 1 Working of automatic smart windshield wiper

In this project CCP1 (PWM) is used to control the speed of DC motor. PWM stands for the Pulse Width Modulation where the width of a digital waveform is varied to control the power delivered to a load. The underlying principle in the whole process is that the average power delivered is directly proportional to the modulation duty cycle as shown in Fig. 2.

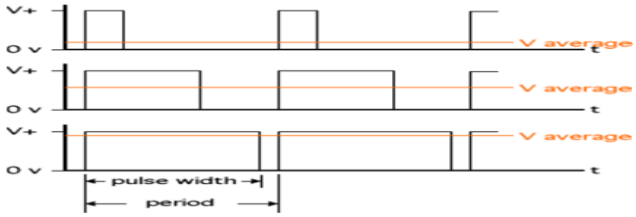


Fig. 2 PWM with different duty cycle

IV. Hardware and Software

This section describes the hardware required for actual implementation and the software used for simulating the test results. The speed of the wiper is controlled electronically with the help of the microcontroller. In the software Description, Matlab 7.0 fuzzy logic toolbox is used predict the intensity of rain such as high rain, normal rain, medium rain and drizzle (low rain) with the help of sensor output voltage.

A. Hardware Description

The grid sensor is used to detect the amount of the rain and give the signal to the controller. The ADC in the controller detects the sensor input and gives the signal to the driver circuit. The motor driver actuates the motor to run at high speed or low speed based on the amount of the intensity of rain detected. PIC 16F877A microcontroller acts like the brain of the automatic smart windshield wiper motor speed control system. The microcontroller chip has been selected for the purpose of controlling the speed of DC motor.

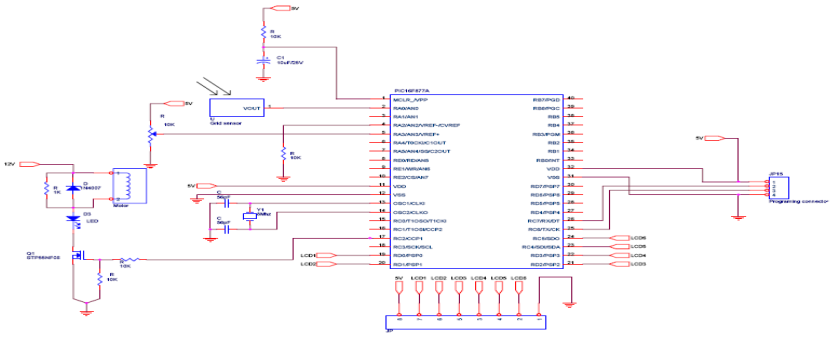


Fig. 3 Schematic circuit of PIC16F877A

Fig. 3 shows the schematic circuit of microcontroller PIC16F877A. Pins not stated in the table are not used and left hanging. At the beginning, microcontroller will receive signal from grid sensor which detect rainsquall & intensity. Accordingly the microcontroller will operate as it programmed to produce a new duty cycle (from CCP1) that proportional to intensity of rain.

B. Software Description

The software used designing and simulating the test results. For software implementation, embedded C is used to program microcontroller. Besides, Matlab 7.0 fuzzy logic toolbox is used predict the intensity of rain such as high rain, normal rain, medium rain and drizzle (low rain) with the help of sensor output voltage. Hence fuzzy logic used for prediction of range of intensity of rain.

V. Experimental Result Analysis

The experimental test carried out for the project. First and foremost, an experiment is conducted to find out the relationship between sensor output voltage and % duty cycle of PWM, which changes the speed of wiper motor according to intensity of rain. Then various data collection of sensor output in voltage and % duty cycle. Cathode ray oscilloscope (CRO) is used to measure % duty cycle.

The Table 1 shows data recorded through experiment to plot the graph of sensor output voltage and % duty cycle is shown in Fig. 4.

Table 1 sensor output voltage and % duty cycle

Sensor output Voltage (V)	% Duty Cycle
4.2	16.67
3.76	24
3.41	30.76
2.87	42.85
2.41	50
1.96	58.33

From the following graph, it shows that as the sensor voltage decreases the % duty cycle increases, this is because the grid sensor is a part of voltage divider circuit. The grid sensor is based on the principle that the intensity of rain increases with decrease in sensor output voltage.

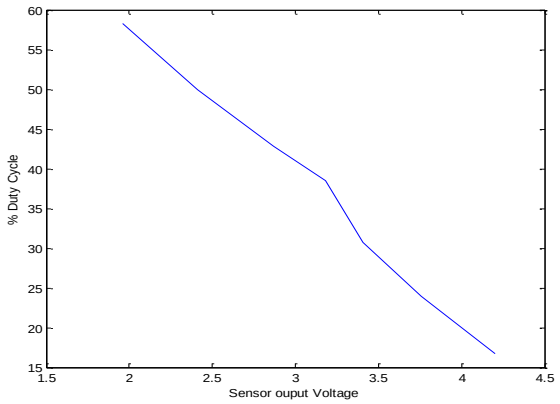


Fig. 4 Graph of sensor output voltage and % duty cycle

VI. Design and Development of Fuzzy logic Rain Intensity Control

Rainfall is the most uncertain part which cannot measure hence to tackle this problem fuzzy logic is used. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon imprecise, noisy, input information [2]. Fuzzy logic Matlab toolbox is used for prediction of intensity of rain with the help of sensor output voltage. The test is carried out by digital multimeter to measure the grid sensor output voltage at different rain intensity. A set of readings (100 readings) of sensor output voltage at different rain intensity position obtained from above test. Data recorded through experiment to plot the graph of Rain intensity and sensor output voltage is shown in Fig. 5.

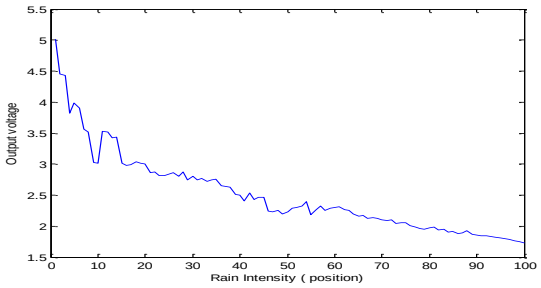


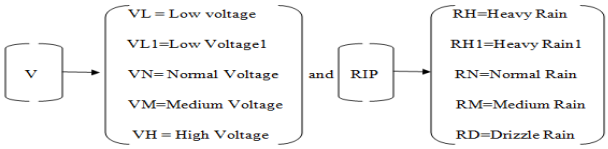
Fig. 5 Rain intensity Verses Sensor output voltages

The above graph describes intensity of rain at various voltages and also explains that up to 2 V it gives linear characteristics and later it gives nonlinear characteristics. Fuzzy logic controller is used to tackle above said problem. Fuzzy Logic steps are discussed below.

1. Fuzzifiction It identifies the input and output of the system,
2. defines appropriate IF-THEN rules,
3. and uses raw data to derive a membership function .[2]

1. Input variable -Voltage (V).
2. Output variables Rain intensity position (RIP).

For the easy and quick identification these sets are coded either by numbers / letters or words or both so called linguistic labels or linguistics variables. For the sake of convenience and simplicity both input/output variables have been linguistically or labels as below.



1.1 Fuzzy C-Means Clustering

The purpose of clustering is to identify natural groupings of data from a large data set to produce a concise representation of a system behavior. Clustering find the partitioned value according to user requirement from the set of reading obtained from the test.

2. Inference Evaluates all rules and determines their truth values.
   FIS uses "IF...THEN" rules for making necessary decision rules.
   E.g. If (Voltage is VL) then (RIP is RH)Fuzzy input output variables have been then fuzzified using triangular membership function with their fuzzy portioned

3. as shown in following Table 2 (a), (b) and Fig. 6(a), (b).

Table 2 (a) Membership Function of fuzzy input variable 'Voltage'

Linguistics Variables (Labels)	Partitioned Value	Fuzzy spaced Values	
		Min.	Max.
VL	2	2	2
VL1	2	2	2.06
VN	2.06	2	2.98
VM	2.98	2.06	3.63
VH	3.63	2.98	3.63

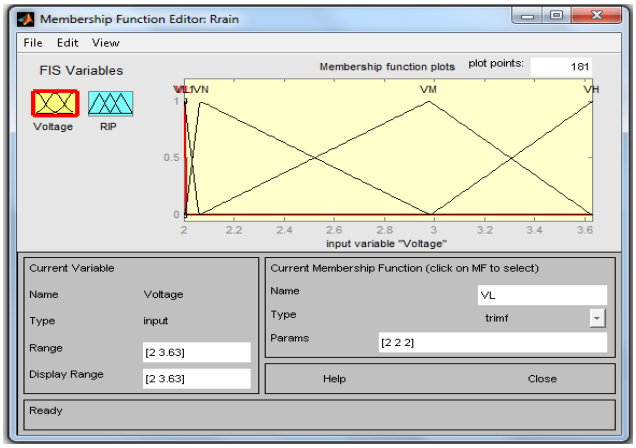


Fig. 6 (a) Triangular membership function of voltage 'V'

Table 2 (b) Membership Function of fuzzy output variables 'RIP'

Linguistics Variables (Labels)	**Partitioned Value**	**Fuzzy spaced values**	
		Min.	Max.
RH	9^{th}	9^{th}	30^{th}
RH1	30^{th}	9^{th}	50^{th}
RN	50^{th}	30^{th}	71^{th}
RM	71^{th}	50^{th}	92^{th}
RD	92^{th}	71^{th}	92^{th}

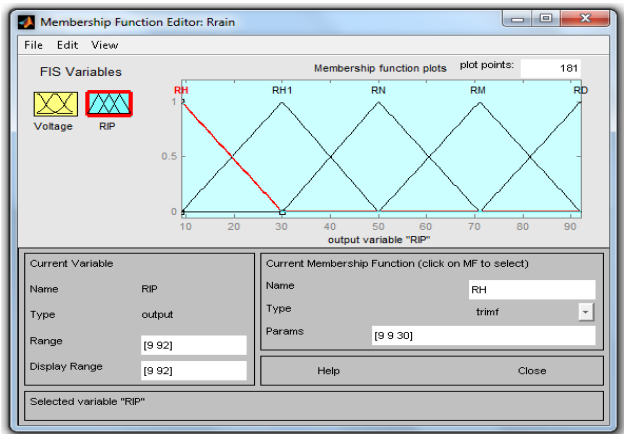


Fig. 6 (b) Triangular membership function of Rain Intensity 'RIP'

3. Composition -Rule Base

The fuzzy rule base structure has been created from the actually data accumulated during real run of the windshield wiper system.

Some rules have been presented in

If (Voltage is VL) then (RIP is RH)

- If (Voltage is VL1) then (RIP is RH1)
- If (Voltage is VN) then (RIP is RN)
- If (Voltage is VM) then (RIP is RD)
- If (Voltage is VH) then (RIP is RD)
- If (Voltage is VM) then (RIP is RM)

4. Defuzzification

The process of converting the fuzzy output is called defuzzification [4]. Rule viewer is the output which is used to predict the rain intensity as sensor voltage changes as shown in Fig. 7.

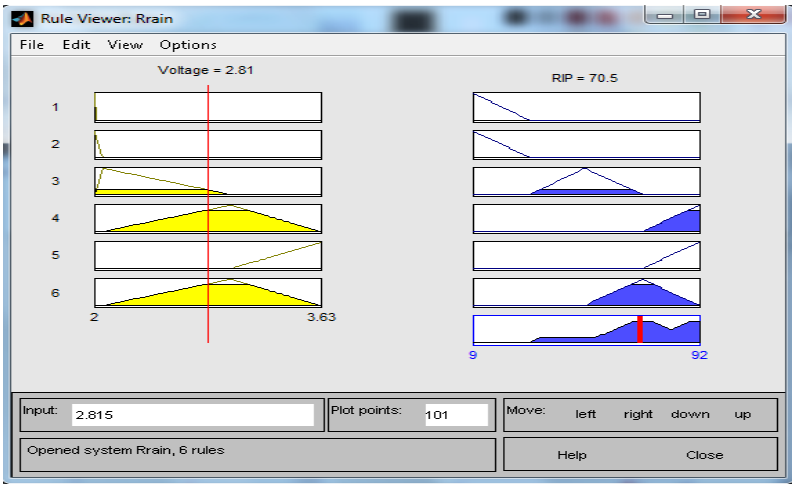


Fig. 7 Fuzzy inference and defuzzication process of Fuzzy logic rain intensity

The defuzzified output value is shown by the thick line passing through the aggregate fuzzy set. The Rule Viewer allows you to interpret the entire fuzzy inference process at once. The Rule Viewer also shows how the shape of certain membership functions influences the overall result

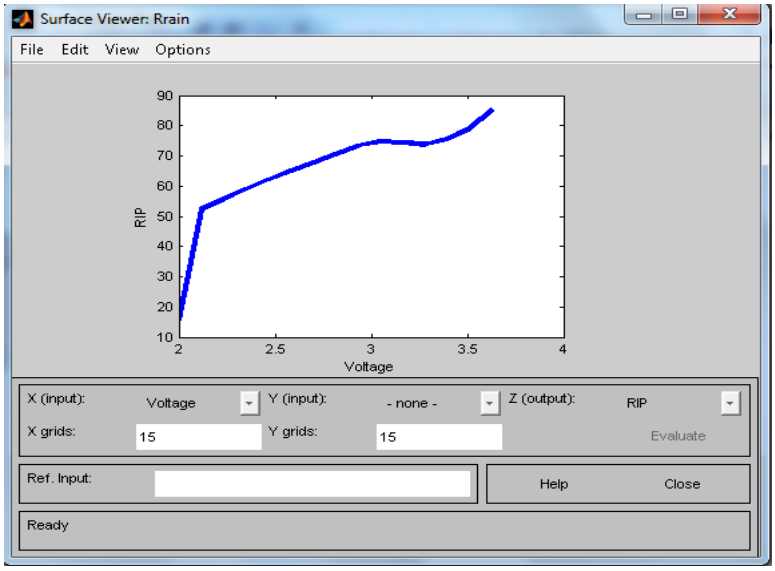


Fig. 8 Fuzzy rain intensity identification curve

The above Fig. 8 gives linear relationship between voltage and rain intensity position (RIP) and it reduces nonlinearity as shown in Fig. 5.

VI. Conclusion

An automated windshield wiper system is designed, developed, and demonstrated to detect rain and actuate the windshield wiper based on the intensity of rain.

An automatic wiper control system which is improved version of intermittent wiper system. This wiper system reduces cumbersome wiper operation and improves driver's comfort level. It will give a new dimension of comfort and aid to the drivers who work at night and traffic prone areas where they already have to concentrate on brakes and clutch. The removal of controlling the wipers during rain will provide them much ease and help them concentrate on the basic ABC (accelerator, brake and clutch) of driving. Hence the focus of this project work was to design and develop an automatic wiper control system to achieve the above mentioned objectives.

Fuzzy clustering is used to analyze the system behavior after taking the sensor output voltage readings at different rain intensity position. FIS editor of Matlab fuzzy logic controller is used to obtain the rule viewer and surface viewer. With the help of rule viewer user can predict the rain intensity by varying sensor output voltage more accurately.

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