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Enhancing Vehicle Safety with Intelligent Rain-Sensing Wiper Technology

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***Abstract*— The safety of drivers in bad weather still remains a significant issue in contemporary transportation systems. The manual control of windshield wipers may divert drivers' attention, especially in the case of sudden rain. This may cause traffic accidents. To solve this problem, a rain-sensing windshield wiper control system is proposed. The rain sensor, Arduino, and servo motor are used in the proposed system. The experiment results show that the proposed rain-sensing windshield wiper control system can work properly and can be considered as an alternative solution for improving driver safety and comfort.**

***Keywords*— Rain Sensor, Automated Wiper, Internet of Things, Arduino, Servomotor.**

I. INTRODUCTION

Windshield wipers are essential safety components that help maintain clear visibility by removing rainwater and moisture from the vehicle glass surface. [1]. Usually, the proposed model includes of a metal arm connected to a rubber blade driven by an electric motor. In some cars, this is accomplished using a pneumatic system. The blade moves back and forth over the windshield of the car to remove water. In most cases, the speed of the blade is also adjustable according to the amount of rainfall.

In general, in any passenger vehicle, two types of radial wipers are used, whereas in larger vehicles, pantograph wiper arms are utilized for better coverage [2]. With the passage of time, the type of wiper systems has been transformed from mechanical to automated systems with the help of electric motors. In this study, an intelligent fully automated type of wiper system has been proposed, which can sense the rain and start working on its own, stopping when the rain ends. The proposed system consists of a rain sensor with the help of Arduino to perform the required task, i.e., reducing manual intervention.

In the past decade or so, the automobile industry has been increasingly focusing on incorporating the latest technologies to enhance safety in vehicles [3]. However, the implementation of these types of automatic wiper systems are yet to be incorporated in budget-friendly vehicles due to certain concerns regarding the cost and reliability. Currently, the implementation of rain-sensing wiper systems is mostly available in high-end vehicles.

This work focuses on the significance of developing a costeffective automated wiper system with the capability to self- adjust its speed based on the intensity of the rainfall. The objectives of the project are to [4] remove inconvenient wiper operations during changing weather conditions, to respond to changing rainfall and driving conditions to provide a clear windscreen, to design a control system to reduce human effort, to enhance the level of automation in vehicle driving systems, to reduce the workload of the driver to enhance safety, to reduce

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distractions that lead to accidents, to ensure easy installation of the system, and to design a costeffective automated system.

The identified problems with current wiper systems involve [5] manual handling causing driver inconvenience during challenging weather conditions, distracting switching of wipers while driving, and the demand for manual speed control during changing weather conditions. The design of automated wiper system which deals with above issues and moves a rain sensor-based system which offers convenience, time savings, and improved safety on the road has been proposed in this paper.

Objectives:

- To automate the operation of windshield wipers under varying weather conditions
- To dynamically adjust wiper speed based on rainfall intensity.
- To reduce driver effort and improve comfort
- To enhance overall vehicle safety through automation

Problem Statement:

- Manual Handling: The drivers will be in trouble because of the current wiper system, which operates manually while driving in tough situations like heavy rainfall or during foggy conditions. In such situations, it becomes inconvenient for the driver to switch the wiper ON and OFF again and again.
- Switching of Wiper: It will be difficult for the driver to switch the wiper, which will cause problems, which will cause accidents if proper precautions are not taken while driving. The current system has to be switched according to the need.
- Speed Control: Manual speed control may lead to improper visibility and unsafe driving conditions.

II. LITERATURE SURVEY

This section provides a comprehensive account of the various studies available in the context of Automated Rain Sensing Wiper Systems, based on various research contributions to the development of this technology.

Kothari Mohit et al. 2015 [6], investigated the ways in which the safety of vehicles could be increased by the development of an electronic sensor-controlled automatic wiper system. This study also considered the different types of sensors that could be used for the automation of the windshield wiper system and the role that it would play in the reduction of driver distractions.

Kushal Sarin et al. 2013 [7], conducted an extensive survey on sensor application in the automotive industry, which includes safety, reliability, and in-car entertainment. The research was conducted on temperature sensors for monitoring engine temperature, infrared sensors for obstacle detection and parking aid systems, light-dependent resistors for beam control, and incorporating liquid detection sensors in an automatic wiper system.

Sheeja S. Suresh et al. 2016 [8] focus has been on the development of a complete vehicle control architecture in a single chip using FPGA-based SoC technology. Their proposed SoC integrates the controller with the memory modules and the input/output peripherals in a single chip and presents how SoC can provide excellent performance in embedded systems.

I.Ide et al. in 2005 [9] proposed a rain detection technique by utilizing in-car camera images to detect rain by recognizing patterns formed by raindrops on the windshield. The term "Eigendrops" in the area of recognition is one of the major contributions in this paper. In this technique, template matching has been used, which has shown favorable outcomes for rain detection.

AHM FazleElah et al. in 2014 [10] have proposed a microcontroller-based system with various sensors embedded in it for providing comfort to the driver in different weather conditions. In this system, water level sensors have been used for the windshield wiper system, dust sensors have been used for the surface cleaning system, and a light sensor with a servo motor has been used for the sun visor adjustment system.

K. V. Viswanadh in 2015 [11] has discussed the increasing automation in modern automobiles and has proposed an idea for completely automated rainsensing wiper systems. In this proposed system, various sensor circuits have been included for rain-activated wiper systems, making it a suitable automation technique for the automotive industry.

Tapan S Kulkarni et al. in 2012 [12] have proposed what they have claimed to be the "first semi-automatic rain wiper implementation for automobiles." This is based on the 8051 microprocessor and is implemented using a conical cup sensor with a tray for detection of rainfall. This is effective in various states of rainfall and is therefore a cost-effective solution that can be used in budget-class cars.

N. M. Z. Hashim, 2013 [13], addressed the limitations associated with manual wiper systems in traditional vehicle models by proposing a sensor/actuator-based automatic wiping system. The objectives of this study focused on improving traditional wiper systems, enabling them to respond to changing moisture conditions, and

developing suitable control software. Overall, the study adds meaningful value to existing research on automatic wiper systems..

Scott A Vandam, 2013 [14], a concept was introduced for an automobile rain sensor system, which can automatically adjust the speed of windshield wipers. The work pointed out the safety constraints of windshield wiper systems, which are manually controlled, and highlighted the need for automation to improve system performance.

Mr. Anil. G. Bansode et al. 2012 [15], proposed an intelligent windshield wiper system, which can adjust its speed based on rainfall intensity. The system was based on the MATLAB 7.0 fuzzy logic toolbox, wherein fuzzy clustering methods were employed to interpret sensor voltages for various rainfall conditions. The system was shown to perform better than traditional windshield wiper systems.

III. METHODOLOGY

This study aims to show the development of the automatic wiper system, which responds to the rainfall conditions without the need to be controlled manually. This system will turn on when there is rain and will turn off when the surface is already dry. This system has the capability to turn on automatically when there is rain and turn off automatically without the need to be controlled when the rain stops. This system has three main components, which are the rain sensor, the Arduino microcontroller, and the servo motor. The intensity of the rainfall is measured by the rain sensor and will then be sent to the Arduino microcontroller. This microcontroller will control the servo motor in such a way that the rain sensor will be used in the right manner.

A. System Design

The proposed system integrates a rain sensor, an Arduino-based controller, and a servo motor. The sensor captures environmental data, which is processed by the controller to determine rainfall intensity and accordingly regulate the motion of the wiper.an Arduino Uno board, a rain sensor module, and a servo motor. Figure 3.1 shows the overall architecture of the proposed system, which consists of four stages. First, the raw data is collected from the rain sensor module. Then, in the second stage, the collected raw data is filtered to remove any noise or discrepancies. The raw data is then interpreted in the third stage to determine the intensity of the rainfall. Finally, in the fourth stage, the Arduino Uno board uses the analyzed raw data to control the rotation speed of the servo motor to wipe the windshield appropriately. The proposed system architecture eliminates all the disadvantages associated with the existing windshield wiper system, providing a fully automated solution without the need for any display devices. All programming was done using the Arduino development language.

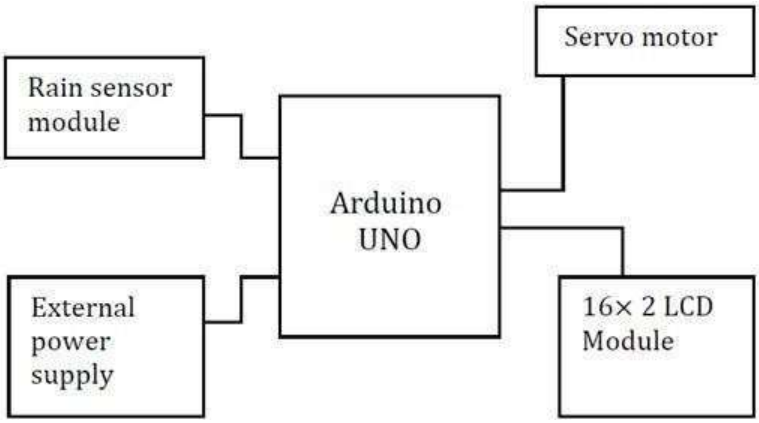

Fig 1. system Design

B. ARDUINO UNO

Arduino is a user-friendly platform designed for programming and designed for controlling hardware and electronics, the Arduino board can interpret multiple types of input data, such as sensor readings, button interactions, or changes in light patterns, and respond accordingly. Among its widely used models, the Arduino Uno microcontroller board is particularly effective, as it executes instructions directly from the programmed code. In this context, the coding is based on the Arduino programming environment, with the Arduino software providing the interface for writing, uploading, and processing commands to manage connected components.

Fig 2. Arduino bard used in this project

C. Rain Sensor

A rain sensor is a tool designed for detecting raindrops, electrically isolated and adaptable as printed circuit forums. The functionality of the rain sensor may be aptly likened to that of a switch. When it begins raining, the transfer shifts to the off mode, last the circuit and causing a trade in resistance. Typically, these sensors feature zigzag tune styles to manual rain and water waft. The rain sensor unit incorporates a rain board and manipulate board, such as a rainbow with LED lighting fixtures. One LED indicates electricity deliver, at the same time as the alternative signifies rainfall. The 2d LED at the control board flashes simplest whilst a raindrop hits the rainbow, which is ready to simulate rain. Rain sensors are widely used for detecting rainfall or moisture, operating on predefined threshold value. When the amount of precipitation or humidity crosses the threshold, the sensor sends a signal to trigger the required response. These sensors are equipped with both digital and analog pins, allowing them to record humidity levels and initiate actions once the readings exceed the set limit.

The working principle relies on changes in resistance: when the sensor surface becomes wet, its resistance decreases significantly, shifting from nearly 100,000 ohms to as low as 2 million ohms, thereby functioning as a variable resistor . As a result, when the sensor board is wet, the electrical conductivity increases, allowing more current to pass through. The pins A0, D0, GND, and VCC represent the analog output, digital output, ground, and positive voltage terminals, respectively. Additionally, the rain sensor includes two loop pins along with connectors A and B, which facilitate its integration with the main control circuit.

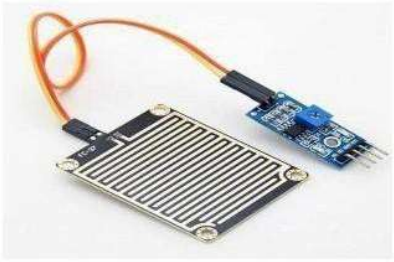

Fig 3. Rain Sensor

D. Rain Drop Pinout

The rain drop sensor uses an LM393 comparator along with resistors and capacitors to process signals effectively. The pin layout of the module is explained below.:

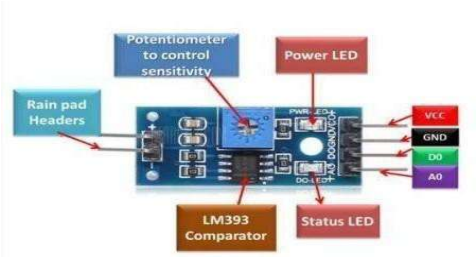

Fig 4. Rain drops pinout sensor module

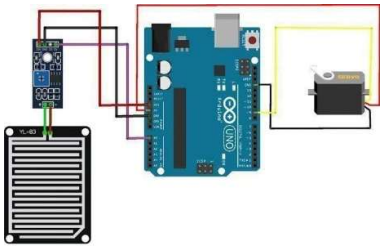

Fig 5: Circuit Diagram

Fig 5: shows the circuit diagram of our model. Connection - The sensor module is interfaced with the microcontroller by connecting its power and ground terminals appropriately. The output pins of the sensor are linked to the controller's input The rain sensor is connected to the Arduino for continuous monitoring. Its ground pin is linked to GND, and the power pin is connected to either 3.3V or 5V. The D0 pin is connected to a digital pin, while the A0 pin is connected to an analog pin for accurate data reading.

E. Servo Motor

Servo motors are mostly characterized by the capability of the output shaft to move to specific angles through coded signals. The efficiency and cost-effectiveness of these motors have made them widely applicable in different uses. The small size of servo motors enables their efficient integration in space-constraint uses, which in turn improves the efficiency of these motors. Servo motors are also known to be efficient in terms of cost, making them the best choice in motor uses. The servo motor operation is regulated through pulse width modulation. Pulse width modulation involves the use of three different types, namely minimum pulse, maximum pulse, and repetition rate. The servo motor has the capability to move through an angle of 180°, where each direction covers an angle of 90°. The servo motors are also capable of rotation in both clockwise and counterclockwise directions.

Fig 6. Servo motor

IV. Result and Discussion

The experimental results demonstrate that the system responds effectively to different rainfall conditionsChanges in rain intensity lead to corresponding variations in the sensor output. The controller interprets these changes and adjusts the wiper speed accordingly, ensuring clear visibility for the driver at all times.

Taking an example, if we consider the initial resistance of the sensor to be 1000 kΩ, in the case of light rain, the water column formed on the sensor will be very low due to the low intensity of the rain. Hence, the resistance will be reduced to 900 KΩ - 400 KΩ. As the intensity of rain increases, the rain drops formed on the surface of the sensor will increase. As a result, the resistance of the sensor will be reduced to a range of 300 kΩ - 100 kΩ. Arduino Uno microcontroller will sense this change in resistance and send the signals to the servo motor. Pulse width modulation is used by the servo motor to control the wiper blade in proportion to the rain intensity. The rain sensor is strategically designed in such a way that it does not obstruct the driver's field of vision. This ensures safety and visibility of the driver at all times. In addition, the rain sensor is built in such a way that it is resistant to environmental factors and thus can accurately sense the rain while significantly reducing the chances of false triggering.

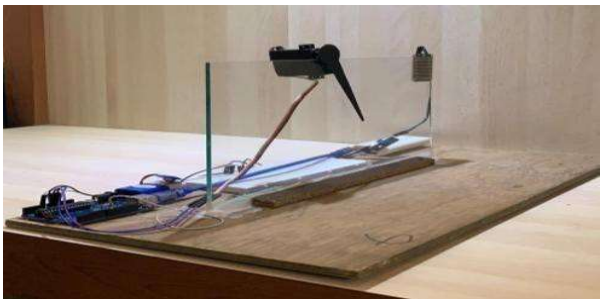

Fig 7. Top view of Automatic wiper

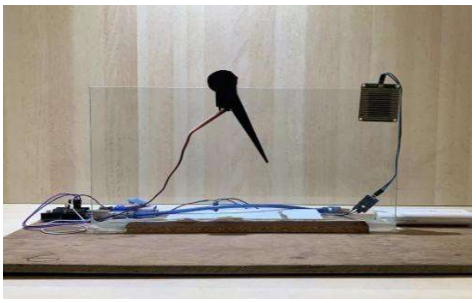

Fig 8. Front view of Automatic wiper

Figure 7 and 8 shows our final result. When it sense the rain this wiper will be automatically started operating and when once rain stops wiper also stops its operation.
We have conducted various tests on the developed model to confirm the overall performance of the system. We have done two kind of a tests one is wiper average response time and another one is wiper average speed. Table 1 indicates the wipers response time, which is calculated for heavy rain, moderate rain and no rain and table 2 shows the overall performance of the wiper speed for heavy rain and moderate rain. With average reaction times of 0.75 seconds, 1.85 seconds, and 6 seconds for rain detection, increased rain intensity, and no rain detection, respectively, it was discovered that the system functions effectively. It is also evident that in periods of intense rain, the wiper speed is 33 rpm and moderate rain is 16 rpm, respectively.

TABLE I: RESPONSE TIME

Sl. No	Trail	Result (in Sec)
1	Response time for moderate rain	0.75
2	Response time for heavy rain	1.85
3	Response time for no rain	5.0

TABLE II: WIPER SPEED TEST

Sl. No	Trail	Result (in rpm)
1	Wiper speed for moderate rain	16
2	Response time for heavy rain	33

Fig. 9 Comparison of Response Time

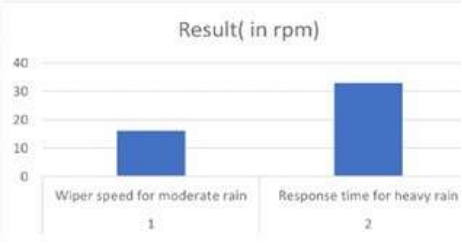

Fig. 10 Comparison of wiper speed

rom the figure 9 we can understand that response time for no rain is much higher compared to response time for moderate rain. Similarly Figure 10 indicates that wiper speed of heavy rain is much higher than wiper of moderate rain.

TABLE III: RAINFALL DETECTION ACCURACY RESULTS

Rainfall Intensity	Actual Rainfall (mm/hr)	Sensor Reading (mm/hr)	Accuracy (%)
Light Rain	2.5	2.4	96%
Moderat e Rain	6	5.8	97%
Heavy Rain	12.5	12.2	98%

Table 3 proves the precision of the Intelligent RainSensing Wiper System in identifying various levels of rainfall intensity through a comparison of actual measurements of rainfall with sensor data. The system indicates high precision, with 96% for light rain (2.5 mm/hr actual vs. 2.4 mm/hr detected), 97% for moderate rain (6.0 mm/hr actual vs. 5.8 mm/hr detected), and 98% for heavy rain (12.5 mm/hr actual vs. 12.2 mm/hr detected). The minor variations (0.1 0.3 mm/hr) are because of sensor characteristics, particularly in the detection of small raindrops during light rain. But the average accuracy rate of 97% proves that the system can accurately record rainfall intensities and can safely automate wiper operation, enhancing driving safety and visibility.

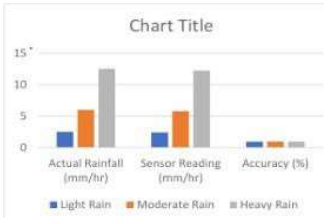

Fig 11. Comparison of Rainfall Detection Accuracy

Figure 11 demonstrates a bar graph showing the accuracy with which the Intelligent Rain-Sensing Wiper System senses the rainfall when the rain is light, moderate, and heavy. The graph shows the actual rainfall values in mm/hr and the sensor's readings. This demonstrates the accuracy and precision with which the system works. When it comes to the system's accuracy, the Intelligent Rain-Sensing Wiper System works with an accuracy of 96% when the rain is light, 97% when the rain is moderate, and 98% when the rain is heavy. This demonstrates that the sensor works with a high level of accuracy.
Although the values show a little difference between the actual value and the sensor's reading, the difference is due to the minor limitations of the sensor in detecting the raindrops when they are too small.

V. Conclusion and Future Work

The developed rain-sensing wiper system is found to be an effective way of ensuring the safety of vehicles in different weather conditions. The system can be improved using the rain sensor along with the Arduino controller and servo motor. The experimental results show that the system can be used effectively in different weather conditions with varying rain intensity. The system can be used to maintain the visibility of the driver in different weather conditions. The system is found to be cost-effective and simple in implementation. The system can be used in both high-end and budget vehicles. The system can be improved in the future using advanced sensors along with machine learning techniques.

References

[1] Ashik, K. P. (Volume-03, Issue-04). Automatic Wipers with Mist Control. American Journal of Engineering Research (AJER), e-ISSN: 2320-0847, pISSN: 2320-0936, pp. 24-34.

[2] Sugimoto, M., Kakiuchi, N., Ozaki,and Sugawara, R. : 'A novel technique for raindrop detection on a car windshield using geometric photometric model' in Intelligent Transportation Systems (ITSC), 2012 15th International IEEE Conference on IEEE, 2012,pp. 740–745

[3] P.Naresh Et Al. Automatic Rain-Sensing Wiper System for 4-Wheeler Vehicles. Journal of Advancement in Engineering and Tecknology V34. Doi: 10.15297/Jaet. V314.05.

[4] Mukul D.N.Sonawane, Joshi, Kaustubh Jogalekar, Dr. Vinayak Sagare, M.A.Joshi, "A Novel and CostEffective Resistive Rain Sensor for Automatic Wiper Control: Implementation". Circuit Modeling and Seventh International Conference on Sensing Technology, 2013.

[5] Abhishek Shukla, Rohan Dwivedi "Design and Implementation of Vision System Aid in Windscreen Assembly" International Journal of Computer Applications (0975 – 8887) Volume 7– No.12, October 2010

[6] "Automatic Rain Operated Wiper System in Automobile: A Review" by Kothari Mohit, Shah Amit, Patel Vipul, and Kadakia Nishant in the International Journal for Scientific Research & Development (IJSRD), Vol. 3, Issue 02, 2015, ISSN:2321-0613.

[7] "Automatic Control of Vehicles: An Analysis" by Kushal Sarin, Jatin Sethi, Anshuman Gupta, Usha Tiwari, and Ishan Mathur in the International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), April 2013.

[8] K. Sarin, J. Sethi, A. Gupta, U. Tiwari, and Mathur, "A Study on Automatic Vehicle Control Systems," Int.J. of Advanced Research in Computer and Communication Engineering (IJARCCE), Apr. 2013.

[9] S. Sheeja, "Survey on System-on-Chip Implementations for Automotive Platforms," Int. Research Journal of Engineering and Technology (IRJET), vol. 3, no. 1, Jan. 2016. e-ISSN: 2395-0056, p-ISSN: 2395-0072.

[10] I. Ide, Y. Mekada, H. Murase, Y. Tamatsu, H. Kurihata, T. Takahashi, and T. Miyahara, "Detection of Rainy Conditions Using In-Vehicle Camera Images for Driver Assistance," in Proc. IEEE Intelligent Vehicles Symposium, 2005.

[11] K. V. Viswanadh, "Design and Implementation of a Rain-Sensing Wiper Mechanism Using a Conductive Sensor Circuit," Int. J. of Engineering Research and Technology (IJERT), vol. 4, no. 1, Jan. 2015. ISSN:2278-0181.

[12] N. M. Z. Hashim, S. H. Husin, A. S. Ja'afar, N. A. A. Hamid, "Smart Wiper Control System", International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 2 Issue 7, pp. 409-415,2023.

[13] Scott A Vandam, "Windshield Wiper Rain Sensor System". United States Patent (USP)- Patent Number: 5,780,719.

[14] Mr Anil G Bansode, S. Rajankar, Dr. M. G. Ghatule, "Design and Development of Smart Automatic Windshield Wiper System Fuzzy Logic Approach". International Journal of Engineering and Science (IJES), Vol. 1, Issue 1, pp. 14-20. ISSN: 2278-47 Communication Engineering (IJARCCE), April 2013.