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Analysis of a Hybrid Model of Automated Vehicle Safety System Consists of Rain Sensor-Controlled Wiper and Ultrasonic Sensor-Based Auto-Braking System

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Abstract:

This paper presents an analysis of a novel hybrid model integrating two crucial safety features in modern vehicles: a Rain Sensor-Controlled Wiper (RSCW) and an Ultrasonic Sensor-Based Auto-Braking System (US-ABS) using Arduino UNO micro-controller. The integration of these systems aims to enhance vehicle safety by addressing two critical aspects: visibility during adverse weather conditions and collision avoidance through automated braking mechanisms. The Rain Sensor-Controlled Wiper (RSCW) component utilizes advanced sensor technology to detect precipitation on the vehicle's windshield accurately. Upon detection, the system automatically activates the wiper mechanism, tuning the wiper speed and frequency according to the amount of rainfall. By ensuring optimal visibility, the RSCW system significantly reduces the possibility of mishaps brought on by vision impairment due to rain, snow, or other weather phenomena. Complementing the RSCW, the Ultrasonic Sensor-Based Auto-Braking System (US-ABS) serves as a proactive safety measure to prevent collisions. Employing ultrasonic sensors strategically positioned around the vehicle, the US-ABS continuously monitors the surrounding environment for obstacles, vehicles, or pedestrians. When an imminent collision risk is detected, the system triggers automatic braking interventions to mitigate or entirely prevent potential accidents. In this analysis, we evaluate the effectiveness of the hybrid model by considering various factors, including accuracy, response time, and real-world performance. We have explored potential synergies between the RSCW and US-ABS components, assessing how their integration can further improve overall safety and reliability.

Keywords: Rain Sensor, Controlled Wiper, Ultrasonic Sensor, Auto-Braking System,hybrid model, Arduino UNO microcontroller.

1. Introduction & Literature

The quick development of the automobile and transportation industries has made travel faster. The quicker moving traffic means that drivers can no longer afford to devote much attention to manually operating several more distinct systems. This kind of equipment is the windscreen wiper system, which helps drivers see more clearly by clearing the windscreen during periods of rain or snow. It may be very challenging to manually operate a wiper system under certain conditions. For example, heavy-duty vehicle drivers have to manually shift the gearbox. In inclement weather, it might be challenging to operate the windscreen wiper system and the ABC (acceleration, brake, and clutch) simultaneously, which increases the risk of catastrophic accidents. Windscreen wiper devices that operate automatically can greatly enhance driving safety and the experience of driving in that circumstance. In motorsport, where racers must drive attentively since even a moment's attention might result in a loss of the race or major accidents, automatic windscreen wiper systems are particularly common. Regardless of the weather, the racers leave the device on throughout the race in order to avoid operating the windscreen wiper. Without the racer active, visibility may be maintained with an automated windscreen wiper system. Babu et al. have designed and given detail the creation of an automated wiper that uses a conductive rain sensor to identify drops of rain[31][33][36]. This autonomous wiper was created by integrating a sensor and controller with an already-existing wiper system. The microcontroller receives a signal from the rain sensor, interprets the information, and then triggers the driver integrated circuit to turn on the wiper motor. These adjustments allow the glass to be automatically cleaned, saving the driver's assistance. A motor that is powered by electricity propels this arm. The droplets are removed from the windshield by the blade pivoting back and forth. The infrared receiver picks up the optical signal and converts it to electrical energy. After shaping and filtering the voltage, the MCU analyzes it and makes necessary adjustments. It then sends out various duty cycles to manage the intermittent operation of the windscreen wiper motor.

As part of the research conducted by Babu et al. (2015), "Design & Fabrication of Rain Operated Wiper Mechanism using Conductive Sensor Circuit," a control system called Automatic Rain driven WIPER is being developed. This system is based on an electronically controlled automotive rain driven motor. According to Sree et al. (2020), "Rain Sensing Automatic Car Wiper Using 555 Timer," International Journal of Technical Research & Science, 2020, when the rain sensor detects moisture, it sends a signal to the microcontroller, which interprets the data and powers on the driver integrated circuit to operate the wiper. The glass can be automatically cleaned with these tweaks, saving the driver's help. An Arduino-based automated rain sensor wiper is modeled in Biswas et al.'s work (2022). This approach may lead to increased safety for all those on the road or near the vehicles, not just the driver. According to Yanyan et al.'s 2011 study, "Design of Intelligent infrared Windscreen Wiper based on MCU," the experiment's results demonstrate the wiper's accuracy, sensitivity, and ability to detect rainfall. In addition, depending on different needs, it can be changed to a constantly variable gearbox. It is valued in usage because of its large development area and flawless functionality."Fabrication of Automatic Braking System Using Ultrasonic Sensor," Sri Krishna et al. (2023), one extremely practical and efficient technique to lower accident rates and raise traffic safety is to incorporate ultrasonic sensors into autonomous braking systems [35][36][37][38]. This gadget works by continuously measuring the distance between the car and objects using ultrasonic sensors. If the gap is too tiny, the brakes are deployed right away to prevent an accident. By enabling a fast and precise assessment of the distance between the vehicle and objects, ultrasonic sensors are employed to guarantee that the brakes are applied in time to prevent accidents. Ram et al. (2017) have presented work titled "Automatic Braking System Using Ultrasonic Sensor,". The future of vehicle security entails a shift in perspective towards health rather than merely producing a novel discovery.Although it is a significant divergence from the conventionalmedical approach, the Ultrasonic Breaking System method is necessary to achieve significant advantages. The publication "Intelligent Braking System Using Ultrasonic Sensor" by Kumari et al. (2019) describes the study and design of a mechatronic braking system that, when in use, may automatically apply brakes to any item that the ultrasonic sensor detects. Intelligent braking is one of the ingenious ways to stop a moving body in many automotive applications without causing spasmodic motion. The study shows that the vehicle's speed is managed in line with the predefined distance and that the development of intelligent braking applications depends critically on the performance of the ultrasonic sensor and microcontroller (motor driver). "Automatic Rain Operated Wiper System in Automobile: A Review," by Kadakia et al. was published in 2015. It will improve visibility and raise the driver's and any passengers' safety. Rain sensors were used in the majority of the articles, and they would activate as soon as they noticed a droplet of water on the windshield. Some of them employed a new sensor for the automatically operating rain-activated wiper, however they encountered some issues. Because of their simple design, rain sensors are the best option for automatically operating wipers when it rains, as shown by research publications. The rain sensor was utilized to develop the windscreen wiper, according to Said et al. (2016), "Design and Fabrication of Modified Circuit Connection for Automatic Wiper Using Rain Sensor." This personalized windshield wiper is easy to use and reduces the need for human intervention. Electricity from non-conventional sources is currently employed as a power source. For this project, the circuit connection still must be changed so that the automated wiper's speed is determined by the amount of rain that falls on the car's windshield."Intelligent Rain Sensing uses Automatic Wiper System," by Madankar et al. (2011), With this wiper technology, driving comfort is increased and the laborious wiper operation is reduced.For drivers who operate at night or in crowded areas where they already have to pay attention to their clutch and brakes, it will provide an additional degree of comfort and help. They'll live a lot easier and be able to concentrate on the three essential driving components—the clutch, stop, and accelerator—now that they won't have to struggle to manually control the wipers in the rain. Our technology's strengths include high sensitivity, high accuracy, and noncontact measurement [32][34].

Considering all the research gaps and recent research there is a requirement of real time experimental study is needed for the hybrid model of automated vehicle safety system consists of rain sensor-controlled wiper and ultrasonic sensor-based auto-braking system. In this analysis, we evaluate the effectiveness of the hybrid model by considering various factors, including accuracy, response time, and real-world performance. The lab-scale model has been designed and C++ programming code has been developed for the rain sensor and experiment has been conducted. The result obtained will be useful for the validation and design of hybrid model of automated vehicle.

2. Methodology:

Ensuring that the produced system satisfies all safety requirements and standards requires adherence to industry standards and regulations pertaining to vehicle safety systems throughout the methodology. Furthermore, cooperation between software developers, safety specialists, and automotive engineers is essential to the creation and successful execution of the hybrid safety system.

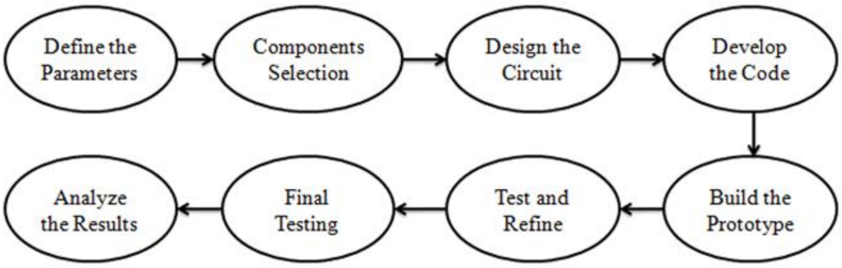

Figure 1 Flow chat for the overall process

2.1 Parameters under consideration:

When considering a hybrid model of an Automated Vehicle Safety System consisting of a Rain Sensor-Controlled Wiper and Ultrasonic Sensor-Based Auto-Braking System, several parameters come into consideration:

1. **Rain Intensity Sensing**: The sensitivity of the rain sensor in detecting various levels of rain intensity is crucial. This parameter determines when the wipers should be activated and at what speed they should operate.
2. **Wiper Activation Threshold**: There should be a threshold level of rain intensity or water accumulation on the windshield that triggers the activation of the wipers. Adjusting this threshold effectively ensures the wipers are activated at appropriate times, avoiding unnecessary usage in light rain or mist.
3. **Wiper Speed Control**: Depending on the amount of rain that is detected, the system must to be able to modify the wipers' speed. This setting makes sure the driver can see as well as possible and isn't distracted.
4. **Ultrasonic Sensor Range and Accuracy**: The range and accuracy of the ultrasonic sensors play a vital role in detecting obstacles or vehicles in the vehicle's path. Calibration of these sensors is essential to ensure reliable detection and avoidance of collisions.
5. **Braking Response Time**: The system's response time to apply brakes when an obstacle is detected by the ultrasonic sensors is critical for ensuring the safety of the vehicle and its occupants.
6. **Safety Margin for Braking**: There should be a predefined safety margin for braking to avoid collisions. This parameter determines how aggressively the system applies the brakes when detecting an obstacle.

7. **Integration and Coordination**: The coordination between the rain sensor-controlled wiper and the ultrasonic sensor-based auto-braking system is crucial. Parameters related to how these systems interact and share information need to be defined for seamless operation.
8. **Environmental Factors**: Parameters related to environmental conditions such as temperature, humidity, and visibility might also be considered to ensure the system's reliability under various circumstances.
9. **User Preferences**: Some parameters may be adjustable by the user based on their preferences, such as sensitivity levels, wiper speed settings, or braking aggressiveness.
10. **System Calibration and Testing**: Regular calibration and testing of the entire system are necessary to ensure that all parameters are set correctly and that the system functions reliably in real-world scenarios.

Overall, these parameters need to be carefully considered and optimized to design an effective and safe hybrid model of an Automated Vehicle Safety System.

2.2 Selection of Components:

Rain Sensor Module:

The output from the rain sensor might be either digital or analog. An analog signal between the supply values of 5V and 0V is provided by the AO (Analog Output) pin. The internal comparator circuit's digital output is provided by the DO (Digital Output) pin. An analog output provides a continuous voltage or current signal that varies according to the amount of moisture detected. In contrast, a digital output generates a binary signal that alternates between high and low levels based on whether rain is falling or not.

Arduino UNO:

The ATmega328P microprocessor is the foundation for the Arduino microcontroller board. It's one of the most well-liked Arduino boards, and a lot of DIY electronics projects, education, and prototyping use it. The Arduino Uno board includes a 16 MHz quartz crystal, 6 analog inputs, 14 digital input/output pins, a USB port, a power jack, an ICSP header, and a reset button. It can be powered by an external power source or a USB cable.

Pulse width modulation (PWM) is supported by the digital pins, which can be used for both input and output. PWM allows for the control of the intensity of digital output signals. Values from sensors or other analog devices can be read via the analog inputs. The Arduino Integrated Development Environment (IDE), a free software package that makes writing and uploading code to the board easier, is used to program the Arduino Uno board. Linux, Mac OS X, and Windows can all use the IDE. You may use the Arduino Uno board to operate a wide range of systems and devices, including lights, motors, sensors, and displays. It works with a variety of shields, which are add-on boards that increase the board's capabilities by including communication modules, sensors, and other features.

Ultrasonic Sensor:

Usually, ultrasonic sensors work by generating a brief burst or pulse of ultrasonic waves, detecting how long it takes for the waves' echo to return after bouncing off an object, and so on. The distance to the object can be computed with the use of this time measurement. The "10us high-level signal" specifies the duration of the pulse during which the ultrasonic sensor emits the ultrasonic waves. It means that the signal remains at a high voltage level (usually 5V) for 10 microseconds. The transducer or piezoelectric element inside the ultrasonic sensor generates the ultrasonic waves in response to this high-level signal. The sensor pulses, waits for an echo, and counts how long it takes for the echo to come back. The distance to the object can be calculated based on the time of flight of the ultrasonic wave "10 us TTL" refers to a 10 microsecond (us) duration pulse that uses Transistor-Transistor Logic (TTL) voltage levels.TTL is a common digital logic family that uses a voltage range to represent logical states. In TTL, a logic high (1 or "on" state) is typically represented by a voltage level near the power supply voltage (e.g., 5V), and a logic low (0 or "off" state) is represented by a voltage level near ground (e.g., 0V). When an ultrasonic sensor specifies a "10 us TTL" signal, it means that the pulse it emits for transmitting ultrasonic waves has a duration of 10 microseconds and follows the TTL voltage levels. During the pulse, the voltage level will be high (e.g., 5V) to indicate the "on" state or logic high. This TTL pulse is used to trigger the transducer or piezoelectric element within the ultrasonic sensor to emit the ultrasonic waves. The sensor then measures the time it takes for the echo of these waves to return after bouncing off an object to calculate the distance.

Table 1 Experimental specifications

Parameters	**Specifications**
Voltage	DC 5V
Current	15 mA
Frequency	40 Hz
Max Range	4 m
Min Range	2 cm
Measuring Angle	15 degree
Trigger Input signal	10 us TTL pulse
Echo Output Signal	Input TTL lever signal and the range in proportion
Dimension	45 x 20 x 15 mm

Motor:

The motor used in this project is powered by battery of 12V and the drawn input current is 1.203 A which is stall current.

Table 2 Specification of Motor

Sr.No.	**Parameters**	**Values**
1.	Current	1.203A
2.	Voltage	12V
3.	Speed (RPM)	64 rpm
4.	Resistance	9.97ohm
5.	Rotational Speed	6.70 rad/sec
6.	P_{out}	23.517 W
7.	P_{in}	14.436 W
8.	Efficiency	3.92

2.3 Design of Electric Circuit:

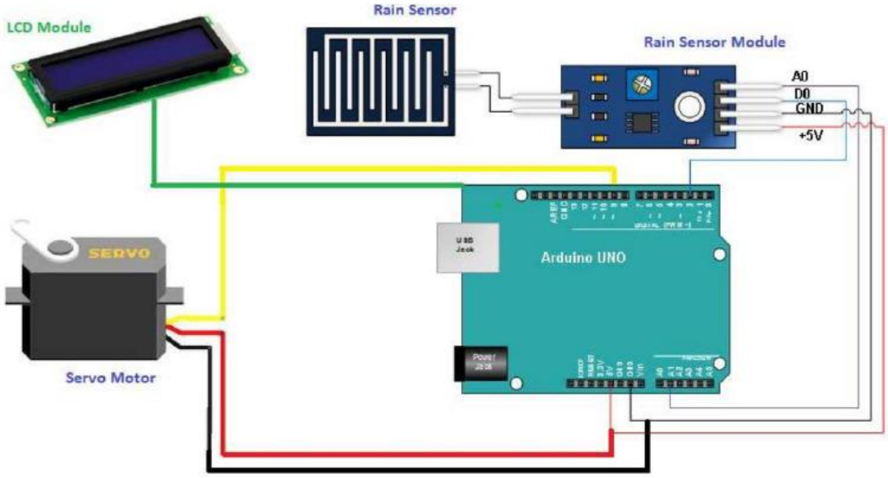

Figure 2 Electric circuit rain sensor module

2.4 Development of code:

C++/Code:

```
const int trigPin = 3;
const int echoPin = 2;
const int RAIN = 4;
const int Relay2 = 5;
#define DC_MOTOR 8
// defines pins
long duration;
int distance;
void setup() {
        pinMode(trigPin, OUTPUT); // Sets the trigPin as an Output
        pinMode(echoPin, INPUT); // Sets the echoPin as an Input
        pinMode(DC_MOTOR, OUTPUT);
        pinMode(RAIN, INPUT);
        pinMode(Relay2, OUTPUT);
        Serial.begin(9600); // For serial communication
}
void loop() {
        digitalWrite(trigPin, LOW);
        delayMicroseconds(2);
        digitalWrite(trigPin, HIGH);
        delayMicroseconds(10);
        digitalWrite(trigPin, LOW);
        duration = pulseIn(echoPin, HIGH);
        distance= duration*0.034/2; //Distance calculation
        Serial.print("Distance:"); // Printinng the distance on the Serial Monitor
```

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```
        Serial.println(distance); // Printinng the distance on the Serial Monitor
        if (distance < 30) {
                digitalWrite(DC_MOTOR,HIGH);
                Serial.println("DC MOTOR is ON Now!!");
                delay(500);
        }else {
                digitalWrite(DC_MOTOR, LOW);
                Serial.println("DC MOTOR is OFF Now!!");
                delay(500);
}       }
```

2.5 Development of Experimental Setup:

A lab scale automatic operated rain wiper system is developed for increasing driving ease inautomobile.A 3D CAD model is designed based on literature survey and selected suitable parameters.After assuming suitable parameters, firstly, a computer model is developed using 3D CAD and CATIA software that can be seen in fig.1 Thereafter, a lab scale experimental model has been developed.

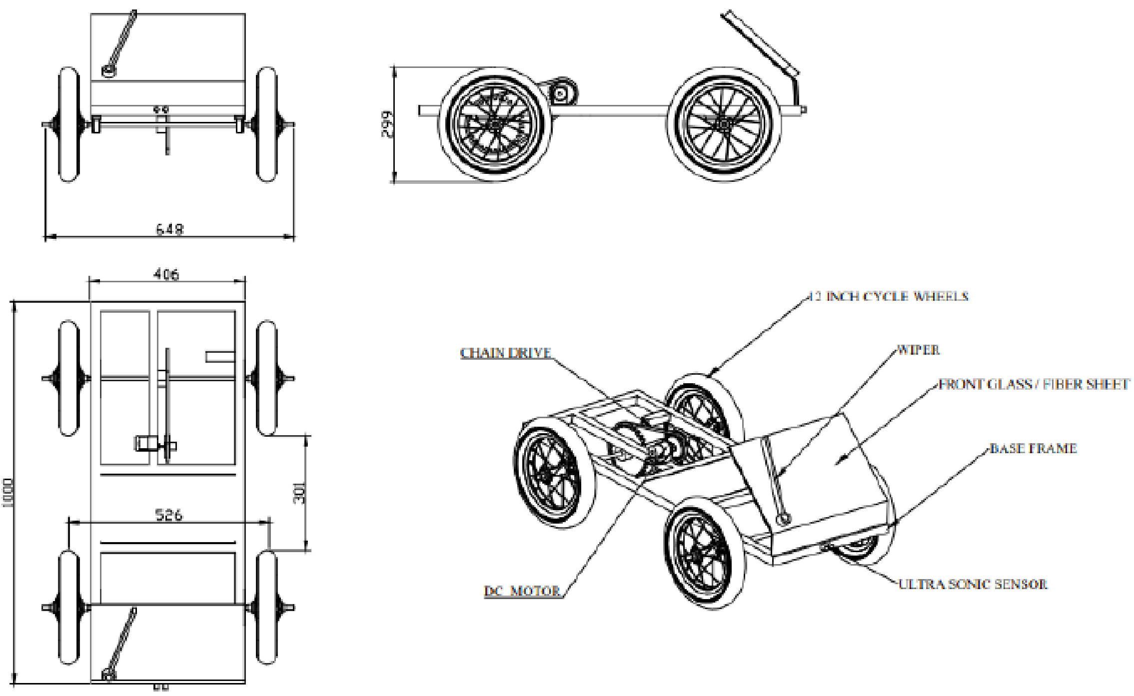

Figure 3 Drafting of experimental model using CATIA.

After assuming suitable parameters, firstly, a computer model is developed using 3D CAD and CATIA software that can be seen in figure 3 thereafter, a lab scale experimental model has been developed as can see in figure 4.

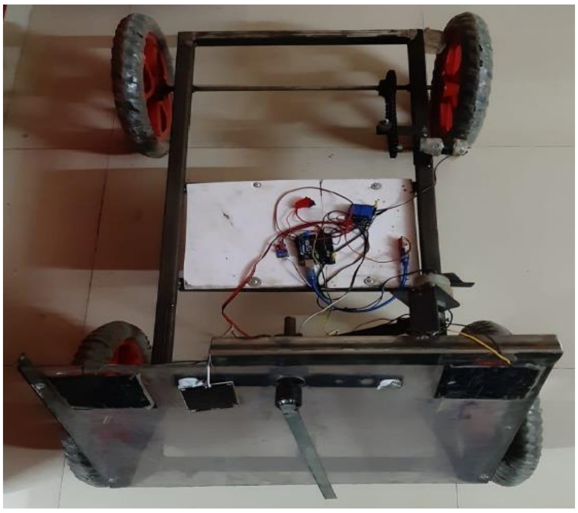

Fig. 4 Lab scale experimental model

Table 3 Component Specification

Components	Diameter(mm)	Length(mm)	Width(mm)
Frame	-	1000	400
Bolt	$D_h = 6$ $D_n = 2.22$	6	-
Chain	$D_{Tii} = 156$ $D_{Mi} = 69$ $D_{To} = 144$ $D_{Mo} = 81$	191.7	6
WindShield	-	400	263
Rim	Di = 191 Do = 215	Thickness = 43	-
Wheel	Di = 215 Do = 299	Thickness = 43	-

The motor used in this project is powered by battery of 12V and the drawn input current is 1.203 A which is stall current. Choose the components required to build the automated rain-operated wiper using an ultrasonic sensor. This includes the wiper motor, ultrasonic sensor, microcontroller, power source, and other components. For a rain sensor in a hybrid model of an Automated Vehicle Safety System, where it controls the wipers, the specifications need to ensure accurate detection of rainfall intensity to optimize wiper activation and speed. Here are some key specifications: Detection Range, Sensitivity, Response Time, and Accuracy.

3. Result & Discussion:

Table 4 Ultrasonic Sensor Experimental Readings

Sr.No	Distance (cm)	Time (milli-seconds)
1.	30	1.74
2.	40	2.3
3.	50	2.9
4.	60	3.4

For a distance of 30 cm, the time of flight is calculated as 1.74 milliseconds. This means that the ultrasonic wave will take 1.75 milliseconds to travel to the target object and back.

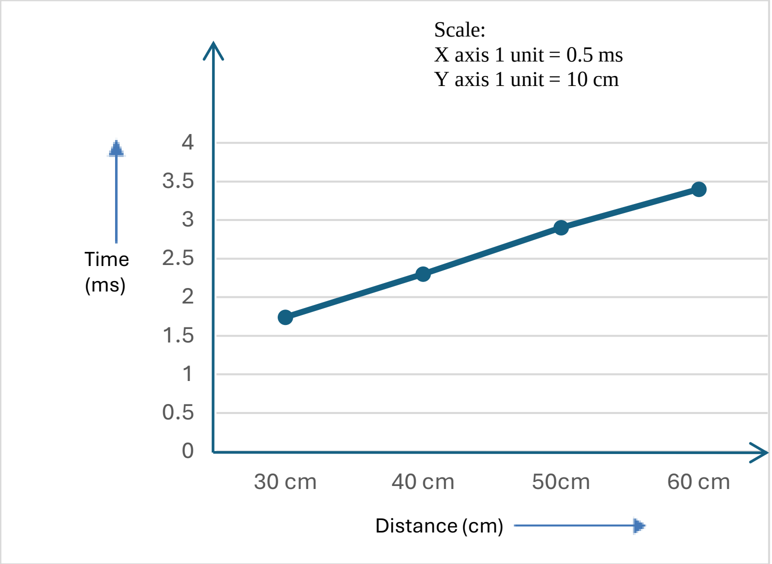

Fig. 5 Distance varies with time.

For Ultrasonic sensor the time for the signals to be received by receiver can be calculated using $S = \frac{v*t}{2}$. The time taken for ultrasonic waves to receiver depends on the distance between object and the sensor. It can be observed that as the distance increases, time increases linearly.

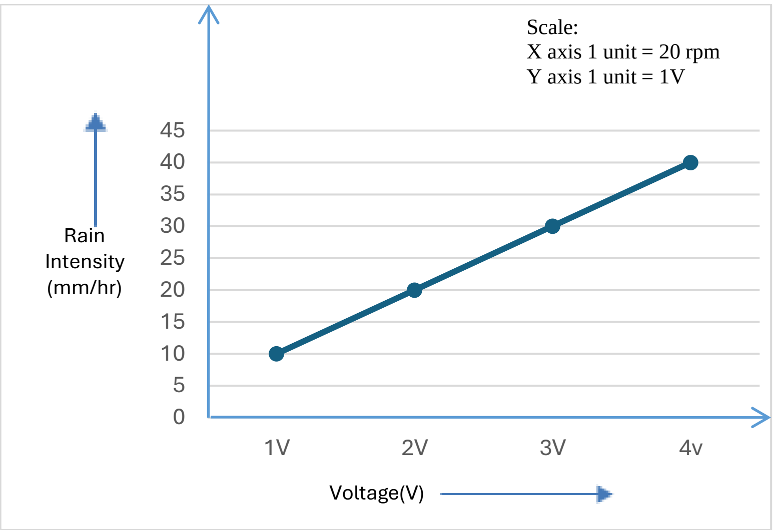

Fig.6 Variation of rain intensity (mm/hr) with voltage

The output voltage mainly depends on the intensity of rain falling on the rain sensor per hour. It can be seen from the data that the more intensity of rain the more will be output voltage. The speed of the wiper motor can be made varying by programming the code necessary.

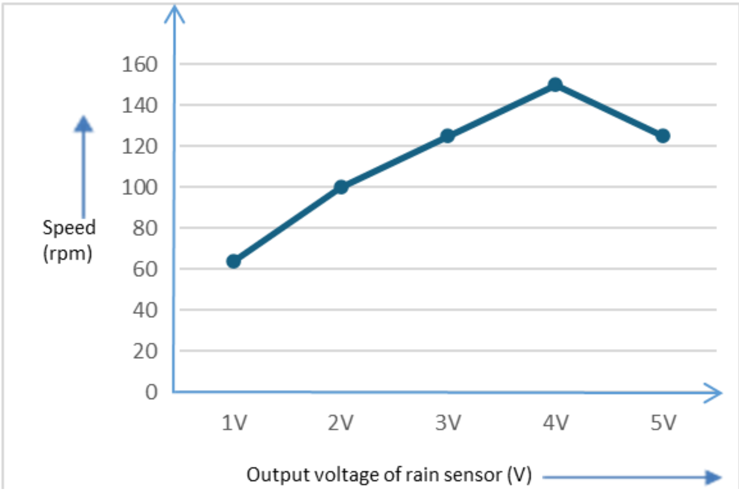

Fig.7 Variation of output voltage of rain sensor with speed

The speed of the motor can be made changeable or can be made dependable on the Voltage output of the rain sensor using programming done in Arduino UNO. The speed of the motor used in this project is fixed. For the given condition, it can be observed that initially rise in speed as well as output voltage and achieve optimum before slightly fall has been noticed.

4. Conclusion

Based on the analyzed data, we conclude that

1. The autonomous car wiper system that can recognize when it is raining and removes the precipitation from the windshield, allowing for clear visibility and a very low chance of an accident.
2. Using ultrasonic sensors, a successful vehicle detection system has been created. It is possible to adjust the distance between ultrasonic sensors to suit user requirements or modify measurement precision. By lowering necessary hazards, both systems employed concurrently will result in an efficient automotive safety system.

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