Systems And Methods to Implement Smart Roof

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***Abstract* — Automation** *using Microcontrollers like Arduino Uno has become increasingly ubiquitous, but there are still many sectors where automation is yet to be fully realized. This paper suggests Improvements in existing outdoor roofing systems by automation integrated with features such as Light intensity and Rain sensing, thus, adding value to existing systems. Proper roof control depending on weather conditions would be possible without the user's need to manually do so. The program developed for this system consists of multiple functions such as rain detection, opening the roof, closing the roof, and so on. Users can even customize the conditions for the opening and closing of the rooftop by calling appropriate functions in the program. The use case of this system is focused on the floriculture sector, where the protection of plants from heavy rainfall and high-intensity sunlight is a must. Further, it can also be used as a rain shield in public areas like bus stands and parks, and places like outdoor parking and lawns.*

Keywords *— Arduino Uno, Automation, Raindrop Sensor, LDR, automatic roof, Rain detection*

I. Introduction

NATURE has provided us with various valuable resources, two of the most important such gifts are sunlight and rainfall. Plants rely on both above-mentioned resources for their survival. But, an excess amount of both can degrade the plant quality, like, too many hours of sunlight can cause bleached foliage [6]-[12]. And excess rainfall can destroy nursery bed herbs, plants, and various ornamental flowers. Problems like soil erosion, water logging, and so forth are also caused by heavy rainfall [6]. *Prevention is better than cure*, thus to address this problem, we propose the development of a smart roofing system that cost-effectively, and efficiently manages rain and sunlight and thus, protects the plants.

The system will make use of high-quality, low-priced sensors and a microcontroller like Arduino Uno to sense the intensity of sunlight and rainfall to adjust the roof accordingly. The data collected will be presented to users in the form of easily-readable graphs. This paper will help outline the implementation and testing of this system, along with its benefits for plant growth.

II. Literature Review

Arduino is an open-source microcontroller that is capable of acquiring Analog and Digital inputs from the external environment with the help of sensors, processing it, and acting upon the changes in surroundings depending upon the program loaded into it [2]. The use of Arduino in automation is popular due to its lower cost, re-programmability, reliability, and repeatability with high accuracy and precision. [2]-[4]. Thus, it is a perfect tool for implementing automation in roofing systems [9]-[13]. Automation in roofing systems includes opening and closing of the roof depending on various environmental conditions and choices of users [9]-[13]. Some of the most common factors that these roofs' open-close state depends on are as follows – *sunlight intensity, the occurrence of rainfall, temperature, humidity, etc* [1]-[9]-[13]. There are several uses of these automatic roofs, some of which includes outdoor uses like in gardens, farms, and grasslands to achieve perfect conditions for growth [1]-[4]-[7]-[15]. It is possible if the roof is capable of protecting plants from heavy rainfall [6]-[7], very high temperatures, and intense afternoon sunlight but at the same time allow sunlight with moderate intensity and a moderate amount of rain to help in the natural growth of plants [6]-[7]-[15]. Indoor uses demand the roof to strictly close upon detection of any rainfall and can also be used to protect from intense sunlight [4]-[8]-[15]. *Sensors play a very important* role in getting data from the external environment as input for the implementation of an automatic system using Arduino [2]. This system also needs some specific sensors and actuators to perform tasks automatically.

Use of *LDR – Light Dependent Resistors* for measuring the intensity of sunlight while working with Arduino is being done to achieve cheap and accurate data [5]-[17]. This data can be used to detect day-night conditions, cloudy conditions, and harmful intensities of sunlight [5]-[17]. The rain detector sensor and module used for the detection of raindrops that fall upon the sensor plate work on the simple concept of the *drop of resistance due to the formation of parallel connections among the nickel strips present above the sensor plate* [18]. The decrease in resistance causes a decrease in value the of potential drop, which is read by the Arduino in digital or Analog pin, thus detecting rain [1]-[9]-[2]-[18]. Thus, this data can be used to change the open/close state of the roof via Arduino. Use of Servo motors is needed for this [10]-[11]. *Servo motors are actuators capable of moving precise degrees depending on the input they receive* [3]-[10]-[11]. This property is being used in the Servo library of Arduino

open-source libraries [2]-[3]. The Servo library provides users with simplified functions like *write* and *attach* which can be used to control the rotation of the servo motor with high precision and accuracy [3]-[10]-[11]. There are several designs available for the roof one of which is the *Louvered roof* [12]-[14]-[15]. It is best suited for outdoor roofing because of its ability to vary the amount of shade quickly as per the user's needs [8]. Many of these louvered roofs implement rain detection and light detection systems to open or close depending on conditions given by users [8]. But the cost of these systems is high [8], which can be brought down significantly with the use of appropriate technology [12]-[14]. With the implementation of rain-drop sensors, LDRs, Servo motors, Arduino, etc. together, it is possible to combine automation with roofing systems, both indoor and outdoor, at an affordable cost. Further, rainwater harvesting systems can be added to these systems to preserve the rainwater from heavy rainfall and use it at a later period in dry and hot seasons [16]-[15].

III. METHODOLOGY/EXPERIMENTAL

A. Components

1) Arduino Uno

The Arduino Uno microcontroller controls the flow of data. It provides voltage to the servo motor and the circuit made in the breadboard. It takes input signals from the rain sensor and LDR and produces appropriate output via the servo motor. The output depends on the functions called by the user in the main loop of the program.

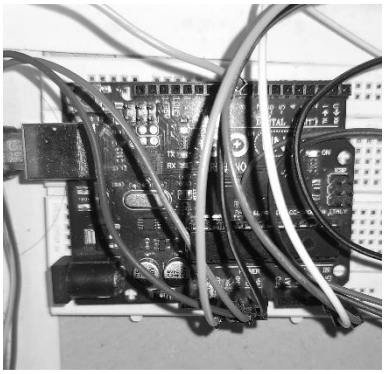

Fig. 1. Circuit Diagram of the Automatic roof system.

2) LDR

Used for sensing the intensity of sunlight in this system. It shows variable resistance depending on the light that falls on its surface. Light intensity during the day is very high compared to the light intensity at night, thus, detection of day and night is possible. Also, if the light intensity is too high in the daytime, the LDR produces very high which will cause the roof to close since too much sunlight can harm plants.

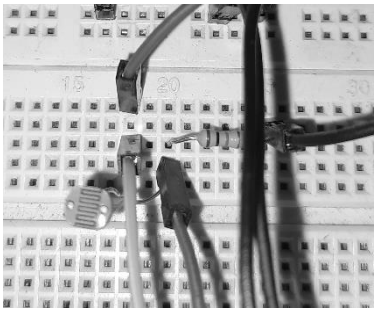

Fig. 2. Use of LDR in the system circuit.

3) Raindrop sensor plate module

The raindrop sensor plate has nickel-coated lines on its surface which act like series resistance. When a raindrop falls upon the sensor plate, it drops the resistance significantly due to the formation of parallel resistance connections, and thus the voltage across the plate drops too. This is further transduced by the Raindrop sensor control module.

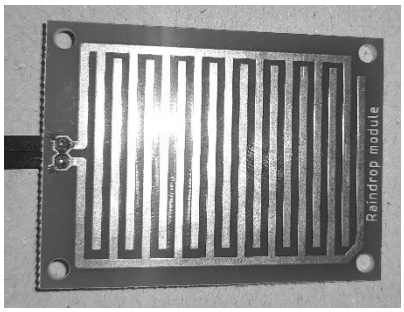

Fig. 3. Raindrop sensor - sensor plate

4) Raindrop sensor control module

The main job of this module is to use the voltage drop of the rain sensor plate, transduce it and send appropriate digital or analog signals to the microcontroller via jumper wires.

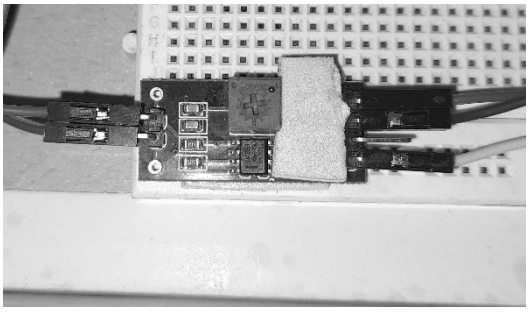

Fig. 4. Raindrop sensor – control module

5) jumper wires

The use of different types of jumper wires like male-male and male-female jumper wires have been done as an interconnection system for the project. Jumper wires are used to form connections between –

Servo motor and Arduino Uno.
Arduino Uno and breadboard.
Components of LDR sub-circuit.
Raindrop control module and sensor plate.
Raindrop control module and breadboard.
Raindrop control module and Arduino Uno

A Detailed circuit diagram of the system is shown in Fig. 6.

6) Breadboard

Breadboard was used as a base, on which the entire circuit was built. The overall circuit is divided into two parts, the first part consists of LDR for light intensity sensing and the other part includes a Raindrop sensor module for sensing the rain. Both of them use a 3.3-volt supply from Arduino Uno.

7) Resistor

A resistor of 1500 ohm was used in the circuit in series with the LDR to protect it from high current flow.

8) Servo motor – Micro Servo 9g SG90

The Servo motor provides controlled rotational motion for the roof to open/close. It produces large torque by drawing large current from the source and reducing the rotational speed by the appropriate gear ratio in the gear system.

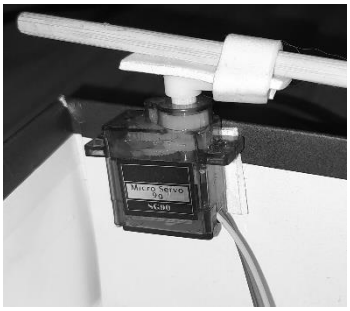

Fig. 5. Use of servo motor for opening and closing of the roof.

9) Software – Arduino IDE

It is open-source software that allows users to write programs for the Arduino board in a high-level language. It is very useful too as the main program is written using this software for the project and is also loaded into Arduino using it.

10) Others

Other software and hardware like Tinkercad for circuit creation, GitHub for version control, and so on are used for the creation of the system.

B. Method

Arduino provides a 5-volt supply to the servo motor and a 3.3-volt supply to the breadboard circuit. The LDR part of the circuit has a potential drop across LDR that is measured by the Arduino. Thus, with the use of the value of this potential drop, the intensity of the sunlight can be calculated. Similarly, using the raindrop control module, we take analog signals input into Arduino and decide whether it is raining or not. Now if it is raining or it is night time then the roof is closed by the Arduino with the help of a servo motor and when it is daytime or the rain stops falling, then the roof is opened again. The servo motor turns by 90 degrees in this project but it can go up to 180 degrees if needed. There are functions for every task and users can call these functions in the main loop of the program depending on their needs.

The circuit diagram for the project is given below –

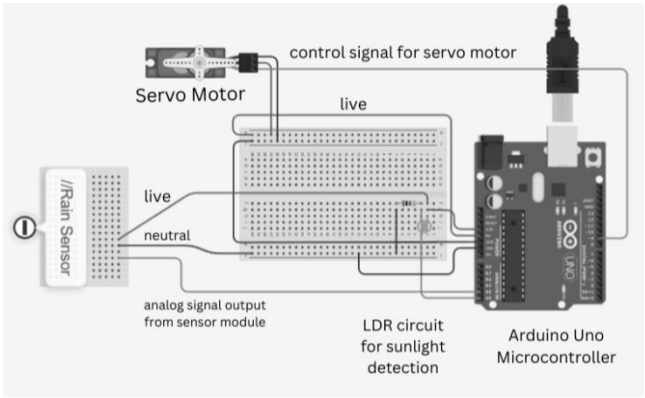

Fig. 6. Circuit Diagram of the Automatic roof system.

C. Code Description

1) Importing servo library

The Servo library is imported to access some of the built-in library functions for controlling the servo motor using Arduino Uno.

2) Declaration of global variables

We declare a Servo object and an array of size 2 to store the two readings from sensors: one from LDR and the other from the Raindrop sensor module.

3) Creation of various functions

a) getAndPrintReadings function

we use this function to get analog values from the sensor and store them in the global array that was declared before declaring any functions. Also, we print the values of these readings in the serial monitor provided in the Arduino IDE.

b) isRaining, isTooBright, and isNight functions

isRaining function performs an analog read of the rain sensor and compares it to the standard value obtained from the testing of the raindrop sensor. The standard value is set to compare the current reading to it and decide whether the current reading indicates a raining or not raining status. *isRaining* function returns true if it is raining and false if it is not. *isTooBright* function returns true if the LDR reading exceeds the standard reading for harmful intensities of sunlight and returns false if the reading is below it. *isNight* function returns true if the light intensity is very low, that is, it is night time and it returns false if it is daytime. Both of these functions make use of LDR readings.

c) closeRoof and openRoof functions

These two functions make use of the Servo motor for opening and closing the roof depending upon the conditions that the user has put in the if-else

statement present in the main loop of the system program.

4) Creation of setup

In the setup, the serial monitor is started for printing the readings. The analog pins of Arduino are set to INPUT mode for reading the values provided by LDR and the raindrop control module. Also, the servo object is initialized here, with digital PIN 9 for sending pulse width modification signals to the servo motor.

5) Running the main loop

In the main loop with a delay of two seconds after every iteration, the conditions that users have put in by calling appropriate functions will be checked by the *if-else conditional statements*, and opening and closing of the roof will be done depending upon whether the conditions were satisfied or not. The opening or closing of the roof is done with the help of the *openRoof* and *closeRoof* functions in the code.

IV. Results and Discussions

The prototype of this system was tested, about 100,000 bytes of data was collected in a .txt file and the following results were obtained after plotting the graphs for analysis –

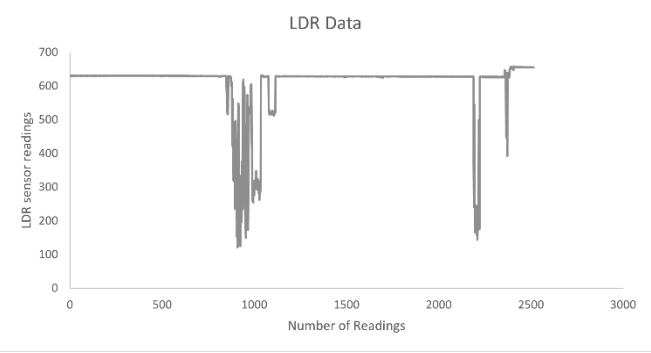

Fig. 7. Graph depicting sunlight intensity reading from LDR vs the number of readings.

The reading number on the x-axis of the graph in Fig. 7. refers to the corresponding time instance at which the reading was taken. The reading number was initiated with a value of 0, and after every few seconds reading was taken from the sensor, and the corresponding reading number was incremented by one. This method was used for better data storage and maintaining proper sequence in the data. From the graph shown in Fig. 7. We can conclude that the light intensity had dropped significantly between readings 500 and 1500. Thus, the roof was in a closed state during that period.

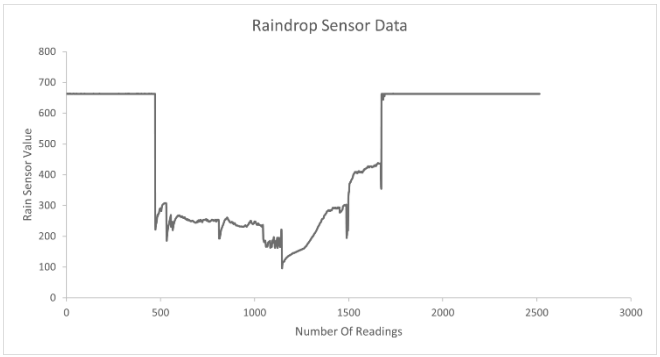

Fig. 8. Graph depicting the readings of raindrop sensor vs the number of readings.

Again, the reading number corresponds to the time instance at which the reading was taken. Fig. 8. Makes it clear that rain had occurred at the time corresponding to approximately reading numbers 500 to 1500. Thus, the roof was closed during this period. Hence, we can conclude that both the LDR part and the Raindrop sensor worked well in the system over the test period. Further, it was found that improvements in the LDR circuit connections were needed for it to work more synchronously with the Raindrop sensor, thus rewiring and proper orientation of the LDR sub-circuit were done. Better results were observed after the above-mentioned improvements were done.

V. Future Scope

The Smart roof system using Arduino is capable of sensing rain and light intensity, this feature can be utilized to produce solar energy by *attaching solar panels* to one side of the louvered roof and at the same time execute *rainwater harvesting* during rain by flipping the louvers of the roof. The slope of the roof should be about *30 to 45 degrees* from the horizontal for optimal rainwater harvesting [19]. Employing the data collected in this project *for the prediction of future weather and climatic conditions* can be done using AIML or any other appropriate technology.

VI. Conclusion

Thus, the Automatic roof based on Arduino Uno automation is a cost-effective and efficient system that protects plants from harsh external environments, high-intensity sunlight, and heavy rain. The system's cost is low, making it affordable and easily accessible to the farmers. The functions in the code are also completed, making the customization of the open-close state of the roof possible by just changing the functions called in the program's main loop. With the proper rain and light control using the automated roof system, farmers can improve the quality and quantity of their harvest [6]-[15]. The impact of this system would be most significant in the floriculture sector, where the protection of plants is a must. Overall, the smart roof system using Arduino automation has the potential to revolutionize the methods by which farmers protect their crops. Also, with further research, the data obtained in this process could be used for predicting future climatic and weather conditions.

VII. Acknowledgment

We extend our sincere gratitude to prof. Priyanka R. Bhatele for their invaluable contributions to our project. Their expertise in writing and formatting the paper helped us write and present our research paper. We would also like to express our appreciation for their guidance in presentations, suggestions for improvements in design, in-depth research of the problem statements, and for providing us with resources for study.

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