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DESIGN, CONSTRUCTION AND PERFORMANCE TEST OF A RAIN SENSING SHADE

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ABSTRACT
This paper presents a design, construction and performance test of micro-controller based rain sensing shade to protect materials from rain, which is an automatic system where water sensors are used to detect rain and send signals to the microcontroller. Then the microcontroller drives the motors to provide a shade over the required area. At the stoppage of rain the full system returns to its initial condition and again the products are open to desiccate under the sun. In this project a model of rain sensing shade is constructed with two sensors where each sensor sends a signal to the microcontroller at every 250 milliseconds. After sensing a drop of water by any sensor, the motors take 1.25 seconds to start and the shade covers 20.3 cm ×10.15 cm area within 20 seconds. The full system returns to its initial state within 20 seconds when the sensor's surfaces are dried out indicating the stoppage of rain. The performance test of the constructed unit shows a good agreement with the desired expectations. By installing this automatic system, industries can utilize their manpower somewhere else without fetching the products during rain and bringing it back to desiccate after rain. So a full time supervision over the products can be introduced by installing this automatic system.

Keywords: Rain, Water sensor, Micro-controller, Shade, Control

1. Introduction

The weather of Bangladesh is mysterious. No one can say whether it'll rain or not. So a system is necessary to develop for those industries where rain causes destruction to their materials.

Every year many industries like Jute Industries, Dyeing Factories even Laundry Businessmen need to delay their delivery dates because of this rain, which can be proved as a hazard from their business perspective. As we know that, Bangladesh is popular for jute. It is one of the principle crops of Bangladesh. A large amount of jute is cultivated here. Bangladesh is the world's largest grower of quality jute. So jute mills are extended here rapidly. Bangladesh Jute Mills Corporation (BJMC), which is a government organization and the world's biggest state owned manufacturing and exporting organization of all kinds of jute products. Also, Bogra has turned into a hot spot of red chili trading with renowned spice producers and marketers sourcing bulk of their raw materials from the place. For producing packaged red pepper, companies like Square, Acme and BD Foods now collect their chilies from as many as 12 purchase centers at Fulbari, Bogra. Over 2000 poor rural women are employed in these centers having potentials of supplying about 3000 MT red chilies. They use to make their business by desiccating their products in the sun. A sudden rain is an obvious threat to them. So a full time maintenance is needed, though doing it manually can be costly and a matter of hardship. By introducing an automatic system these obstacles can be overcome.

A rain sensing shade can be introduced in this purpose which can be operated automatically with the help of microcontroller and water sensors, where, the water sensor module is a part of the Grove system. So, it can indicate whether the sensor is dry, damp or completely immersed in water by measuring conductivity. The sensor traces have a weak pull-up resistor of 1 MΩ. The resistor will pull the sensor trace value high until a drop of water shorts the sensor trace to the grounded trace. Motors and other mechanical parts can be used as the brawny member of this system. Batteries can be used as power supply for remote places and in the case of electrical unavailability.

Modern day control engineering is a relatively new field of study that gained a significant attention during 20th century with the advancement in technology. It can deal with multi-input and multi-output (MIMO) systems. Control engineering or control systems engineering is the engineering discipline that applies control theory to design systems with desired behaviors. The practice uses sensors to measure the output performance of the device being controlled and those measurements can be used to give feedback to the input actuators that can make corrections toward desired performance. When a device is designed to perform without the need of human inputs for correction, it is called automatic control.

This project requires basic knowledge on microcontroller and electronics. Computer programing knowledge comes handy for microcontroller programing. This project also requires the knowledge of designing some mechanical components, power transmission and CAD (Computer Aided Design).

This rain sensing shade can cover required area during rain and save the dry products from being wet. So industries don't need to use their manpower to fetch the products during rain and bring it back to desiccate after rain. A considerable amount of time can be saved by minimizing the times for fetching and bringing the products back manually. A full time supervision can be introduced by installing this automatic system.

2. Design

2.1 Structure Design

Wood was used for framing the structure. For a shade capable of covering 20.3cm×10.15cm area, base of the structure was 40.6cm×20.3cm for proper observation.

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Design of the structure had been done by using SolidWorks platform. The mechanical drawing of the structure had been also extracted from the 3D design for guiding the construction work. Proper dimensions were included in the drawing as shown in Fig.1.

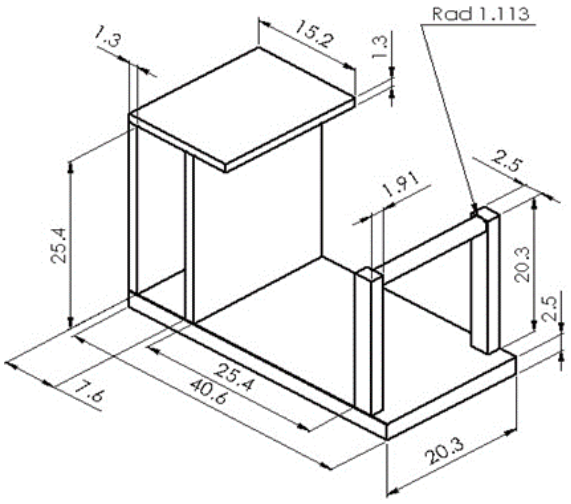

Fig.1 Mechanical Drawing of the structure
(All dimensions are in centimeters)

2.2 Microcontroller Selection

As microcontroller the Arduino Uno was used. Because it could be simply connected to a computer with a USB cable or could be powered with an AC-to-DC adapter or battery to get started. It was based on the ATmega328. It had 14 digital input/output pins, 6 analog inputs, a USB connection, a power jack, and a reset button. It contained everything necessary to support the microcontroller.

In this rain sensing shade, microcontroller was being used as the brain. It received signals from the sensors mounted on the roof and analyzed the signals to determine whether it was raining or not with the help of the code uploaded in it. After that it sent output signals according to the code.

2.3 Water Sensor Selection

Among many water sensors Grove Water Sensor was used because it could sense a single drop of water on its surface by measuring conductivity. The sensor traces had a weak pull-up resistor. The resistor would pull the sensor trace value high until a drop of water shortened the sensor trace to the grounded trace. This circuit worked with Arduino.

The structure of rain sensing shade had two seats mounted on the roof for two sensors. Sensors acted as the nerve of this system. They sent signals to the microcontroller about the environment. Each sensor sent an analog signal in every 250 milliseconds. If the weather was dry then their analog values ranged from 900 to 1100 and if the sensors sensed any water then their analog values ranged from 100 to 300.

2.4 Motor Selection

Motors were the muscles of this project. For covering an area of 20.3cm × 10.15cm within 20 seconds two motors of 2.19×10^{-6} Nm torque were needed. A gear motor of 6 volt, 250 mA and 120 rpm was available in market which was used in this model as it could give 0.12 Nm torque which was good enough for this purpose. It could also be empowered by microcontroller so the complications of power supply could be avoided.

These two gear motors were mounted on the structure of rain sensing shade. The microcontroller operated these motors according to the code uploaded in it. These motors ran efficiently at 6 volt connection.

2.5 Shade Selection

As a model of rain sensing shade was being constructed in this project rexine sheet was used as it was light in weight and could be folded easily over the shaft after serving its true purpose by resisting water to penetrate.

2.6 Selection of Shaft and Bearing

Plastic shafts were used for minimizing the weight of the motor arrangement. One end of a shaft was connected with a gear motor and the other end was attached with a bearing. Ball bearings were used in this project. This ball bearing is a type of rolling element bearing which uses balls to maintain the separation between the bearing races. The purpose of using this ball bearing was to reduce rotational friction and support radial and axial loads.

2.7 Other Accessories Selection

The followings were the accessories used for the unit:

- Cord String
- Bread Board
- Batteries
- Connectors
- Jumper Wires

3. Construction

For the construction of rain sensing shade wood was used for the structure. According to the mechanical design the structure was made. The structure provided a place for keeping the batteries, microcontroller and rest of the electrical circuit.

Motors, shafts and bearings were mounted on the structure at their certain positions. Motors and bearings were clamped with the structure by means of metal sheets.

On the opposite side of the motors there was a cylindrical support for changing the direction of the cord strings from the first motor toward the second one. That cylindrical support was engraved cylindrically at two points to allow the cord strings to pass over. The height of the cylindrical support was somewhat less than that of the first motor, so the rexine would be inclined during rain and could minimize the risk of storing rain water on it.

Fig.2 Wooden frame for the rain sensing shade

Plastic pens were used as shafts and attached with the gear motors. Plastic shaft was used for diminishing the weight of the gear arrangement. On the other side of the shaft a ball bearing was mounted over the shaft to give it a frictionless rotation and support.

Fig.3 Gear Motor, Shaft and Bearing arrangement

Rexine was used as the shade and it remained folded over the shaft when the weather was sunny. Rexine sheet was sewed with cord strings and the strings were tied with the shafts. Each shaft contained two holes for attaching the strings.

Fig.4 Rexine sewed by string cord

The power supply was a 9 volt battery to run the microcontroller and the microcontroller empowered the motors and the sensors. So the electrical circuit consisted of one 9 volt battery, one Arduino Uno Microcontroller Board, two water sensors, one bread board and several jumper wires.

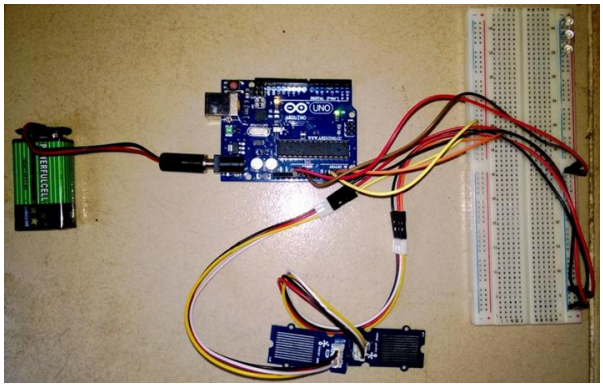

Fig.5 Electrical circuit of the model

Wires were connected to the motor poles by the process of soldering. The bread board was used for connection convenience.

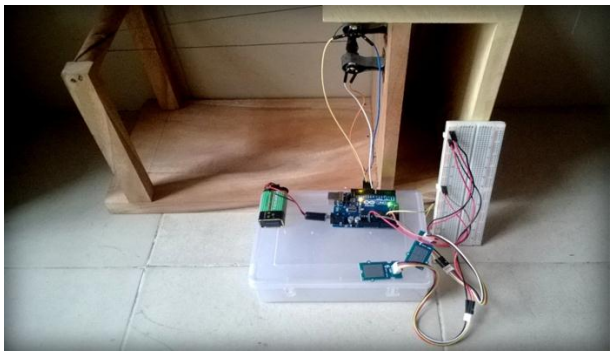

Fig.6 Model with electrical circuit

On the roof of the structure two seats were made where the sensors were mounted. The sensors were kept slightly inclined by design so that the risk of storing droplets of rain water on them could be minimized. The roof also offered rain protection to the motors, shafts, bearings and electrical circuit.
Final view of the constructed model is given below:

Fig.7 View of the constructed model when sensor's surfaces were dry

Fig.8 View of the constructed model when sensor's surfaces were wet

4. Performance Test

For testing the performance of the model two sensors were set on the roof of the model. Each sensor used to send a signal to the microcontroller at every 250 milliseconds. If the surfaces of the sensors were dry then the shade would remain folded. But when any one of the sensors would sense any water on its surface then the microcontroller would detect the water by analyzing the signals sent by the sensor and it would start the motors and the shade would be provided over the required area. After that when the sensors would sense dry surfaces on them then the microcontroller would detect the dry environment by analyzing the signals sent by the sensors and run the motors in reverse direction.

Table 1 Data for the test of performance of rain sensing shade

No. of obs.	Time for starting the motors after sensing water (sec.)	Time for covering the required area (20.3cm × 10.15cm) (sec.)	Time for starting the motors after sensing dry surfaces of sensors (sec.)	Time for returning to initial position (sec.)
01	1.25	19.3	1.25	19.2
02	1.25	19.1	1.25	18.9
03	1.25	18.9	1.25	19.4
04	1.25	19.1	1.25	19.2
05	1.25	18.8	1.25	19.1
Avg.	1.25	19.04	1.25	19.16

5. Results and Discussion

From table 1, it was observed that, after sensing a drop of water by any sensor the motors took constantly 1.25 seconds to start and the shade covered 20.3cm×10.15cm area within 19.04 seconds on average. The full system was found to return to its initial state within 19.16 seconds on average when the sensor's surfaces were dried out indicating the stoppage of rain and again the motors took constantly 1.25 seconds to start.

Here, it has been seen that times for covering the required area (20.3cm×10.15cm) are not same for all observations. Times for returning to initial position also vary. These slight variations may happen because of friction between the string cord and the cylindrical support. Although times for starting the motors after sensing water and times for starting the motors after sensing dry surfaces of sensors remain constant for all observations.

So, after testing the performance of the model it can be said that the rain sensing shade satisfies the design assumptions and this project achieves its goal successfully.

6. Conclusion

The following conclusion could be made for the project:

- A rain sensing circuit has been designed by making a suitable electrical circuit and placing the sensors in proper positions.
- A rain sensing shade has been designed and constructed according to design assumptions.
- Performance of the rain sensing shade has been tested and found to respond during rainy and sunny weather as per the design.
- After sensing a drop a water by any sensor the motors take 1.25 seconds to start and the shade covers 20.3cm×10.15cm area within 20 seconds. The full system returns to its initial state within 20 seconds when the sensor's surfaces are dried out indicating the stoppage of rain.

7. Recommendation

The following recommendations could be made for the project:

- Instead of two motors, single motor can be used by gear arrangement for shade movement.
- AC power supply can be used instead of battery.
- Pulleys can be mounted on cylindrical bar for frictionless movement of rope.
- Metallic sheet can be used as shade instead of rexine.

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