Automatic Solar Tracker

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Design Lab Project

Automatic Solar Tracker

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Contents

Abstract

The goal of our project is to design an automatic solar tracking system, which will locate the position of the sun. This will help to get the maximum output from a solar cell. The designed model will keep the panel perpendicular to the incident light the whole time.
We have designed the two-axis rotation system. It can increase or decrease the elevation of a panel according to the position of the light source. Also, it can follow the light source horizontally. Here, we made the set-up for a laboratory scale but this project when implemented on large scale can boom the solar energy production of our country. Our planet receives 84 Terawatts of solar power daily and we consume about 12 Terawatts only. These smart solar panels will be of great significance. We are already using single-axis solar panels on a considerable scale but that doesn't keep facing the sun the whole day.

1 Introduction

The Sustainable Development (SDG) goals were adopted by the United Nations General Assembly in September 2015. After a series of negotiations and discussions, 193 members agreed on 17 SDGs to be fulfilled by 2030. One of these goals is goal 7: 'Affordable and clean energy'. The goal aims to ensure universal access to inexpensive, reliable, sustainable, and clean energy for all people. There are various sources of energy but most of them which are used on large scale are non-renewable fossils. They harm our nature with toxic gases released during the process.

Talking about energy production in India, 70 percent of the total electricity produced in 2020 was from coal. We all know coal is a non-renewable fossil fuel, which causes global warming and consequently many environmental hazards. Keeping in mind the seventh SDG goal, India aims to achieve 450 gigawatts (GW) of renewable energy capacity by 2030, with 280 GW coming from solar power. Our country is located in the tropical belt, due to which we receive over 5,000 trillion kWh of power from the sun. As mentioned earlier only a few percentage of this is utilized to fulfill energy requirements. We can use this fact to achieve our goal in a sustainable way. Solar cells are the way. But it's not possible to produce this much energy with a fixed solar panel.

A fixed solar panel produces less power than its capacity. Due to the static placement of panels, the time of exposure to light is less. To solve this issue we designed a two-axis rotation solar panel that can be used to get around 45 percent more power when compared to the fixed solar panel. The automatic solar tracker project helps to get the maximum electricity from a solar cell by keeping it perpendicular to the sunlight. The proposed model is based on a dual-axis solar tracker controlled by a microcontroller. Single-axis solar tracker won't give the maximum output because its unable to follow the sun's elevation.

We tried to keep incoming light perpendicular to the panel, in order to get the best results. The model will follow a light source like a sunflower. Later on, we will discuss various factors affecting solar cell efficiency, angle of incidence is one of them. Please note that we just demonstrated how a solar panel should move with the sun to get maximum output. So, we used cardboard in place of the actual solar cell.

2 Components Used

Components used to make the Automatic solar tracker are:

- Arduino UNO
- Servo Motors
- LDR sensors
- Resistors
- Breadboard
- Connecting Wires
- Jumper ofc
- Cardboard (dummy for the solar panel to show rotation)

2.1 Arduino UNO

Arduino UNO is a programmable microcontroller board. It can be erased, and reprogrammed, very easily. It is based on the ATmega328P microcontroller, which is a low-power, high-performance 8-bit AVR microcontroller with 32KB of in-system programmable flash memory and 1KB of EEPROM.

The Arduino Uno board provides a variety of features to support an easy way to program and interface with different electronic devices. Including:

- A USB port - for programming and serial communication with your pc
- 14 digital input/output pins
- 6 analog input pins
- A 16 MHz quartz crystal oscillator
- A power jack for external power supply
- A reset button

Arduino uses the Arduino development board as hardware and the Arduino IDE (Integrated Development Environment) as software part for programming. we can use C or C++.We used Arduino UNO to control the rotation of the servos according to feedback given by LDR sensors.

2.2 Servo Motor

A Servo motor is a type of rotary actuator, i.e. a mechanical device that converts rotational motion into linear or angular motion. We used two servo motors to get a linear and angular rotation of the panel. These are widely used in many different applications, including robotics, industrial automation, and remote control vehicles.

Basically, they are used to control the position, velocity, and acceleration of a rotating shaft or axis. we can power them with various DC voltages. Also, they can be controlled using a variety of interfaces, like pulse width modulation (PWM) signals, serial communication, or analog voltage inputs.

Servo can be understood as a combination of three parts:

- Controlled device
- Output sensor
- Feedback system

It can be looked at as a closed-loop system with a positive feedback system to control motion and the final position of the shaft. This is controlled by a feedback signal which is generated by comparing reference i/p and o/p signal. A feedback signal is generated by comparing the reference i/p and reference o/p signal. This third signal acts as an input signal to control the device. This signal remains there as long as the feedback signal is generated or we can say as long as there is a difference between the reference input signal and the reference output signal. So the main task of servomechanism is to maintain the o/p of a system at the desired value in the presence of noises.

2.3 LDR Sensor

LDRs are Light-Dependent Resistors, which means their resistance changes according to the intensity of incident light. The most common material used to make them is cadmium sulfide (CdS). Cadmium Sulphide is a semiconductor material with great sensitivity to light. TA thin film of this material is deposited on a ceramic substrate to make an LDR sensor. The ceramic substrate is used to protect the sensor from moisture and provide it mechanical stability. LDRs do not require any external power source to operate, they are passive elements.

The working principle of LDR lies in the fact that its resistance changes according to the intensity of incident light. When light falls on it, the semiconductor used (cadmium sulfide) absorbs photons from it which excites the electrons and decreases its resistance. Consequently increasing the conductivity as well.

We used four such sensors to know from which side the light is coming. We placed four LDRs on four corners of the panel to do so. If the reading of the upper right LDR is more than the rest, we move the panel in that direction and accordingly in all other directions as well.

3 Efficiency of solar cell

Efficiency is one of the most important criteria to decide the quality of the output of any device. Here, the device of our interest is a solar cell. There are lots of factors that can change the efficiency of a solar cell. Before jumping to the factors, let's first know what parameters define the efficiency of a solar cell.

For any system, efficiency is basically the ratio of output we are getting in terms of power to the power that we provided to the system as input. So for a solar cell its the ratio of the max power generated by the solar cell to the energy of the sun. Its efficiency is controlled by the light intensity, material used, temperature, etc.

The maximum power output, denoted by P_{max}, is given by the product of the open circuit voltage V_{OC}, the short circuit current I_{SC}, and the fill factor FF. Thus, we have the equation:

$$P_{\text{max}} = V_{\text{OC}} \cdot I_{\text{SC}} \cdot FF$$

The efficiency of a solar cell, denoted by η, is then calculated as:

$$\eta = \frac{(V_{\text{OC}} \cdot I_{\text{SC}} \cdot FF) \times 100\%}{P_{\text{in}}}$$

where V_{OC} is the open circuit voltage, I_{SC} is the short circuit current, FF is the fill factor, and P_{in} is the power input.

3.1 Factors affecting solar cell efficiency

1. Cell material: The efficiency of a solar cell is fundamentally determined by the material used to make the cell. Efficiency is directly affected by the amount of light absorbed by the cell and absorbance, reflection are material properties. The most commonly used material is silicon. Silicon is present in abundance and it gives high efficiency.
2. Cell design: Physical factors like the thickness of the cell can impact the efficiency of solar cell. Including an anti-reflective coating on top of cell can significantly increase the efficiency.
3. Angle of incidence: The angle at which light falls on the surface of the solar cell determines the energy incident on the cell. Light should be perpendicular to the surface, hence parallel component of incident light is useless for us. Our goal is to minimize this parallel component of incident light in order to get higher efficiency.

There are various other factors as well like electrical resistance, the reflection coefficient of the material used, etc. In our project, we tried to minimize the effect of the third factor, i.e, the Angle of incidence. We made the sunflower model of a solar panel, which always tries to face the sun directly. Consequently, incident sunlight is always perpendicular to the panel.

4 Working Principle

The logic behind the functioning of our automatic tracker includes three main components:

1. LDR for sensing the light
2. Arduino UNO for programming/processing the logic
3. Servo motors for executing the necessary action. (Actuation part)

The LDR senses the incident light and gives back the analog data to the Arduino board. 4 LDR sensors are used in four different directions. Analog data given by sensors is used to calculate the angle of rotation of both servos. This is done by the Arduino board, explained in the flow chart and methodology sections. The movement of the panel is done by rotation of the servos. The commands are given to the servos as per the calculation done by the Arduino board.

5 Methodology

- The four LDRs are placed in the top-left, top-right, bottom-left, and bottom-right directions of the solar panel. These are then connected in a voltage divider circuit with a fixed resistor in order to change the voltage across each LDR depending on the amount of sunlight it receives.
- The Arduino(microcontroller) reads the voltage across each LDR and stores them in four variables V1, V2, V3, and V4 corresponding to top-left, top-right, bottom-left, and bottom-right LDRs.
- Now, calculate the average value of V1, V3 and V2, V4. Take their difference and divide it by a factor of 50 to keep the angle in the range [0,180] degrees. This is the obtained angle for horizontal rotation.
  Similarly, calculate the angle to be changed in elevation by taking the difference between the average(V1, V2) and average(V3, V4) and dividing it by a factor of 50.
- The microcontroller then sends signals to servos to add calculated horizontal and elevation angles to their current positions. This process runs in a loop until we interrupt. In this way, it keeps facing incident light the whole time.

6 Circuit Diagram

We simulated our circuit in Tinkercad. The circuit view and schematic view of the model are provided below:

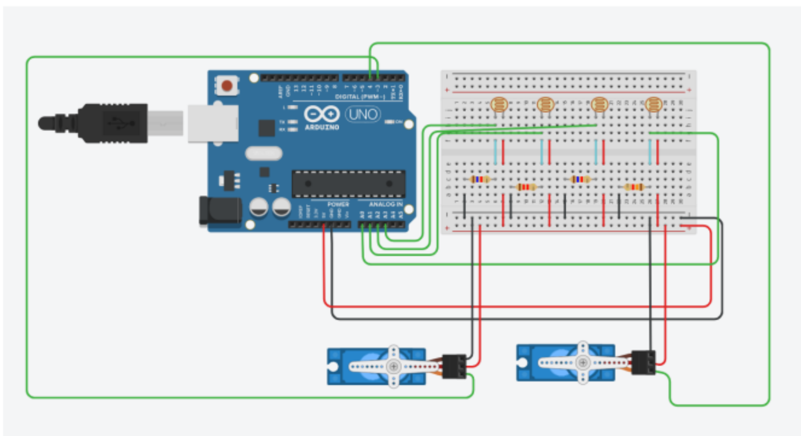

Fig. 1 Circuit view of model

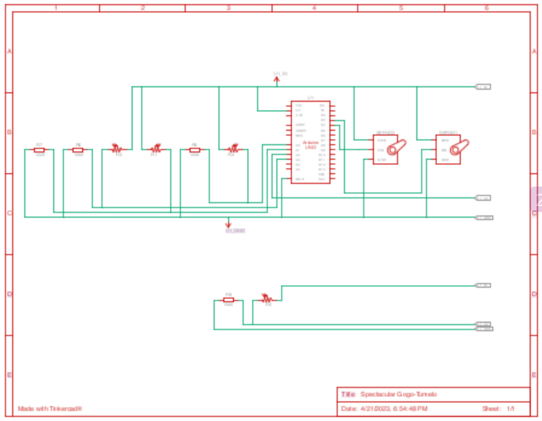

Fig. 2 Schematic view of model

7 Flow chart of Algorithm

We followed the following steps to implement the code. Here V1, V2, V3, and V4 represent the LDRs reading.

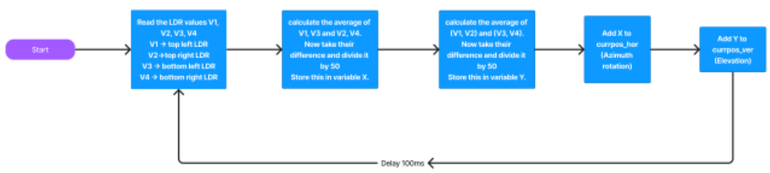

Fig. 3 Flow chart of process

8 Arduino code

```
#include <Servo.h>

Servo azith, elev;
int currpos_hor=90;
int currpos_ver=20;

void setup() {
  pinMode(A0, INPUT);
  pinMode(A1, INPUT);
  pinMode(A2, INPUT);
  pinMode(A3, INPUT);
  azith.attach(3);
  elev.attach(4);
  Serial.begin(9600);
}

void loop() {
  int v1= analogRead(A0);
  int v2= analogRead(A1);
  int v3= analogRead(A2);
  int v4= analogRead(A3);
  Serial.print(v1);
  Serial.print(',');
  Serial.print(v2);
  Serial.print(',');
  Serial.print(v3);
  Serial.print(',');
  Serial.println(v4);
  currpos_hor+=((((v4+v2)/2)-((v3+v1)/2))/50);
  if(currpos_hor<=0)
  currpos_hor=0;
  else if(currpos_hor>=180)
  currpos_hor=180;
  currpos_ver+=((((v1+v2)/2)-((v3+v4)/2))/50);
  if(currpos_ver<=0)
  currpos_ver=0;
  else if(currpos_ver>=110)
  currpos_ver=110;
  azith.write(currpos_hor);
  elev.write(currpos_ver);
  delay(100);
}
```

9 LDR measurements

position	LDR1	LDR2	LDR3	LDR4
1	7	28	13	5
2	110	820	130	20
3	870	60	60	10
4	20	30	700	80
5	8	40	90	750
6	4	20	75	90
7	690	660	110	4
8	6	26	650	670

*Note : due to the dimensions of the images, they couldn't be included here. The images corresponding to the positions can be found below from images 6 through 13.

10 Discussion

10.1 Cost Analysis

Sr. No.	Component	Quantity	Price
1	Servo Motors	2	340
2	Resistors	8	8
3	Jumper Wire pack	1	100
4	Breadboard	1	85
5	LDR sensor	4	10
6	Connecting Wires	1	45
7	Arduino UNO	1	550
8	UNO cable	1	40
Total			1548

10.2 Scopes

- Automatic tracker module when integrated with a static solar panel can dramatically increase the o/p of static solar panel. This will save energy. It can be used to meet daily household energy requirements in a sustainable way.
- A stepper motor can be used in place of the micro servo for more precise positioning. The stepper motor can be easily interfaced with the microcontroller using the stepper motor driver module.

10.3 Limitations while scaling from lab to reality:

- Increased complexity of the set-up. The use of sensors and dual-axis rotation increases the complexity of the system which will be difficult to maintain and install when compared to static solar panels.
- Space required to install this will be more in comparison to normal solar panels.
- Increased components increases the cost also.

11 Results/Conclusions

- Our model was able to effectively adjust the position of the panel to follow the incident light.
- We have made sure that the motion is smooth and for small deviations, the panel's position is immediately adjusted.

12 Images of Model

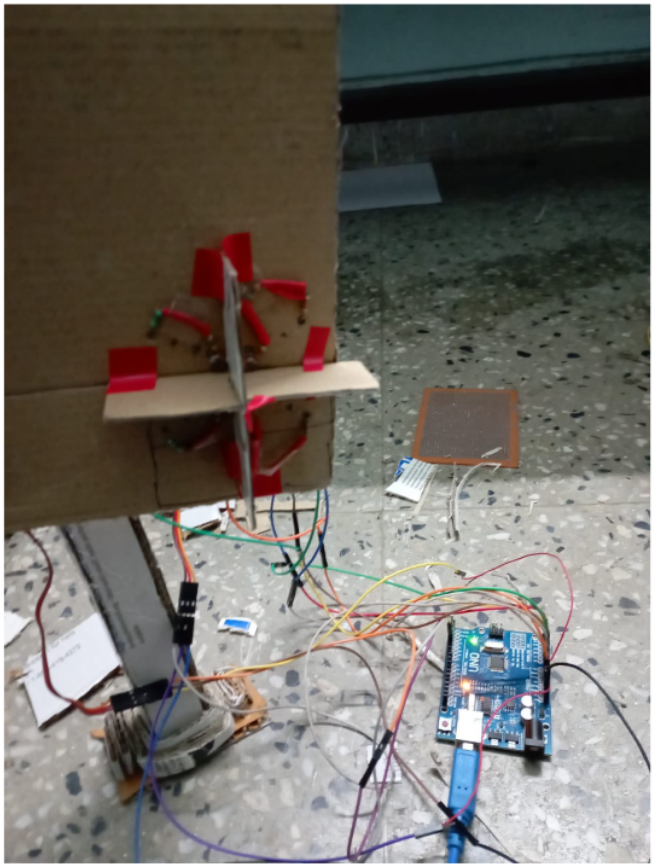

Fig. 4 Front view of our apparatus

Fig. 5 Rear view of our apparatus

Fig. 6 position 1, LDR Measurements

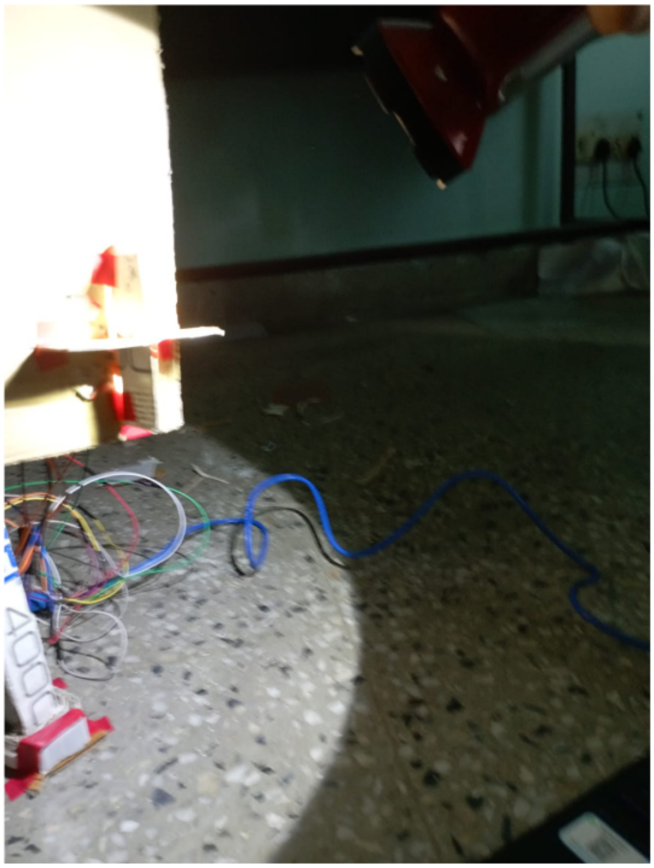

Fig. 7 position 2, LDR Measurements

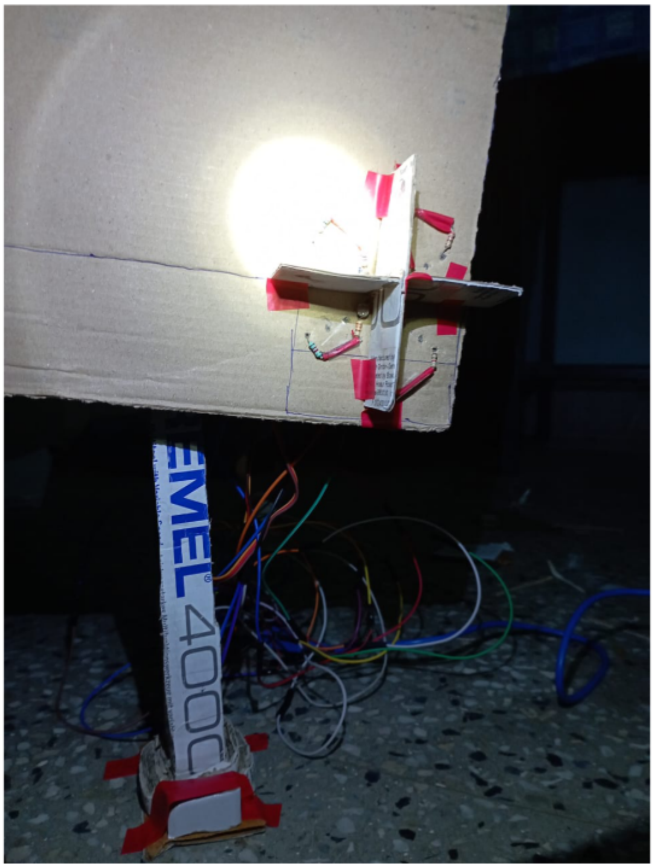

Fig. 8 position 3, LDR Measurements

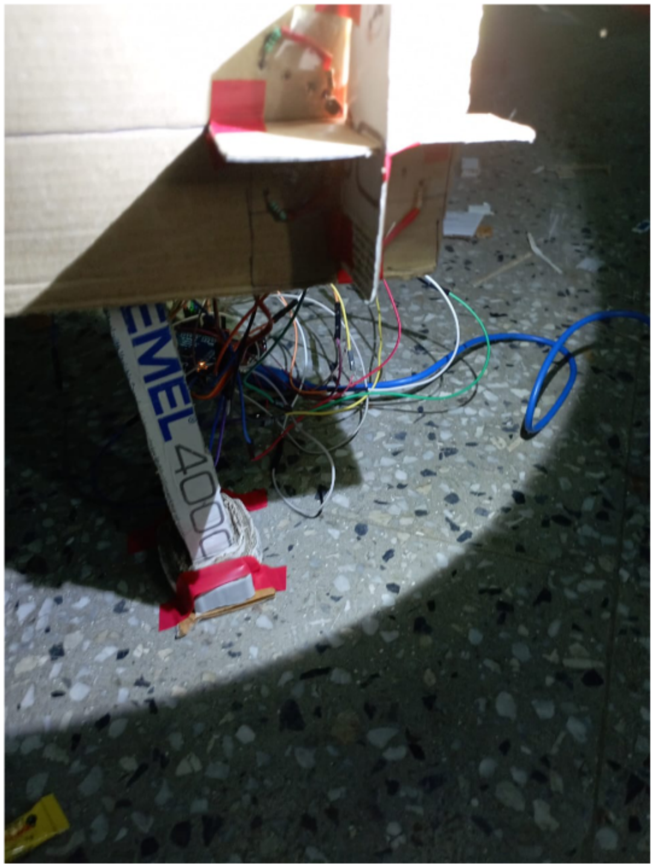

Fig. 9 position 4, LDR Measurements

Fig. 10 position 5, LDR Measurements

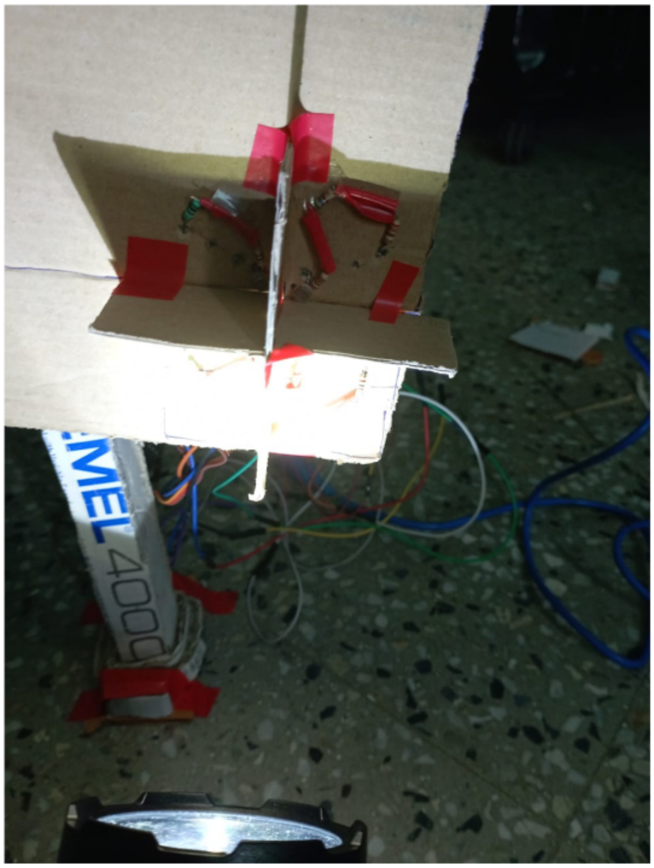

Fig. 11 position 6, LDR Measurements

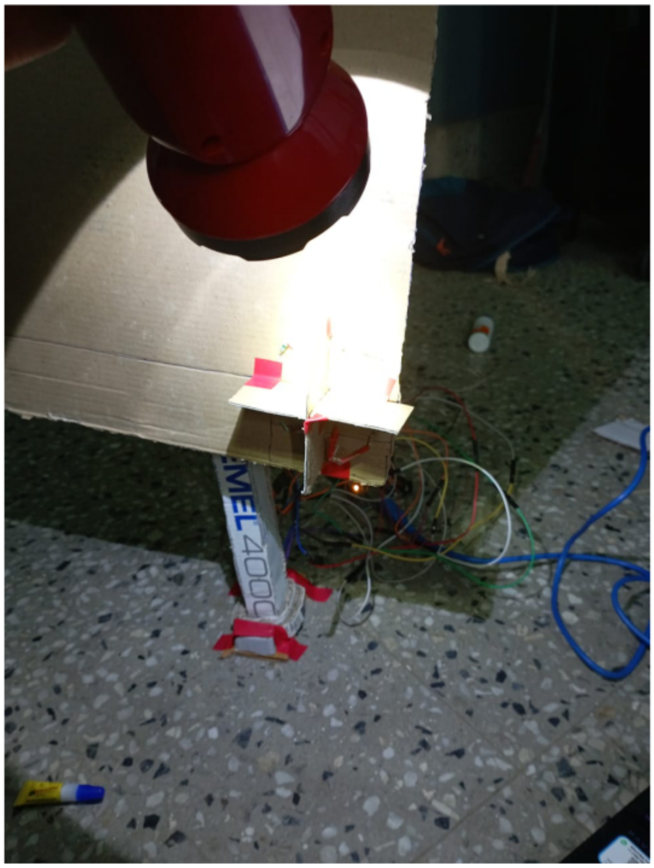

Fig. 12 position 7, LDR Measurements

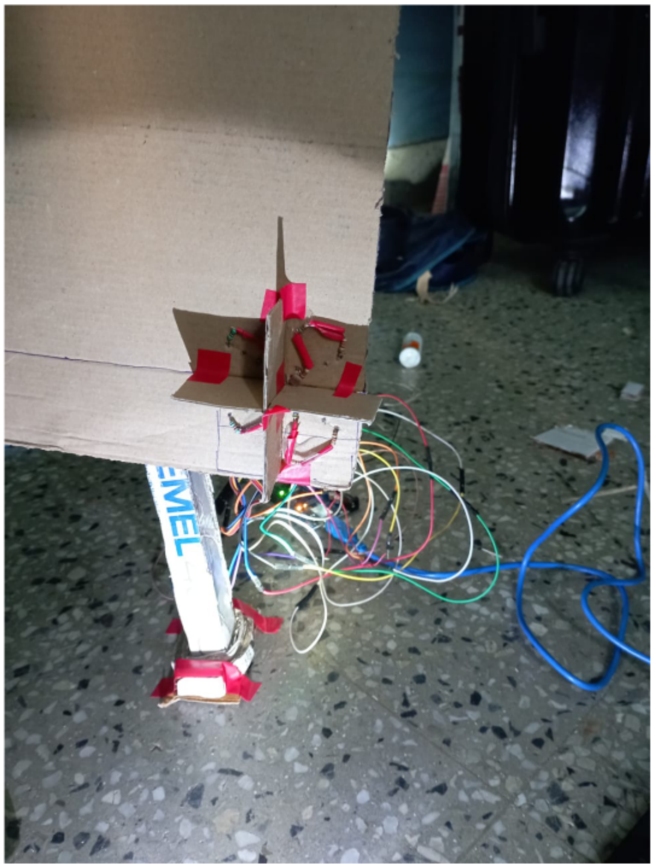

Fig. 13 position 8, LDR Measurements

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