

# Development of Automatic Solar Tracking System for Small Solar Energy System

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## Abstract

The main purpose of this paper is to present a novel idea that is based on design and development of an automatic solar tracker system that tracks the Sun's energy for maximum energy output achievement. In this paper, a novel automatic solar tracking system has been developed for small-scale solar energy system. The hardware part and programming part have been concurrently developed in order for the solar tracking system to be possible for it to operate accurately. Arduino Uno R3, Sensor Shield V4 Digital Analog Module, LDR (Light Dependent Resistor), MPU-6050 6DOF 3 Axis Gyroscope has been used for tracking the angular sun movement as shown in Fig. 1. Accelerometer, High-Efficiency Solar Panel, and Tower Pro MG90S Servo Motor have been used for the hardware part. High-level programming language has been embedded in the hardware to operate the tracking system effectively. The tracking system has shown significant improvement of energy delivery to solar panel comparing to the conventional method. All the results will be shown in the full paper. There are three contributions the research presented in this paper which are, i.e. perfect tracking system, the comparison between the static and tracking system and the development of Gyroscope angular movement system which tracks the angular movement of the sun along with another tracking system.

**Keywords:** MPU-6050 6DOF; Solar Panel, Solar Tracker.

## 1. Introduction

Over the recent years, the foremost reasons behind global warming are greenhouse effects, which have caused precarious climate changes all over the world. Unfortunately, these severe weather changes are the negative effects of damaging the Earth. Many methods and attempts have been used to tackle the continual global warming in order to reduce its effect. For instance, the Kyoto Protocol, which has been signed and endorsed by many national governments in an effort to educate people and correspondingly improve their environmental awareness about limited current energy sources and their relatively high demand. The main purpose of this study is to design and develop an automatic solar tracker system. At the present, the use of solar energy is not new. The known drawback of widely used solar panels is not maximizing its utilization to fully absorb the solar energy. It is believed that the sunlight has two basic components. These are the "direct beam" that contains about 90% of the solar energy and the "diffuse sunlight" that carries the remaining solar energy. Therefore, the aim of this project is to improve on the function of the regular solar panel with an addition of LDRs, motor, gear and wheel mounting.

Malaysia is situated in the North of the Equator where the exact latitude and longitude are 2° 30' N and 112° 30' E respectively. At this location, solar irradiation can be optimally extracted. Contrary to the usage of non-renewable energies such as coal, gasoline, and oil, solar power has become more popular as an environmentally

friendly renewable energy source that produces no pollution and requires minimal maintenance. Moreover, energy from the Sun is free and also has an advantage of reducing power usage from conventional energy resources based on fossil fuel. It is, therefore, necessary to maximize the solar energy usage through solar panels and conversion system. Hence, one of the means to maximize solar energy power delivery is to use the solar tracker. The Gyroscope angle tracking system shown in Fig. 1 has perfectly tracked the angular movement of the sun and strengths of the tracking system.

This also shows the movements of the motor and angular movement showing that what angle each rotation stands for the solar tracking positions.

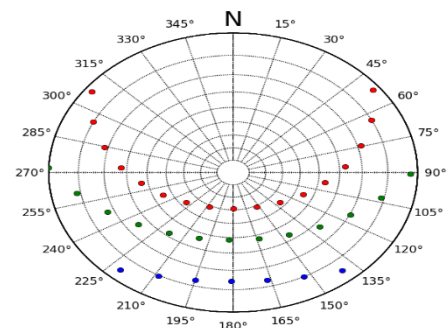


Fig. 1: Gyroscope Angle Tracking

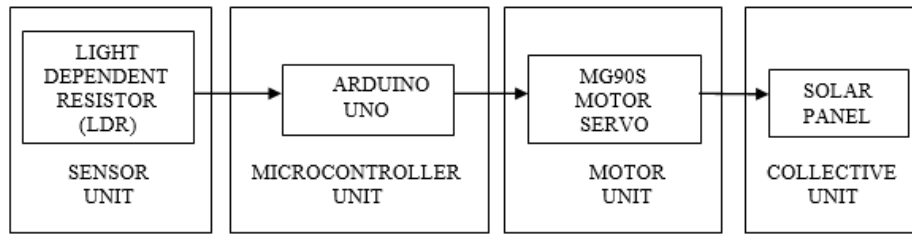


Fig. 2: Block Diagram of Automatic Solar Tracker System

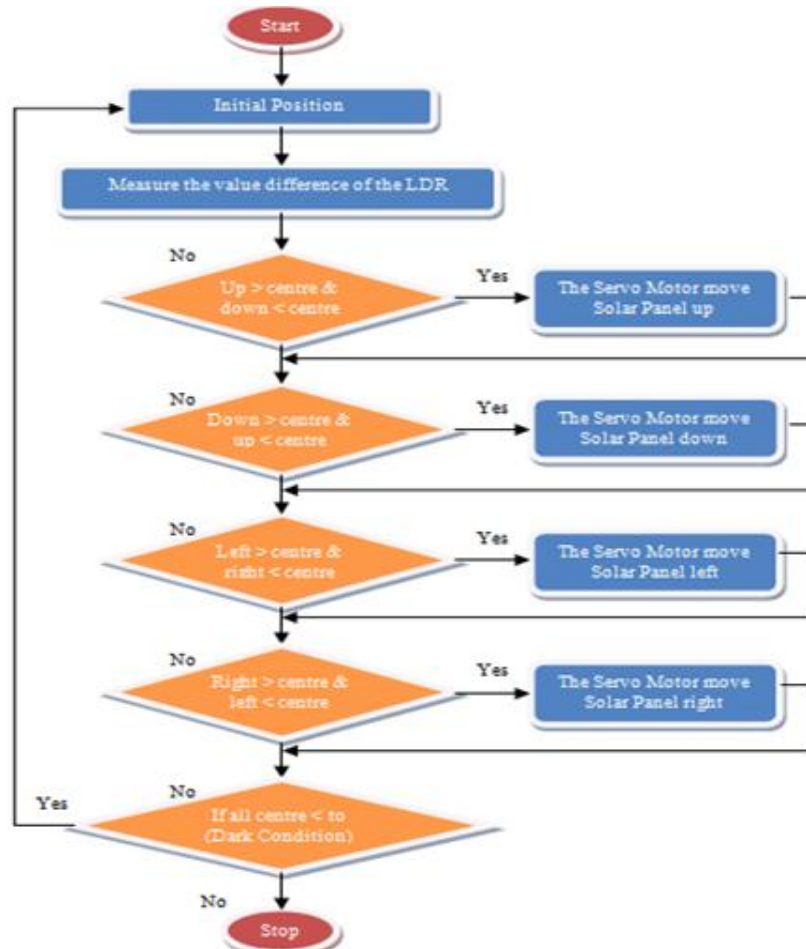


Fig. 3: Algorithm for the Automatic Solar Tracker

## 2. Methodology

The block diagram of the automatic solar tracker shown in Fig. 2 consists of four main parts including a sensor unit, a microcontroller unit, motor unit, and collective unit. The sensor unit of the automatic solar tracker consists of only one sensor which is Light Dependent Resistor (LDR). The LDR is a light sensor that detects the absence or presence of light. In this project, the application of the LDR in the automatic solar tracker is the detection of the sunlight from the Sun throughout the day in order for the solar panel to obtain the direction of the maximum power of the solar irradiation. The tracking of the movement of the Sun by the LDR will increase the extraction of solar energy by the solar panel. Therefore, the LDR is a sensor which assists the solar panel to realize its function of absorbing and extracting the solar energy more efficiently.

The signal from the sensor unit (the LDR), is controlled and processed by the Arduino Uno. The Arduino Uno works as a microcontroller for the automatic solar tracker hardware. It is an open-source electronics platform, consists of easy-to-use hardware and

software, and therefore is specialized on reading inputs such as light detected by a sensor. As a result, few calculations are required to process the signal sent from the sensor. It therefore processes the incoming signals using different calculation formula according to the signal received. The Arduino Uno is then used to send a signal to both of the motor servo so that it can move according to its coding. This coding is programmed in the Arduino Uno software (the IDE software). The movement of the motor servo depends on the input received by the LDR, which is processed beforehand by the microcontroller. There are four LDRs which must obtain or detect the same amount of Sunlight. Whenever there is a change of light intensity in either one of the LDR, the motor servo will move correspondingly according to the light intensity received by the LDR. The movement of motor servo will settle down only if the received light intensities of all four LDRs are equivalent to one another. The algorithm for the automatic solar tracker is shown in Fig. 3. The algorithm begins with supplying the Arduino Uno R3 with power supply or switching it on the power supply. Then, each of the LDR measures the difference in light intensity for all four LDRs. For example, the decision of the servo motor moving the solar panel upwards is determined when both the upwards light intensity is greater than the center and

downwards light intensity is lower than the center. Then a decision is made to move the solar panel upwards. The second decision is made when the downwards light intensity is higher than the center while the upwards light intensity is lower than the center. By that decision the solar panel will rotate downwards. This is how the rotation direction of solar panel is controlled using the information from the four LDRs located upward, downward, left and right, with a center.

### 3. System Architecture

For this project, the hardware development consists of multiple combinations of electronic components as shown in Fig. 2. The hardware development is divided into 3 parts: the detection part, the movement part, and the acceleration part. The detection part uses LDR sensor to detect the light intensity. The movement part consists of 2 servo motors and an axis. The acceleration part uses the MPU6050 sensor, the combination of a gyroscope sensor and an accelerometer. Each of these three parts is critical for the project's hardware development. The components used in this project are Arduino Uno R3, Sensor Shield V4 Digital Analog Module which connects servo motor to Arduino Uno R3, LDR as sensors, MPU-6050 6DOF 3 Axis Gyroscope plus Accelerometer to detect changes in direction and acceleration, High Efficiency Solar Panels with 80mA, 15W each and Tower Pro MG90S Servo Motor.

#### 3.1 Sensing part

The sensing part is the combination of 4 LDR sensors with Arduino Uno R3. The interconnection between the two components is shown in the schematic diagram in Fig. 4.

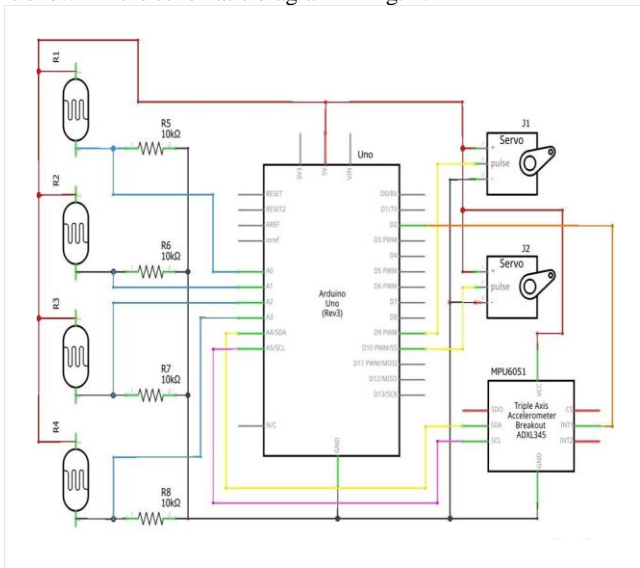


Fig. 4: Automatic Solar Tracker Hardware

The development for the detection part starts with the interconnection between the four LDRs and the Arduino Uno R3. From the schematic in Fig. 4, it can be seen that all four negative wires of the LDRs are connected with a 10kΩ resistor which is then connected to the ground pin on the Arduino Uno R3. There are four connections of negative LDRs wires that were split up before the connection of the wires with the 10kΩ resistor. Each of the wires is connected to the analogue port A0, A1, A2, and A3 to give analog inputs to the microcontroller. Meanwhile, the positive wires for the LDRs are connected to Arduino Uno R3 5V pin. The programming code for the four LDRs is uploaded into the Arduino Uno R3 and was carefully tested through an observation conducted by using the Arduino IDE software. Figure 5 shows the coding for the LDRs movement by calculating the difference in light intensity. The coding is shown for upwards movement, where top left light intensity is added with top right light intensity and the

total is then divided by 2 to initiate the movement. Similarly, in the coding for the downwards movement, the sum of the bottom left light intensity and bottom right light intensity is divided by 2. The next line indicates the left side movement where both the top left light intensity and bottom left light intensity are summed up and divided by 2. The same applies for the right-side movement, where the sum of the top right light intensity and the bottom right light intensity is divided by 2. The last two lines indicate the difference in vertical and the difference in horizontal. Then, the vertical movement is produced from the subtraction of the average bottom value from the average top value. Similarly, the horizontal movement is produced from the subtraction of average right value from the average left value.

```
int lt = analogRead(ldrlt); // top left
int rt = analogRead(ldrrt); // top right
int ld = analogRead(ldrld); // down left
int rd = analogRead(ldrrd); // down right

// int dtme = analogRead(4)/20; // read potentiometers
// int tol = analogRead(5)/4;
int dtme = 10;
int tol = 50;

int avt = (lt + rt) / 2; // average value top
int avd = (ld + rd) / 2; // average value down
int avl = (lt + ld) / 2; // average value left
int avr = (rt + rd) / 2; // average value right

int dvert = avt - avd; // check the difference of up and down
int dhoriz = avl - avr; // check the difference of left and right
```

Fig. 5: Coding for Light Dependent Resistors

#### 3.2 Motion Part

This part comprises Arduino Uno R3 and 2 servo motors, their interconnections are shown in the schematic diagram of Fig. 3. Both of the pulse wires for both servo motors are connected to digital pins 9 and 10. For both servo motors, the negative wires are connected to the ground pin of the Arduino while the positive wires are connected to the 5V Arduino pin. For the motion part of the hardware implementation, the coding for the two servo motors used is shown in Fig. 6.

```
#include <Servo.h> // include Servo library

// 180 horizontal MAX
Servo horizontal; // horizontal servo
int servoh = 180; // 90; // stand horizontal servo

int servohLimitHigh = 180;
int servohLimitLow = 65;

// 65 degrees MAX
Servo vertical; // vertical servo
int servov = 45; // 90; // stand vertical servo

int servovLimitHigh = 80;
int servovLimitLow = 15;
```

Fig. 6: Coding for Servo Motor

The first line of coding initiates the horizontal servo, setting its maximum limit of rotation to 180 degrees. Then, the minimum limit for the horizontal servo is set at 65 degrees. For the vertical servo, the maximum limit of rotation is fixed at 80 degrees while the minimum rotation limit is set at 15 degrees. For both of the servo, the coding for the maximum limit and minimum limit are set by trial and error. Therefore, both the structure of the hardware as well as the placement of servo are taken into consideration to determine the optimal maximum and minimum limits for both the servo motors.

#### 3.3 Acceleration Part

This part comprises of Arduino Uno R3 and the MPU6050 sensor, their interconnection is shown in Fig. 4. The Vcc pin of the MPU6050 is connected to the 5V of the Arduino pin. For data and

clock signals, the analog pins A4 and A5 of the Arduino are connected to the SDA and SCL pins of the MPU6050 sensor. Furthermore, one of the digital pin D2 of the Arduino is connected to the INT pin of the MPU6050.

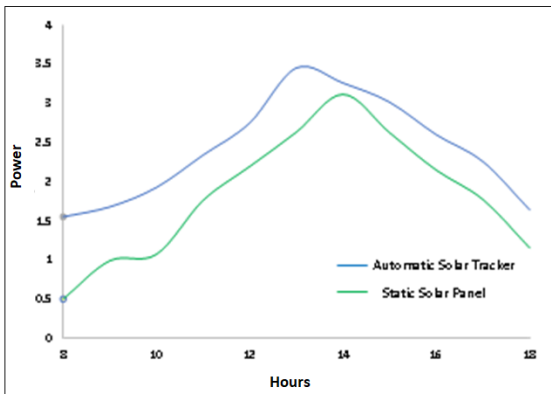
### 4. Results and Discussion

After the sketch was run and tested separately, the three parts (the sensing part, motion part and accelerometer part) were combined to obtain the required results. In this project, the obtained results are compared with the static solar panel. The comparison between Static Solar Panel and automatic Solar Tracker during the cloudy day is shown in Table 1 for different time periods in terms of voltage, current, and power.

**Table 1:** Comparison between Static Solar Panel and Automatic Solar Tracker during Cloudy Day

Hours	Static Solar Panel			Automatic Solar Tracker		
	V	A	W	V	A	W
8	8.40	0.060	0.504	9.15	0.170	1.555
9	8.50	0.117	0.994	9.45	0.178	1.682
10	8.60	0.125	1.075	9.70	0.199	1.930
11	9.70	0.182	1.765	9.85	0.238	2.344
12	9.90	0.222	2.197	10.2	0.270	2.754
13	10.3	0.256	2.636	10.8	0.320	3.456
14	10.5	0.297	3.118	10.7	0.305	3.263
15	9.70	0.271	2.628	10.3	0.293	3.018
16	8.60	0.250	2.15	9.90	0.263	2.603
17	8.30	0.214	1.776	9.30	0.243	2.26
18	8.10	0.143	1.158	8.8	0.187	.645
Average Power			1.818	2.41		

The data in Table 1 shows that the automatic solar tracker produces more power compared to the static solar panel. From the table, the highest power reading of 3.118 W is caught by the static solar panel for 14.00 Hours. The lowest power reading of 0.504 W caught by the static solar panel occurs for 8.00 Hours. On the other hand, the highest power produced by the automatic solar tracker is for 13.00 Hours, the power value is 3.456 W while for the lowest power reading of 1.555 W was for 8.00 Hours. Therefore, the automatic solar tracker has the higher average power of 2.41 Watt while the static solar panel only has an average power of about 1.818 Watt. Fig 7 shows the line graph of power readings collected from 8 hours to 18 hours (or 8.00 Hours until 18.00 Hours) for both solar panels.



**Fig.7:** Plot of Power versus Time for Static Solar Panel and Automatic Solar Tracker from 8 Hours to 18 Hours during a cloudy day

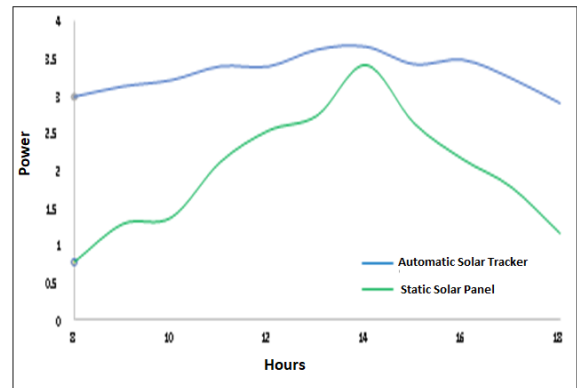
In the observation, the red line indicates automatic solar tracker power readings while the blue line indicates power readings for the static solar panel. It can be observed from the line graph that the peak power for the automatic solar tracker is at 13.00 Hours. Similarly, the peak of the power of static solar panel is at 14.00 Hours but is not enough to surpass the line graph of the automatic solar tracker. It is calculated that the efficiency for the automatic

solar tracker is better than the static solar tracker for about 32.17%. Table 2 shows the comparison between the static solar panel and automatic solar tracker in terms of voltage, current, and power collected during the sunny day. From the readings gathered, it is shown that the automatic solar tracker produces more power compared to the static solar panel. For the static solar panel in Table 2, the highest power reading is caught for 14.00 Hours whose value is 3.413 Watt while the lowest power reading of 0.774 Watt is caught for 8.00 Hours. On the other hand, the highest power produced by the automatic solar tracker is also at 14.00 Hours whose power value is 3.658 W while its lowest power reading of 2.988 W was generated at 8.00 Hours. The automatic solar tracker has the higher average power with 3.31 W while the static solar panel only has about 1.994 W.

**Table 2:** Static Solar Panel and Automatic Solar Tracker Readings during Sunny Day

Hours	Static Solar Panel			Automatic Solar Tracker		
	V	A	W	V	A	W
8	8.7	0.089	0.774	10.20	0.293	2.988
9	8.8	0.146	1.284	10.35	0.302	3.125
10	8.9	0.154	1.371	10.42	0.308	3.209
11	10.0	0.211	2.110	10.51	0.323	3.394
12	10.1	0.251	2.535	10.60	0.320	3.392
13	10.3	0.265	2.736	10.80	0.335	3.618
14	10.5	0.325	3.413	10.73	0.341	3.658
15	10.0	0.330	2.628	10.40	0.329	3.421
16	8.9	0.279	2.15	10.55	0.330	3.481
17	8.6	0.243	1.776	10.36	0.312	3.232
18	8.4	0.172	1.158	10.29	0.282	2.901
Average Power			1.994	3.310		

Fig. 8 shows the line graph of power readings collected from 8.00 Hours until 18.00 Hours for both solar panels on a sunny day. In the observation, the red line indicates automatic solar tracker power readings while the blue line represents power readings for the static solar panel.



**Fig.8:** Plot of Power versus Time for Static Solar Panel and Automatic Solar Tracker from 8 Hours to 18 Hours during a sunny day

The observation from the line graph shows that the peak power caught by the automatic solar tracker occurs at 14.00 Hours. The static solar panel peak power point also comes at 14.00 Hours but is not enough to surpass the line graph of the automatic solar tracker.

The results obtained using the MPU6050 that is mounted on top of the board whilst it is moving by following a phone light (detected by the LDRs) is shown in Fig. 9.

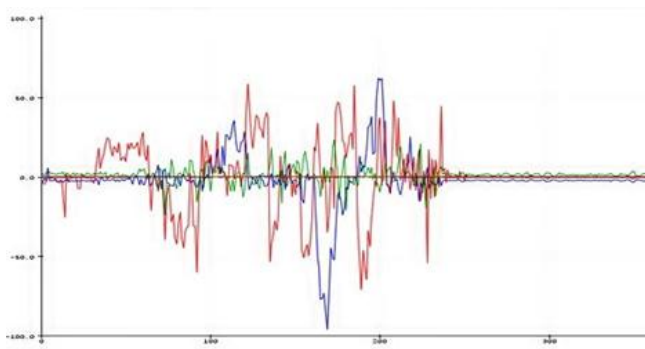


Fig. 9: Results from Serial Plotter

Firstly, the board is in resting place which is at 135 degrees to the front then set back to its normal resting place. Then the board is moved to the left and moved 135 degrees to the front then back to its normal resting place, the vice versa for the left side. The MPU6050 is very helpful in detecting the changes in x, y, and z-axis. It also helps measure the acceleration from the movement of the board.

## 5. Conclusion

In this paper, a prototype of an automatic solar tracker is presented which is able to obtain maximum power from the solar energy over the conventional static solar panel. The system is constructed and operated successfully. The automatic solar tracker has an advantage because it uses servomotors as the driving devices for a solar panel to give a much higher performance and less power consumption compared to the old stepper motor. The automatic solar tracker is cost-effective, simple, and efficient and operates automatically.

## Acknowledgment

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