Light intensity/incident angle measurement

By

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ABSTRACT

This project aims to measure the angle at which light intensity is at its maximum using an Arduino Uno, an LDR (Light Dependent Resistor), and an MPU6050 module. The project leverages the Arduino Uno's capabilities to interface with these components and gather the required data. The LDR is utilized to sense the ambient light intensity, employing a voltage divider circuit to translate it into an analog voltage. The MPU6050 module, equipped with a gyroscope and accelerometer, provides orientation information such as roll, pitch, and yaw angles. The project's main focus lies in determining the angle at which the light intensity reaches its peak.

The Arduino code facilitates the coordination of these components. It initializes both the LDR and MPU6050 in the setup function, capturing analog data from the LDR and orientation data from the MPU6050. By continuously integrating the gyroscope readings, the Arduino calculates and updates the orientation angles over time. Mapping the LDR's analog values to representative light intensity levels enhances the correlation between the orientation angles and the corresponding light intensities.

As a result, this project underscores the connection between physical orientation and environmental conditions. Through the data collected, users can identify the angle at which light intensity reaches its maximum, potentially offering insights into optimal lighting conditions for specific applications. The project's output, displayed via the Arduino's serial monitor, provides a real-time view of the relationship between orientation angles and light intensity, contributing to a more nuanced understanding of environmental interactions.

OBJECTIVE

The main aim of this project is to measure the angle with respect to the ground where the intensity of a particular light source is maximum, using Arduino and Matlab ide.

It could give us a precise angle from the ground, at what angle the light intensity is maximum, the high end implementation of the same embedded system is applicable to the outer-space rovers where the main source of their energy is sunlight and accordingly they have to tilt their solar panels incident to the sun rays to get maximum of the flux intensity.

Whereas the low end implementation was observed in our smart phones as proximity sensors and automatic screen brightness ability.

THEORY

MPU6050 (ADXL335- 3-axis)

MPU6050 has an integrated 3-axis MEMS (Micro Electrical Mechanical Systems) accelerometer and 3-axis MEMS gyroscope. The MPU 6050 is a 6 DOF (Degree of Freedom) or a 6-axis IMU (Inertia Measurement Unit) sensor i.e. it will give 6 values in output. Three values from accelerometer and three from gyroscope. This sensor uses I2C protocol for communication.

Accelerometer is an electromechanical device provides the information of force acting on or experienced by the object. Once the acceleration of the object is obtained, successive integral computation can be used to calculate the velocity and distance covered by the object. The rate of change of velocity gives the acceleration which can be interpreted as the tilt angle.

The basic and important application of accelerometer is tilt measurement, tilt is the static measurement where the gravity of the acceleration is measured and this measurement employed in positioning, aliasing, leveling and navigation.

One of the general method of sensing tilt angle is to integrate the output of gyroscope.

A. Measuring tilt using one axis

As in the case of a dual axis accelerometer(xy) is fixed and perpendicular to gravity, the tilt algorithm is restricted to one axis of sensitivity. The accelerometer is tilted along x-axis and y-axis remains at 0g output during the full form rotation of y-axis If x-axis is used to analyze the tilted angle of the accelerometer then:

$V_{OFF} = V_{OUTX} + S * SIN\theta$

[Where,

V_{OFF} = offset voltage, **V_{OUTX}** = voltage output from x=axis, s= sensitivity of the accelerometer. And **θ=** the tilt angle.**]** **θ=** sin inv((**V_{OFF}-V_{OUTX}**)/s)

Disadvantages

In the above arrangement tilt sensitivity between -90 degree and - 45 degree and between +90 degree and +45 degree. The resolution problem between these values makes the method calculation of the tilt angle inaccurate when the accelerometer output is near +1g or -1g range. Another disadvantage is it makes difficult to identify te variance between two tilt angle that overcome in the similar sensor output.

B. **Measuring tilt using two axis**

The resolution problem and the tilt orientation problem can be addressed by mounting the accelerometer vertically. So that the y-axis is parallel to gravity or by using a tri-axis accelerometer using at least 2-3 axis. In the the sine component along x=axis measure the inclination and that of the y-axis is done by cosine component.

The formula is given by: A_{outx} $/A_{outy} = \sin\theta * 1g/\cos\theta * 1g$ $\theta =$ tan inv(A_{outx} / A_{outy}).\

This is also useful in distinguising between the quadrants and to measure angles throughout the entire 360 degree arc.

The dual-axis accelerometer is most responsive to change in tilt when the sensitive axis is perpendicular to force of gravity and least responsible to change tilt when the sensitive axis is oriented in +1g or -1g position. Also accelerometer cannot indicates detection of inversion due to the absence of z-axis and causing improper functioning

C. **Measuring tilt angle using three axis**

In order to define the accelerometer in all dimensions the pitch, roll and yaw are sensed using all three outputs of the accelerometer, where the pitch is the angle of x-axis, roll is the angle of y-axis and the yaw is the angle of z=axis.

$R_X = [((V_x * V_{ref})/2_n -1) - V_{zero}] / V_{sensitivity}$

$R_y = [((V_y * V_{ref})/2_n -1) - V_{zero}] / V_{sensitivity}$

$R_z = [((V_z * V_{ref})/2_n -1) - V_{zero}] / V_{sensitivity}$

$R = sqrt(R_x^2 + R_y^2 + R_z^2 +)$

A= cos inv (R_x /R)

B= cos inv (R_y/R)

C== cos inv (R_z /R)

The value of V_{ZERO}, V_{ref}, $V_{SENSITIVITY}$. Is measured from the data sheet of the MPU6050.

LDR

LDR stands fro light dependent resistor.

The working principle of an LDR is photo conductivity, that is nothing but an optical phenomenon.When the light is absorbed by the material then the conductivity of the material reduces. When the light falls on the LDR, then the electrons in the valence band of the material are eager to the conduction band. But, the photons in the incident light must have energy superior than the band gap of the material to make the electrons jump from one band to another band (valance to conduction).

Hence, when light having ample energy, more electrons are excited to the conduction band which grades in a large number of charge carriers. When the effect of this process and the flow of current starts flowing more, the resistance of the device decreases.

REQUIREMENTS

1. Arduino uno / nano
2. UART Cable
3. MPU6050 Module
4. Jumper wires
5. Bread board
6. LDR
7. 1k Resistance
8. Arduino IDE
9. Matlab
10. I2C master/slave bus function
11. Arduino Hardware Package For Matlab
12. Bluetooth module - HC-05 13. 9V battery

CIRCUIT DIAGRAM

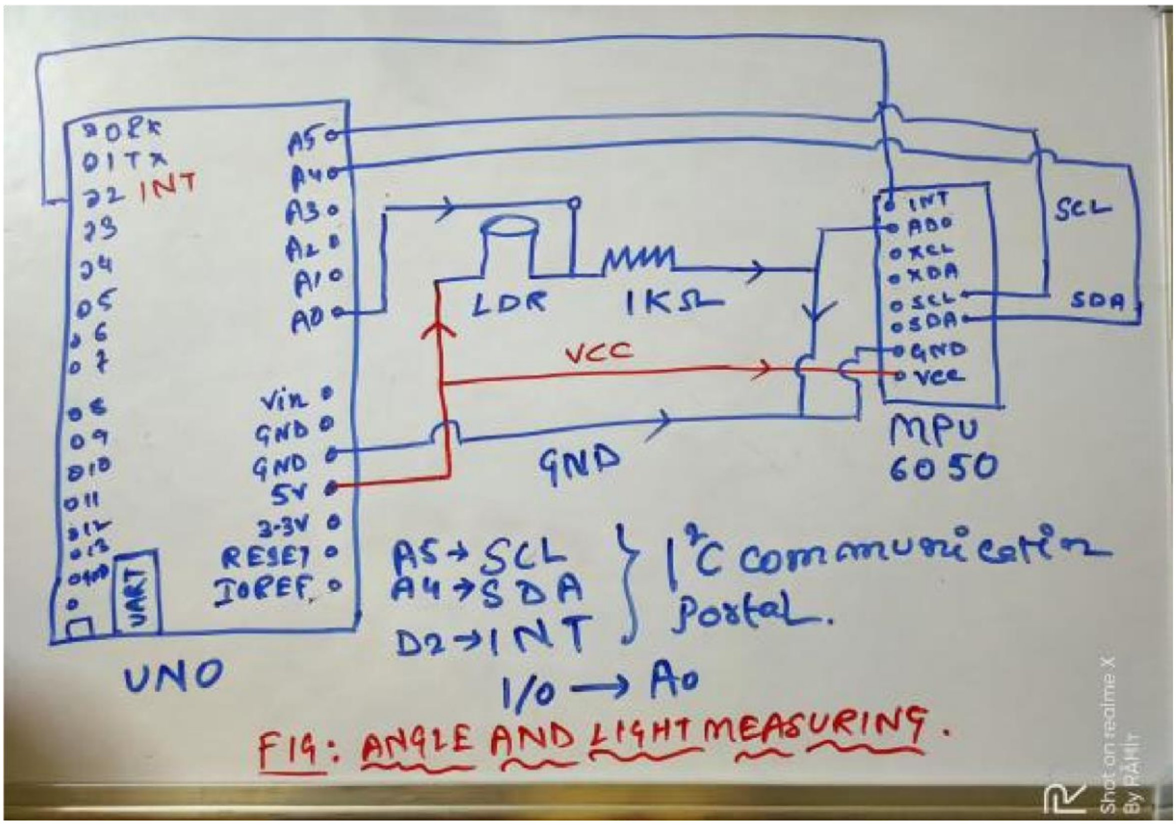


Figure 1: pin-out presentation of Arduino UNO- MPU-6050- LDR

ARDUINO	**MPU 6050**	**LDR**	**BLUETOOTH (HC-05) (0PTIONAL)**
5V	VCC	ONE TERMINAL OF LDR	-
ANALOG PINAO	-	ANOTHER TERMINAL(ALONG WITH 1K RESISTANCE	-
ANALOG PIN- A4	SDA	-	-
ANALOG PIN- A5	SCL	-	-
DIGITAL PIN-2 (INT)	INT	-	-
GND	GND - AD0 (TO MAKE IT SLAVE-0B00000000)	OTHER TERMINAL OF 1K RESISTANCE	GND
3V	-	-	VCC
DIGITAL-PIN 0 (RX)	-	-	RX
DIGITAL PIN 1 (TX)	-	-	TX

DESIGN CALCULATIONS/ CODE DEVELOPMENT

DESIGN:

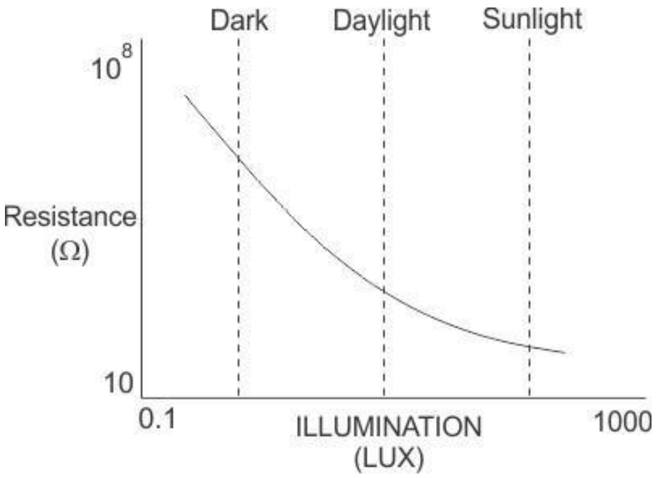
1. After the circuit is conplete with the help of following circuit diagram.
2. Connect the arduino with your PC using the UART-USB cable.
3. Open the arduino IDE.
4. Write the code attached with the report.
5. Go to compile tab and compile the codes
6. After debugging upload the code into your arduino uno board. Make sure you have chosen the correct communication port before uploading.
7. Now open the serial monitor in the EDIT tab.
8. Observe the output

CALCULATION

```
  //Subtract the offset values from the raw gyro values from the MPU
    register gyro_x -= gyro_x_cal; gyro_y -= gyro_y_cal;
    gyro_z -= gyro_z_cal;

    //Gyro angle calculations . Note 0.0000611 = 1 / (250Hz x 65.5) angle_pitch
    += gyro_x * 0.0000611;
//Calculate the traveled pitch angle and add this to the angle_pitch variable angle_roll
    += gyro_y * 0.0000611;
//Calculate the traveled roll angle and add this to the angle_roll variable
    //0.000001066 = 0.0000611 * (3.142(PI) / 180degr) The Arduino sin function is in
radians

    angle_pitch += angle_roll * sin(gyro_z * 0.000001066);                    //If the
IMU has yawed transfer the roll angle to the pitch angel
    angle_roll -= angle_pitch * sin(gyro_z * 0.000001066);                    //If the
IMU has yawed transfer the pitch angle to the roll angel
    //Accelerometer angle calculations
    acc_total_vector = sqrt((acc_x*acc_x)+(acc_y*acc_y)+(acc_z*acc_z));
//Calculate the total accelerometer vector
    //57.296 = 1 / (3.142 / 180) The Arduino asin function is in radians angle_pitch_acc
    = asin((float)acc_y/acc_total_vector)* 57.296;      //Calculate
the pitch angle angle_roll_acc = asin((float)acc_x/acc_total_vector)* -57.296;
          //Calculate
the roll angle
```

```
    angle_pitch_acc -= 0.0;
//Accelerometer calibration value for pitch angle_roll_acc
    -= 0.0;
//Accelerometer calibration value for roll

            angle_pitch = angle_pitch * 0.9996 + angle_pitch_acc * 0.0004;
//Correct the drift of the gyro pitch angle with the accelerometer pitch angle angle_roll
        = angle_roll * 0.9996 + angle_roll_acc * 0.0004;          //Correct
the drift of the gyro roll angle with the accelerometer roll angl angle_pitch
            = angle_pitch_acc;
//Set the gyro pitch angle equal to the accelerometer pitch angle angle_roll
        = angle_roll_acc.
```

Theoretical calculation of LDR PROCEDURE

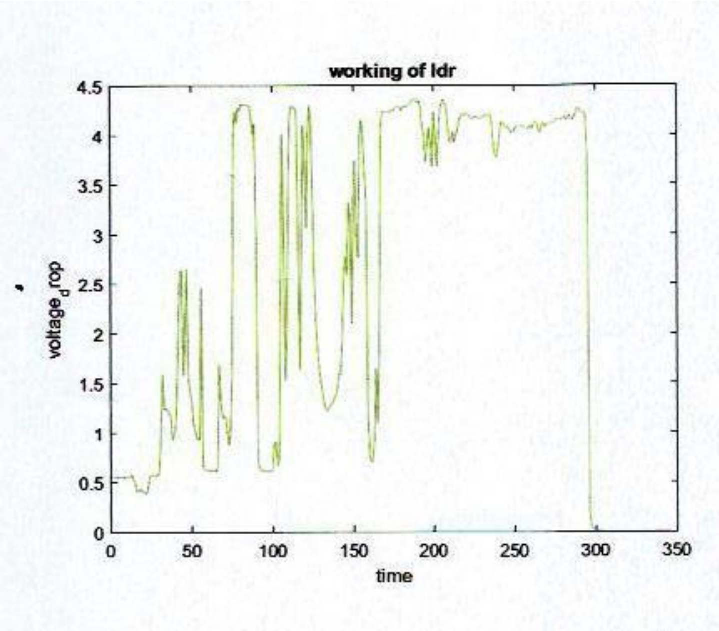


Y-axis:

Tilt for left direction:

1. Initially the accelerometer is slightly tilted towards the left direction and observe the serial monitor
2. The angle tilted is manually noted using protractor
3. Later the ADC values from MPU is noted and substituted in the formulas of sec.c as R_x ,R_Y, R_Z ,under theory portion.

4. The obtained R from the substituted value in further substituted in ‘b’ at the same section to obtain the degree along y-axis



Tilt for right direction:

1. Initially the accelerometer is slightly tilted towards the right direction and observe the serial monitor
2. The angle tilted is manually noted using protractor
3. Later the ADC values from MPU is noted and substituted in the formulas of sec.c as R_X ,R_Y, R_Z ,under theory portion.
4. The obtained R from the substituted value in further substituted in ‘b’ at the same section to obtain the degree along y-axis

A. X-axis

Tilt measurement for forward direction.

1. Initially the accelerometer is slightly tilted towards the front direction and observe the serial monitor
2. The angle tilted is manually noted using protractor
3. Later the ADC values from MPU is noted and substituted in the formulas of sec.c as R_X ,R_Y, R_Z ,under theory portion.
4. The obtained R from the substituted value in further substituted in ‘a’ at the same section to obtain the degree along x-axis

Tilt measurement for backward direction.

1. Initially the accelerometer is slightly tilted towards the front direction and observe the serial monitor
2. The angle tilted is manually noted using protractor
3. Later the ADC values from MPU is noted and substituted in the formulas of sec.c as R_X ,R_Y, R_Z ,under theory portion.
4. The obtained R from the substituted value in further substituted in ‘a’ at the same section to obtain the degree along x-axis

GRAPH PLOT USING MATLAB (OPTIONAL)

The graph between the light intensity and the angle was done by using matlab and ‘arduino hardware package for matlab’, We have to separate the LDR values and angle reading and bypass it through another communication port using the bluetooth module- hc-05. By allowing a real time graph plotter the plot can be done

OBSERVATIONS/RESULTS

OBSERVATION:

DIRECTION	ACTUAL ANGLE (deg)	THEORETICAL ANGLE(deg)	DISPLAYED ANGLE (deg)	ERROR	LDR
left	54	53.05	52.00	0.025	624
right	67.5	66.34	65.88	0.019	526
forward	63.5	63.12	62.76	0.011	500
backward	56.5	55.93	55.40	0.019	611

DISCUSSION OF RESULTS

- The left direction angle was measured to be 54 and theoretical angle was found to be 53.05 and the displayed angle was found to be 52 with an error of 0.025.
- The right direction angle was measured to be 67.5 and theoretical angle was found to be 66.34 and the displayed angle was found to be 65.88 with an error of 0.019.
- The forward direction angle was measured to be 63.5 and theoretical angle was found to be 63.12 and the displayed angle was found to be 62.76 with an error of 0.011.
- The backward direction angle was measured to be 56.5 and theoretical angle was found to be 55.93 and the displayed angle was found to be 55.40 with an error of 0.019.
- Correspondingly LDR value is displaying the amount of light intensity at that angle with respect to the ground.

CONCLUSION:

The tilt of the accelerometer is compared with three different ways like actual value, theoretical value and displayed value. As the theoretical value is calculated describes the conversion of ADC output to the corresponding angle which is actually the micro controller does, hence the error between the actual value is obtained. The error obtained was acceptable ans is minimum. Hence, with the obtained result of 3-axis accelerometer has proven that effective in measuring the tilt angle.
The LDR detect the light flux efficiently and the angle together with complete the task to detect the maximum flux intensity at any angle.

REFERENCES:

https://www.electrical4u.com/light-dependent-resistor-ldr-working-principle-of-ldr/ https://forum.arduino.cc/
https://components101.com/sensors/mpu6050-module