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ON or OFF: Automated Arduino-based smart street light system based on environmental light conditions

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Abstract

People desire to live sophisticated lives while enjoying all the amenities in today's modern environment. The advancement of science and technology is accelerating rapidly to satisfy these needs. Internet of Things (IoT) plays an important role in automating a diverse arena, including health monitoring, agricultural irrigation, traffic management, street lighting, classrooms etc. with the help of cutting-edge innovations. Street lights are now operated manually, which waste a significant amount of energy globally and has to be altered. Especially in Sri Lankan, with the country facing an economic crisis, the wastage in the process of street lighting may cause a huge additional loss to the economy. The best approach in plugging this additional expenditure is by implementing a smart street lighting system using Arduino to control the energy wastage. Also, this smart system does not need any humans to operate it as it is a fully automated system as well. The system is implemented in Tinkercad - an online platform allowing users to design and simulate 3D models - and it works perfectly. The system fills the gap of this research as well.

Keyword: *Internet of Things (IoT), Tinkercad, Arduino, Street light*

1. Introduction

The introduction of electricity in day-to-day life has brightened and brought liveliness to people's daily schedules. Much of the electrical energy used to power household appliances, street lighting etc. is decided by various control stations. In Sri Lanka, the bulk of the roadways are illuminated for an average of roughly twelve hours each day, regardless of whether there are vehicles or people crossing the streets or not. Most of the time, electrical energy is wasted when streetlights are manually controlled as they continue to glow even in the mornings, afternoons and evenings when there is ample daylight (Karthiga et al., 2020). The daylight in the environment does not need any additional lights to brighten the streets.

The authors propose a system through which such wastages and shortcomings can be minimized or eliminated. The suggested approach will assist in conserving energy and boosting the national economy by circumventing these restrictions (Sanchez-Sutil & Cano-Ortega, 2021). This system may be set up to enable the light intensity to accommodate circumstances. When the Light Dependent Resistors (LDR) detect adequate light, the lights are automatically turned off. This prevents wastage of energy from bright streetlights at unnecessary locations, thus resulting

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in significant energy savings (S& R, 2022).

1.1 Background of the study

The Smart Street Light System is a robust and controllable concept which is used to automate the deactivating or activating - or OFF/ON of streetlights. When the intensity of daylight reduces, the lights are automatically turned ON. Lights are automatically turned OFF or ON by keeping an eye on the brightness of the sun. The LDR sensor, which monitors the light exactly like the human eyes, does this task. The system determines whether light is required. Streetlights are automatically turned ON when darkness approaches to a certain degree; or otherwise, they are turned OFF.

1.2 Recent studies

The Internet of Things (IoT) is utilized for diverse purposes, including monitoring systems that look for security irregularities, RFID tags in baggage, chemical industry sensors, smart homes, military applications, healthcare, industrial management, as well as varied surroundings (Archibong et al., 2020) and (Kumar et al., 2020).

A sensor known as an LDR detects any reduction in the resistance of light falling on it. This type of sensor is frequently utilized in light sensor circuits in open spaces; one such example being to regulate street lighting. Another potential use is in spectroscopic equipment. Continuous light or pulsed light can be employed in this type of equipment. In typical spectroscopic equipment continuous light is employed. Pulsed light, which is frequently utilized in photo acoustic spectroscopy, has made it easier to be used in spectroscopy using lock-in amplifiers. Semiconductors are used in LDRs to create light (Raju et al., 2022). The microcontroller unit is set up to handle data after receiving detected signal information from LDRs, PIR sensors and ultrasonic sensors. Additionally, the controller unit is set up to operate the actuator relay to regulate the streetlights. This relay module serves as a switch between the Direct Current (DC) and Alternating Current (AC) sources of power in this system. Additionally, the controller unit is set up to transfer the street light status data to a cloud server. The system turns the lights OFF and ON, and also manages the streetlights' intensity based on the movement of vehicles and people, thus saving energy (Saputra & Supriyanto, 2020). LDRs are used in LED streetlights, and PIR sensors and LDRs are used to automate street lighting to save electricity (Prasad, 2020; Kamoji et al., 2020 and Zullkuffli et al., 2022). The Passive Infrared (PIC) controller is used during the implementation (Gudadhe et al., 2022). The presence of vehicles and people near the lights is taken advantage of by the fuzzy light intensity control system, which makes use of sensors and microcontrollers. A small streetlight's performance has been evaluated, and the results of monitoring and controlling it

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have been recorded (Eriyadi et al., 2021). When there is no demand the SSLS circuit functions as an open circuit, effectively controlling the amount of electricity used (Yahya & Aziz, 2021).

Thanks to communication technologies like WiFi, GSM, ZigBee and others, a wide range of devices and objects are embedded with sensors, software and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet. This has given rise to the Internet-of-Things (IoT) paradigm, a new network framework. An IoT architecture's design depends heavily on the communication technology used, which is also directly tied to the application under consideration. For instance, the life cycle of a body sensor node, which is often equipped with a relatively restricted energy source in wearable IoT devices, is greatly influenced by the dimensions of the battery as well as the duty-cycling of processing and communication (Gagliardi et al., 2020).

The Artificial Neural Network (ANN) is chosen for some systems because of its capacity to train created neural networks and change their parameters, as well as its frame's malleability and ability to familiarize itself with a range of inputs (Smys et al., 2020). Also, if a collision does happen, it can be detected using an ultrasonic sensor, IR sensor, as well as some sound and heat sensors. When a moving vehicle is detected, the sensor sends the information to the Raspberry Pi that turns on the following three streetlights in a row to provide the driver in the darkness with a noticeable path to drive (Manani et al., 2021). Related to this, a timer that is activated when a vehicle or an obstruction moves away from the sensor causes the light to turn OFF (Kumari et al., 2019). According to Ravikumar et al., (2020), Chen et al., (2020) and and Prasanth et al., (2022), by employing energy effective occupancy and illumination sensors, the ZigBee-based light monitoring and control system aids in decreasing the energy consumption of interior office environments and outdoor lighting environments by satisfying user needs and thus opens the door to designing the Advance Metering Infrastructure (AMI). The intelligent street lighting system can identify four different classes of items, including vehicles, bicycles and motorbikes during nighttime near the KMUTT football field (Saokaew et al., 2021).

There are several piezoelectric sensors accessible to automate and sense daily living activities. Piezoelectric sensors are a unique class of sensors which generate energy through load, force or pressure (Hans et al., 2022). Key elements of automation and the primary focus of the study are smart cities as well as societies (Ahmad et al., 2021). RTC, an HC RF communication module, which is also an ultrasonic sensor, makes up the system. In terms of hardware, a prototype was created with three street poles that are each equipped with an Arduino UNO. Every Arduino comes with an RF module, an RTC as well as an ultrasonic sensor (Arshad

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et al., 2020). The gateway node will receive the safety information from the smart lamppost via an I2I communication mechanism (Song et al., 2020). In order to create a smart street light system, the light pole may support a variety of urban functional equipment. This system can offer a wealth of site resources for the extensive installation of urban functional facilities (Liu et al., 2022).

The most popular gadget for IoT applications is the ESP8266 Wi-Fi serial transceiver module (Saleem et al., 2020). The ESP8266 is used to construct the IoT-based smart street light system by a mesh network (Hassebo & Ali, 2020; Delsing, 2021 and Fuada & Adiono, 2021). Also, power is measured as the simple link with the energy in the circuit, and the power is quantified as the influence of supply voltage fluctuation that is straightly determined by the on power. When computing the LiFi system, it is crucial to signify a data-dependent low-power 10T SRAM cell, which is very energy-efficient (Neha Gupta et al., 2020).

2. Methodology

2.1 Proposed method

This project offers an improved automation and control system for streetlights. The temperature and humidity sensor, microcontroller, relays, LDR, and several more electronic parts make up the system. Four to eight lights may be controlled by a single system, which can also keep an eye on the area's humidity and temperature. We are using an inexpensive ESP-12 Wi-Fi module here. Relays are controlled by an Arduino microcontroller, which also uses a WiFi module to get sensor data and upload it to a database. The normal lamp is replaced by smart LED light technology which consumes low power and provides high-intensity light and effectively illuminates the surrounding. The Light Dependent Resistor (LDR) helps in controlling the intensity of the LED lights. The resistance of the LDR varies according to the amount of light falling on its surface. When the LDR detects light, its resistance will decrease, thus if it detects darkness its resistance will increase. Therefore high-intensity light can be provided when needed. During the rest of the time the light intensity can be set at a low degree to boost power saving and minimize energy wastage. The DHT11 Temperature Humidity sensor is used to sense the surroundings accurately and respond fast. The whole system is implemented with a Wi-Fi module, Arduino Nano Microcontroller, relays, an HTML web page to control and obtain the status of the system and a few other electronic components. This study suggests developing a system, as seen in Figure 1, to intelligently regulate streetlights. By mounting this system to the streetlight poles, it recognizes the brightness/light in the environment and turns the light OFF or ON consequently. This system does not need any human presence to turn the streetlight ON or OFF. The automated system helps the people, vehicles and others on the streets.

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2.1.1 Hardware requirements

1. Light bulb
2. Resister
3. 5, 5 power supply
4. Photoresistor
5. NPN Transistor (BJT)
6. Arduino UNO R3

2.1.2 Arduino

This is an open-source PC hardware, programming project, organization, user association that designs as well as develops microcontroller units and single board microcontrollers for constructing sophisticated devices and aggregate items that can control and detect issues in the real as well as the digital world.

2.1.3 Power supply

The "power supply" is the source of electricity. A device or system that supplies electrical or other types of energy to an output load or group of loads is known as a power supply unit. The term is most used in relation to electrical energy sources, less frequently in relation to mechanical ones, and seldom in relation to other renewable resources. The power supply portion is necessary in order to lower the signal's amplitude and convert AC signals to DC signals. The main voltage signal is 230V/50Hz, which is an AC voltage. However, different applications may call for a DC voltage with an amplitude of +12V and+5V.

2.1.4 Sensor LDR

A photo resistor is another name for an LDR (light dependent resistor). These gadgets are light reliant. When the light is turned off for the LDR, the resistance will decrease because it is now at a low intensity level. If the LDR is positioned in a dark area, the resistance levels grow and are higher. The resistivity factor of an LDR, also known as a photoresistor, is a function of electromagnetic radiation. Therefore, they are comparable to human eyes, in that they are light-sensitive sensors. Other terms for them include photoconductors, conductive cells and just plain old photocells. High resistance semiconductor materials are used in their construction. A LDR works according to the knowledge of photo conductivity. An optical phenomenon identified as photo conductivity occurs when light is immersed by a substance, dropping the medium's conductivity. However, as soon as light hits the LDR, its resistance drops and current begins to flow into the base of the first transistor, and then the second.

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2.1.5 NPN Transistor

A bipolar junction transistor is a transistor that equally uses electrons and electron holes as charge carriers (BJT). On the contrary, a unipolar transistor uses only one kind of charge carrier, similar to a field-effect transistor. Terminals may be used for amplification or as a switch by enabling a small current to be injected at one of its terminals to regulate a much larger current flowing between both the bipolar transistors.

2.1.5 Light Bulb

LEDs use far lesser energy than incandescent lights since the diode light is significantly more power effective than filament light. LED bulbs consume at least 75% less energy than incandescent lights. The other advantage of LEDs is their lack of "fuss." LEDs last far longer than regular lights.

2.1.6 Software requirement Tinkercad

As it validates the circuit we will be developing the actual components, where the simulation software can help us design more effective and efficient projects. The Smart Light System offers the groundwork for the creation of further intelligent and automated systems. The Tinkercad provides the virtual simulation, and the user can write code within that.

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2.1.7 Schematic diagram

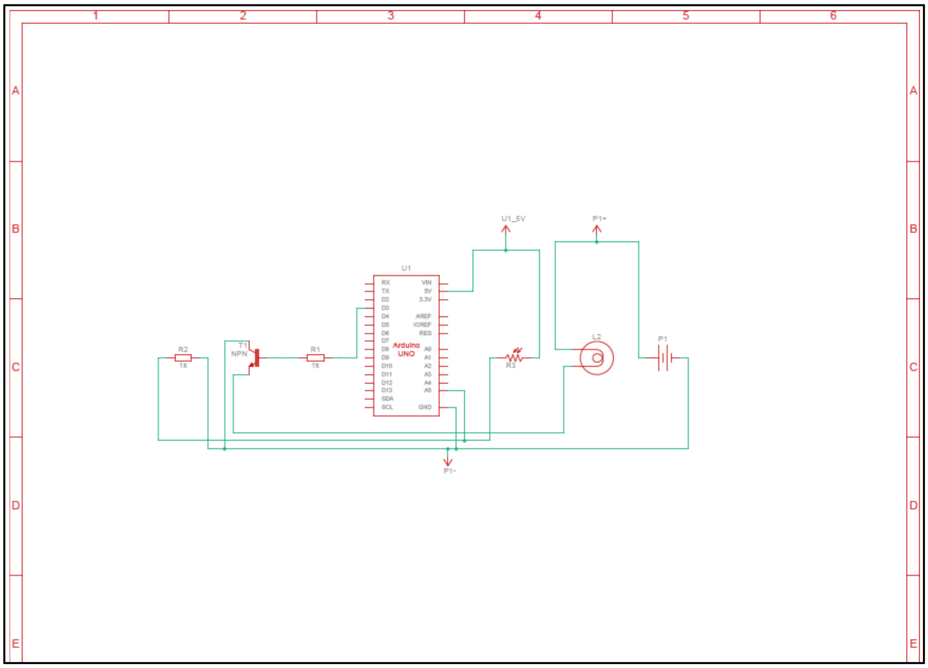

Figure 1: Schematic View

Table 1: Component list

Name	Component	Quantity
L2	Light bulb	1
R1, R2	Resister	2
P1	5, 5 power supply	1
R3	Photoresistor	1
T1	NPN Transistor (BJT)	1
U1	Arduino UNO R3	1

According to Table 1, we used 01 light bulb, 02 resisters, 01 power supply, 01 photoresistor, 01 NPN Transistor and 01 Arduino UNO R3 microcontroller. The hardware used in this system is minimal. But when it comes to the real system it will need more quantities of hardware according to the requirements. According to the Schematic Diagram, the Arduino board's 5V supply pin is linked to terminal one of the LDR. The input analog pin of the LDR (A5) is linked to the second terminal of the

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LDR. And through the resistor, the same terminal is also linked to the Arduino's Ground line. One of the terminals of the Bulb is linked to the positive terminal of the power source. Also, the ground terminal of the Arduino Board is linked to the negative terminal of the power source. Next, the Emitter pin of the transistor is linked to the second terminal of the light bulb. Next, the ground linking of the power supply device is connected to the transistor's collector terminal. Finally, a resistor is used to link the transistor's base terminal to either of the Digital pins (D3) on the Arduino Board.

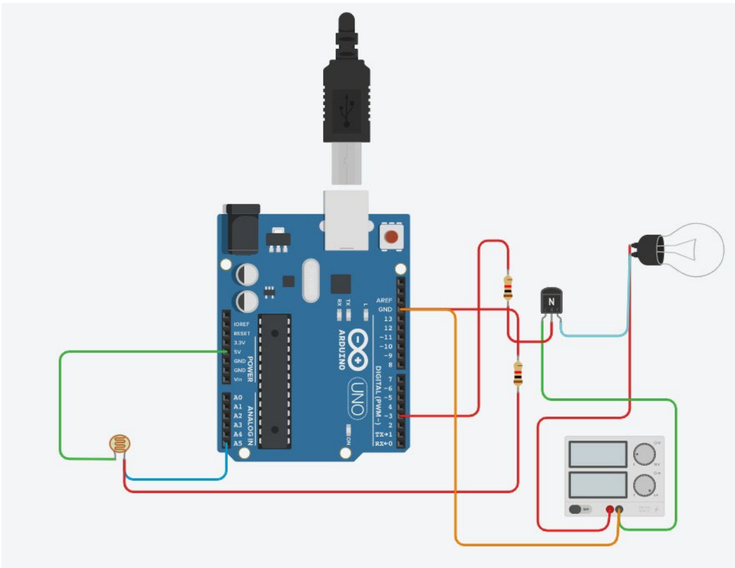

Figure 2: View of circuit of Smart Street Light System

```
int ldrsensor = A5;
int ldrsensor_value;
int brightness = 3;
void setup()
{
  pinMode(brightness, OUTPUT);
  pinMode (ldrsensor, INPUT);
}

void loop()
{
  ldrsensor_value = analogRead (ldrsensor);
  if (ldrsensor_value>512)
    digitalWrite (brightness, LOW);
  else
    digitalWrite (brightness, HIGH);
}
```

Figure 3: Simulation code

C++ programming language is used for the coding in this system. Only two variables are used in the coding. This simple coding is used to operate the Smart Street Light System.

3. Results and discussion

The Smart Street Light System, which is used to automatically turn street lights on and off, is a reliable and manageable idea. The lights automatically go ON as the amount of sunshine decreases. By monitoring the brightness of the sun, the lights are switched off automatically. And the LDR sensor performs this function by monitoring the light in the same way that human eyes do. Whether or not light is necessary is determined by the system itself. When darkness falls to a predetermined point, street lights are automatically switched ON; otherwise, they turn OFF.

The photoresistor, also known as an LDR, is a sensor with semiconducting material on its surface. The electrons in the material's valence bond are stimulated to the conduction band when light impinges on the LDR's surfaces. Based on the input light intensity, this will create a voltage that will be sent as an output. The value is saved by the board itself when the LDR outputs to the Arduino's analog pin A5. (It includes a Flash memory.) In this circuit, the transistor serves as a switch. Based on the output value of the sensor, it will regulate the light bulb. The Ground is connected to the #collector. The Arduino's digital pin is linked to the transistor's base terminal, which will operate the light bulb. In other words, because the transistor's emitter extends farther to link to the light bulb's second terminal, whenever the pin 3 is changed, the status of the light bulb also changes.

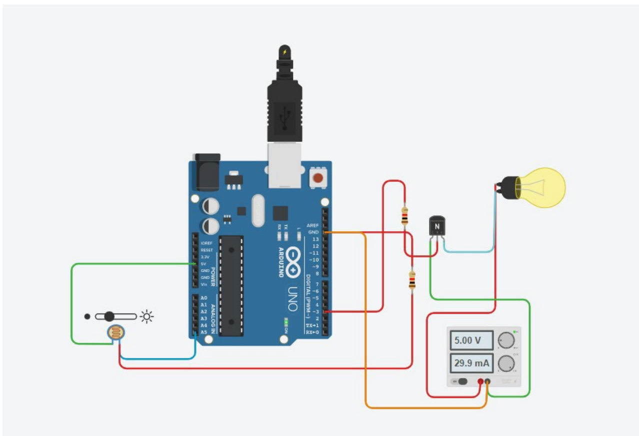

Figure 4: Light bulb ON when LDR senses darkness in the environment

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The LDR sensor monitored the surroundings and detected the light and darkness, as shown in Figure 4. Figure 4 illustrates how the light bulb will switch on when the surroundings become dark, especially when the brightness is less than 512(2.5V). Included in the power supply display are the volts and milliampere (mA) values. The results of reduced ambient brightness are displayed in Figure 4. With the help of the power supply unit and LDR sensor, the light bulb in Figure 4 clicked on.

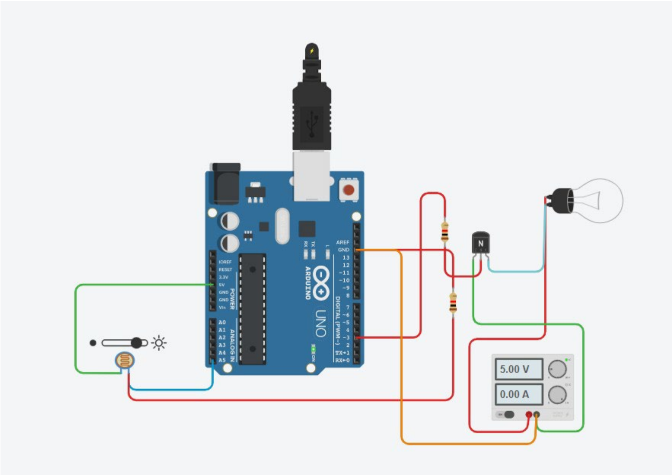

Figure 5: Light bulb is OFF when LDR sensed brightness in the environment

According to Figure 5 the LDR sensor senses the environment and detects darkness and brightness. Also, when the brightness is less than 512 (2.5V) the light bulb will turn OFF accordingly, as in Figure 5. The Milliampere (mA) value and volts are also shown in the power supply display. Figure 5 shows the output of high brightness in the environment. So the light bulb turned according to the given instruction in the coding area.

To summarize how the LDR sensor operates - it gets information based on the input light intensity. The power supply device panel shows such voltage values. The transistor functions as a switch that is attached to the Arduino board, and it will control the light through this connection. Moreover, the entire system works perfectly in accordance with the given instructions in the coding and relevant sensors. To alleviate the economic crisis in Sri Lanka, we recommended this type of innovation to reduce or minimize the wastage of electricity in the form of streetlights. When compared to the other systems used in various research articles such as those by Yoshiura et al., (2013), Alvarez et al., Chen et al., (2020) etc. they are expensive. Also, our system is simple, and we have suggested this efficient model while taking into consideration our country's current economic situation.

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4. Conclusion

Saving money and electricity is the primary objective of this Smart Street Lighting. The gear and sensor network do not cost a considerable amount of money. Commercializing this adaptable street lighting system will not have a significant impact on the country's economy or finances. Current street lighting wastes a tremendous amount of electricity all around the globe. The main goal of our work is to provide a durable, energy-efficient rehabilitation for the current street lighting system. We were able to create a design that offers an effective solution by investigating the factors that contribute to the energy waste of lighting at night and looking at the specifications required for the selected residential areas.

The system only detects the lightness/brightness of the environment to turn the electric light bulb ON/OFF. But when there are no people and or vehicles on the road/street, then the light bulb does not need to turn ON. So the system needs further improvements to detect objects like vehicles and people and turn ON electric light bulb. Only then can the smart system save energy.

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