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Prediction and IoT Based Solar Street Lights with Intensity Control

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Abstract

Street lights are an essential part of road transportation network, and huge amount of money is incurred by the government in keeping them operational at all times. The operational cost includes generation of electricity and therefore electricity is a resource that should be utilized judiciously. We propose an IOT based solar street light monitoring and controlling system to ensure, low power consumption through the automatic dimming of lights as per external lighting conditions, consumption monitoring and instant faulty light detection. Our proposed system consists of smart street lights that automatically turns on at desired intensity based on amount of lighting needed. The solar output is predicted throughout the day and adjusts the lights at desired intensity enabling the monitoring person to estimate power consumptions as per the current intensity of light this can also be extended to predict monthly power consumptions. Also, each of the unit has load sensing functionality that allows it to detect if the light has a fault. It then automatically flags that light as faulty and this data is sent over to the IOT monitoring system so that necessary action can be taken to fix it. The status of the light can be monitored through an android app.

Keywords: *IoT, Street Lights, Arduino, ESP8266, IR Sensor, LDR Sensor, Solar Panel, Decision Tree Regressor, Android, Intensity Control.*

1. Introduction

IoT is a network of physical objects that are embedded with sensors, software and other technologies for the purpose of exchanging information with each other over the internet. Access to affordable and low-power consumption sensors has been one of the key factors in making the IoT technology a reality.

The system proposed uses IoT to improve the existing system present for street lights in terms of power consumption. Official government data has shown that power consumption has been reduced in recent years due to the substitution of Sodium Vapor bulbs with LED of bulbs, however this cost can be cut even further by reducing the illumination of the bulb when streets are desolated or by switching them off automatically at day time (this takes care of the cases when the street lamps are left on even during the day time).

The system also proposes the use of solar energy to power street lamps. The amount of solar energy that can be generated during the day is predicted using Decision Tree Regression and accordingly the bulb intensity is decided when the system turns on at night time.

As mentioned earlier the system switches on and off as well as dims and glows automatically based on the traffic on the street. This is achieved through the use of LDRs and IR sensors. A Light Dependent Resistor (also known as a photoresistor or LDR) is a device whose resistivity is a function of the incident electromagnetic radiation. So,

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with the help of a transistors during night time the LDR will cause the bulb to glow and during day time will cause the bulb on turn off. An infrared sensor is an electronic device that emits in order to sense some aspects of the surroundings. IR sensors can be used to detect heat or motion of objects.

Additionally, the system also supports faulty light detection and concerned authorities will be made aware of the status of the bulb with the help of an android app.

2. Objective

Global demand for energy has tripled in the past 50 years and might triple again in the next 30 years. While much of this growth will come from the rapidly booming economies of China and India, many of the developed countries, especially those in Europe, are hoping to meet their energy needs by expanding the use of renewable sources.

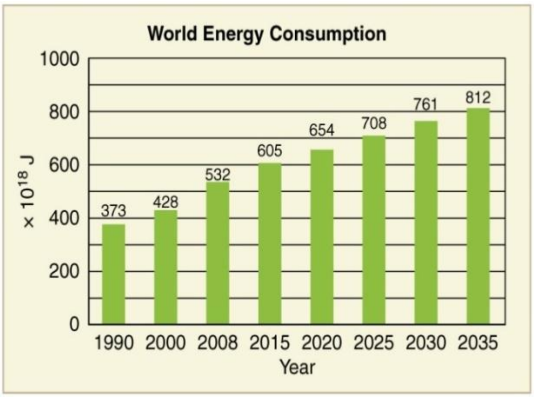

Figure 1: Past and projected world energy use (source: Based on data from U.S. Energy Information Administration, 2011)

The figure below shows that it is important to shift towards renewable sources of energy to meet the future emerging energy demands of the world as most of the current energy demands are met by the use of non-renewable sources of energy.

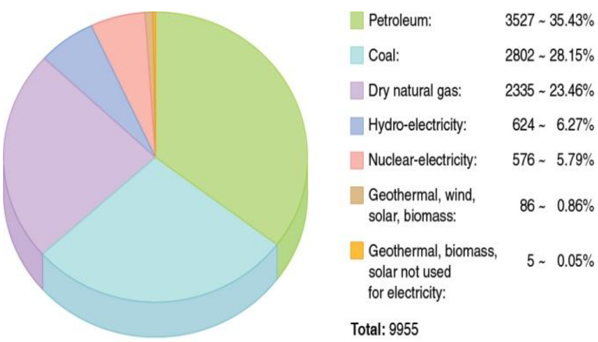

Figure 2: World energy consumption, in billions of kilowatt-hours: 2006. (credit: KVDP)

It is also seen that a maximum amount of energy budget of different countries across the world is used for street lights. Therefore, this street light system is important to reduce energy consumption and encourage the use of renewable energy.

3. Literature Survey

These papers were referred for the planning and execution of the project with due credits to the respective authors.

[1] This paper describes the use of LDR and IR sensors for intensity control of street lights based on external lighting conditions and object detection. The main aim of the authors is to reduce the power consumption of street lights as the author believes intensity control would reduce the power consumed by about 40%. LDRs are used to power the street lights ON and OFF based on sunrise and sunset while IR sensors are used to detect objects and change intensity based on speed of the objects. The authors use an Arduino to control the system and a Battery to power the Arduino and other components. Though, the method will reduce the amount of power consumed, the authors have used conventional non-renewable sources to power the components which could have been avoided by the use of solar energy.

[2] This paper proposes the use of Solar Energy for power supply as well as intensity control based on the output of solar cells at real time. The author tries dual use of solar panels for both power supply and intensity control. The use of solar power will be very power effective and help in sustainable development. Though, the system would prove effective but LDRs are more efficient as compared to solar cells for brightness detection. Also, as no IR sensors are used, the street lights would be glowing at full intensity throughout the night even if no objects/traffic.

[3] This paper describes the use of solar energy for power supply, LDR for external brightness detection and IR Sensors for object detection. The authors' aim is to reduce the power consumption as well as to make a completely automated system for switching the street lights ON and OFF by the use of LDR and the IR Sensor to control brightness based on objects around the street lights. The proposed system though is one of the most efficient in terms of power consumption and automation, it does not have fault detection capabilities which makes it tough to detect errors in the street lights.

[4] Street Light Energy Saver, a work that focuses on the pressing issue of energy consumption worldwide, is built with the aim of decreasing the power usage of street lamps during the time with no sunlight when their requirement in certain areas is minimum. The aim is improving the efficiency by decreasing the illumination factor of lights. The above is achieved by the use of IR sensors for object detection and intensity control based on the sensor data. This would reduce the power consumption slightly but that wouldn't have much impact as the power saved is very negligible using only object detection. Therefore, the use of LDR sensors would have helped reduce the power consumption to larger extent.

[5] In recent decades, the rate of urbanization has expanded massively. Increasingly upgraded administrations and applications are required in urban regions to give a superior way of life. Smart city, which is an idea of interconnecting current digital innovations with regards to a city, is a potential answer to improve the quality and execution of urban administrations. The authors try to achieve the above by the use of LDR, IR Sensors programmed with an Arduino. The LDR Sensor is used to switch the Street Lights ON and OFF based on the external light conditions whereas the IR is used to control the brightness of the lights by detecting objects around it. The method is good for efficient use of power, though, could have been better by the use of solar energy and a fault detection system.

[6] In this paper, the authors make use of an LDR Sensor to control the intensity of the lights and also MQTT Server to remotely control the lights. The biggest advantage of the system is use of an ESP8266 Wi-Fi module and MQTT server to remotely control the lights which helps reduce the amount of physical wires used in the system. Though the idea of using remote access would be of great advantage but only the use of LDR sensor does not make the system very effective in terms of power efficiency. The use of IR sensors would have helped in improving the power efficiency. Also, the authors should have used solar energy to power the complete system instead of the conventional non-renewable sources of energy.

[7] In this paper, the authors believe that automation, power consumption and cost effectiveness are major aspects of technology. To achieve the above, the use of IoT technology is very important. To achieve the same for street lights as well, the author makes use of Arduino controlled IR Sensor, LDR Sensor and an ESP8266 Wi-Fi Module, all the components are then powered by a Solar Panel. The LDR Sensor are used to control the light intensity based on the external conditions, the IR Sensor for object detection and the Wi-Fi module is used for remote access. Though the method used by the author has covered all the required aspects, a fault detection system would have helped in the maintenance of the street lights.

[8] The authors of this paper are using two methods to automate the street lights. The first one is intelligent on/off switching which is achieved by the use of LDR Sensor and the second is progressive dimming which is achieved by the use of IR Sensors. Also, the author believes use of intelligent on/off switching and progressive dimming can reduce the electricity cost by about 35%. The method proposed is efficient in terms of energy saving but the authors use non-renewable sources of energy and not renewable sources of energy, therefore use of solar or wind energy would have been more effective.

[9] The authors of this paper aim at automating the process of switching the street lights ON/OFF and they have also proposed an app for the fault detection of street lights. Automated switching ON/OFF is achieved by the use of LDR Sensors based on the external brightness. Another LDR is used under the lights to detect if the light is ON during night time and the data is sent to the mobile application by use of GSM module. The main aim is to only automate the process and detect faults but an IR sensor to detect objects and save energy would have been more efficient.

[10] This paper was referred for the ML part of the project. Solar energy is one of the major types of renewable energy but the amount of solar energy that can be obtained from power plant is very uncertain and therefore, a prediction mechanism based on an ML algorithm is required to find the amount of solar output in a day for given weather conditions. The authors of this paper have made use of Random Forest Regressor algorithm to find the solar output for a power plant based on the weather conditions. The predictions done by the authors' algorithm was very accurate with about 93% accuracy and a similar approach has been used in our project as well.

4. System Design and Analysis

The proposed street light system is a completely automated and power saving system. The system has three major parts –

A. IoT Part

This is hardware part of the system. The IoT part of the project is controlled using the Arduino microcontroller. The LED lights are connected to the Arduino and the power and intensity of the LEDs is based on the data from following sensors–

One LDR is used to switch ON/OFF the LEDs based on the external brightness therefore switching the LEDs ON when the brightness is low and OFF when there is high brightness. Another LDR is used for fault detection i.e., when it is mounted under the street lights to check if it is ON during low external brightness. IR Sensor – It is used to detect objects (i.e., vehicles or people) around the street lights. Based on the input of this sensor, street light will glow at high or low intensity. High intensity when no objects around and vice-versa. Also, a solar panel is used to power the Arduino, the sensors and the lights.

B. Android App

We have also designed an Android based mobile application which displays the following –

The state of the LED i.e. whether the LED is on, off or in a non – working state and intensity at which the LED is currently glowing. This information is obtained real-time with the use of "Firebase Realtime Database".

To connect the android app to the Realtime Database a google-services.json file needs to be generated on the "Firebase Portal" and be copied to the app repository of the Android project as well as adding of the implementation 'com.google.firebase:firebase-database:19.2.1' to the build.gradle [app:module]. The data fetched from the real-time database will be displayed using TextViews and ImageViews.

C. Machine Learning Part

It is used to predict the daily solar output of the solar panel. WeatherBit API is used to obtain the predicted weather data, based on this data, solar output is predicted for that particular day. Based on the output, the intensity of the street lights is controlled to run the whole system only on the solar energy for the day and not rely on other power sources. To predict the above, Decision Tree Regressor algorithm is used programmed in Python using the Sci-kit learn library. The machine learning model is then generated using the pickle library and deployed in the Arduino IDE for prediction.

5. System Requirements

A. Hardware Requirements

- Arduino ATMEGA – Microcontroller chip from the 8-bit AVR microcontroller family. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. In this project, it is used to program and control all the sensors and other hardware components.
- Wi-Fi Module (ESP8266) – A low cost Wi-Fi Chip. It is used for communication between different devices or to connect the Arduino to the internet. In this project, it is used to make communication between the Arduino and Android Application possible.
- LDR – Light Dependent Resistor. It is a light sensitive device whose resistivity changes based on the light intensity. In this project, it is used to turn the LEDs ON/OFF based on the external light conditions. Also, it is used for fault detection.
- IR Sensors – It is a low-cost sensor that has a transmitter and a receiver which help in detecting objects. Infrared sensors used to detect objects around the street lights and to automate the level of intensity of the LED.
- LED – Light Emitting Diode is a semiconductor diode that emits light when current passes through it. It is used as the main light source for the street lights.

B. Software Requirements

- Arduino IDE - Arduino Integrated Development Environment is a cross-platform application with functions written in C and C++. It is used to program an Arduino based microcontroller to control the sensors.
- Jupyter Notebook - The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text.
- Android Studio – It is an official developing environment for developing applications for the Android operating system. In this project, it is used to develop the android fault monitoring and consumption monitoring app.
- Firebase Realtime Database – It is a cloud hosted database provided by Google. In this project, it is used for writing and reading data generated by the sensors so that it is accessible by the android application.
- Scikit-learn Python Library – It is a python machine learning library. It features various classification, regression and clustering algorithms including support vector machines, random forests, gradient boosting, k-means and DBSCAN. In this project, it is used to run the Decision Tree Regressor Algorithm for Solar energy output prediction.
- NumPy Python Library – NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays.
- WeatherBit API – It is a weather prediction API, the prediction from this is provided to the ML model and solar output for the day is predicted using it.
- Other Python Libraries – Pandas library is used for reading and writing csv files, Pickle is used to deploy ML models and Matplotlib is used to plot graphs for the results obtained.

6. Methodology

The flowchart below describes the methodology of the system -

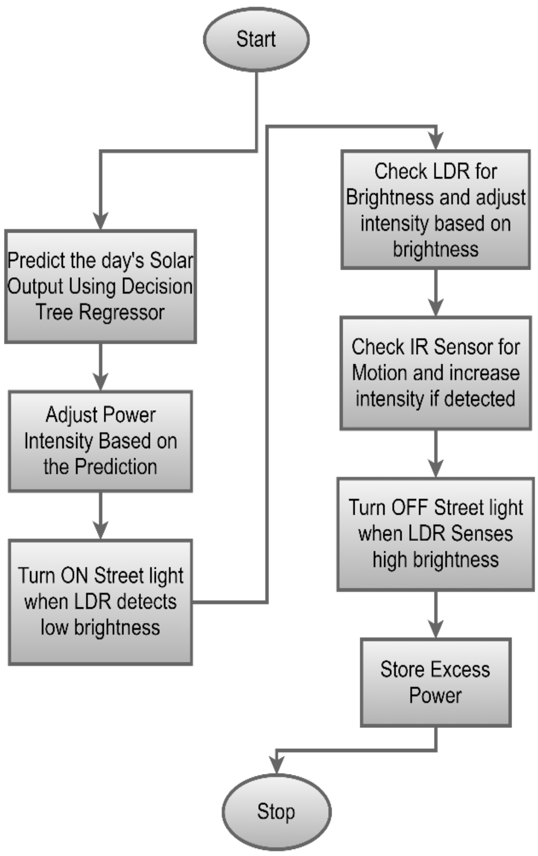

Figure 3: Methodology Flowchart

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The IoT part of the project is based on the given circuit diagram. This shows the use of two LDRs and two IR Sensors and Arduino as the microcontroller –

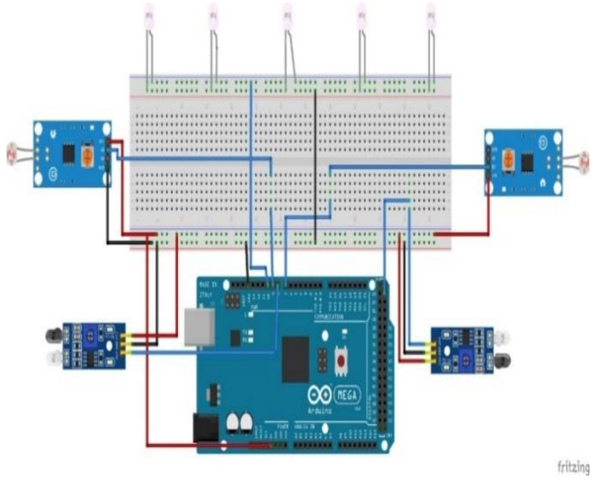

Figure 4: Circuit Diagram

7. Results

After running the Decision Tree Regressor algorithm on our testing dataset, a maximum accuracy of 94% was achieved. Though some factors like rain, cloudiness, snow may hinder this accuracy, but accuracy remains consistent on a sunny day. Also, accuracy is a minimum 76% on a snowy day which will not affect the working on most days and may run on the backup solar power obtained on sunny days. Based on the predicted value of solar energy stored we were capable of deciding the intensity at which the LED should turn on when deemed necessary i.e., about 90% of the predicted value to have backup power stored for usage when necessary.

The LDR switched on the LED automatically when the external lighting was dim and turned it off when the surrounding was well lit. The IR Sensors successfully detected objects approaching the LED and increased the brightness (i.e. only if it was decreased when the surrounding was deserted). The same was true for the opposite, i.e. when the surrounding was deserted the LED reduced its brightness. We even experimented by using a faulty LED to ensure that the mechanism for faulty light detection was working. Lastly, we monitored the status of the LED on the Android Application to finalize the overall working of the project.

Also, power consumption was reduced to a considerable amount enabling the use of the power generated by the solar panels itself for completely powering the street lights without relying on the non-renewable sources of energy. This will help cut the governmental costs on street lights and use that energy for more relevant purposes like electricity for rural areas.

The diagram below shows the RMS error rate of the prediction system with respect to minimum number of instances per node. It is observed that the error rate is reduced as the number of instances of nodes increase.

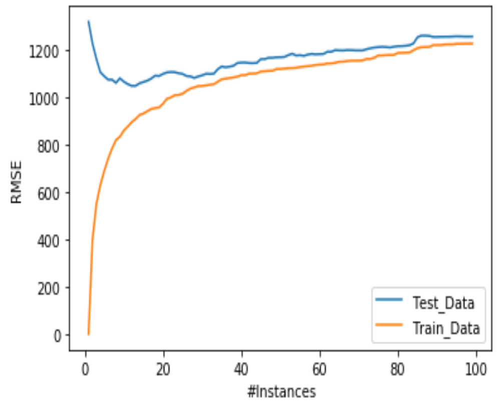

Figure 5: RMSE Graph of Train vs Test Data

The image below shows the working of the fault detection android app. The app displays if the street lights are in a working condition or not and also the intensity at which the street lights are glowing in real-time.

Figure 6: Android App

8. Applications

The following are the expected applications from the smart street light system -

- Automatic switching of street lights – LDRs can automate the task of switching on and off the LED based on external lighting conditions i.e. whether it is day or night.
- Reduction in CO_2 emission – Some streets lights are powered through the electricity generated by thermal power stations that use coal as a leverage to generate

electricity emitting CO2 in the process. Use of solar energy takes care of this problem.

- Reduction of light pollution – Present systems like the lights at fixed intensity irrespective of the surrounding (traffic). However, in the proposed system the nights are dimmed when not required. This may play a small role but definitely reduced light pollution to some extent.
- Wireless communication – Communication between the Arduino and Android app take place wirelessly and therefore amount of wiring is reduced significantly.
- Energy saving – The automating of the task of switching off and on of lights as well as reducing their illumination based on external scenarios plays a significant role in reducing energy consumption.
- Effective use of renewable energy – The proposed system makes use of solar energy to power the bulb to the maximum possible extent.

9. Future Enhancements

As previously mentioned, the sole purpose of this project was to cut down operational cost needed to keep street lights functional. In the proposed system we have demonstrated the working with only one LED. However, this mechanism can be implemented on a large scale i.e. for a greater number of LEDs whose status can also be monitored on an app. In doing so, we can expect the proposed system to be deployed not only for street lights but also be used as a lighting scheme for organization's campuses such as IT firms, Universities and so on. Scientific research is underway to find better sources of light to replace LEDs [11]. In the near future we can expect further reduction in energy consumption as technology advances.

10. Conclusion

From the results, we can conclude that the factors such as automatic dimming of the LED based on the surrounding as well as the automatic switching on and off of the LED will definitely play a vital role in cutting down operational cost incurred by the government. The prediction of solar output was also done with a good accuracy enabling the use of only solar energy for completely powering the street lights without depending on non-renewable sources of energy. Also, for now LEDs are the best available option for powering street lamps not only because they are efficient when it comes to saving energy but also because they have a long life, have an exceptional colour range among others. The fault and consumption monitoring app helps in fast action to avoid delays in repairs. In all, the system is very efficient in all aspects of a street light's working.

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