SMART STREET LIGHT SYSTEM USING IoT

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Abstract— **The ubiquitous presence of streetlights underscores their critical role in ensuring nighttime safety and security within our cities. However, conventional lighting systems suffer from inefficiencies, leading to wasted energy and unnecessary light pollution. This research delves into the potential of the Internet of Things (IoT) to revolutionize street lighting infrastructure. The researchers propose a Smart Street Light System (SSLS) that integrates advanced sensors and communication protocols to achieve dynamic lighting control and real-time monitoring. This paper investigates the design and implementation of the SSLS, exploring its potential to optimize energy consumption, physical and software security of the system, minimize light pollution, and enhance public safety within the framework of smart city development.**

Keywords— Internet of Things (IoT); Thingspeak; Arduino; Smart Street Light;

I. INTRODUCTION

The rapid rate of urbanization leads to a growing demand for clever ways to maximize resource utilization and enhance the daily lives of the populace. However, one of a city's most fundamental features is its street lighting. However, a change in strategy is necessary due to the relatively traditional architecture of today's street lighting systems and the high energy consumption that drives up the cost of this infrastructure. Because of this, the current study looks at the practical aspects of creating and deploying a smart street light system that would benefit from the Internet of Things.

The proposed SSLS uses Light-Emitting Diode (LED) technology to get around the generally accepted drawbacks of full-spectrum lighting. Apart from being advantageous in many ways, the best LED technology of the lighting industry is currently more power-saving than its major opponent, the conventional fluorescent bulb; it also has less environmental impact and reduces the cost of construction. Our project does not only focus on energy efficiency. This project will also integrate smart motion detection using Ultrasonic sensors into SSLS so as to allow for adaptive dimming of RGB LED light depending on movement around it. This feature will deliberately dim certain street lights when there are no cars or pedestrians passing by, thereby further reducing energy spent but still keeping necessary illumination for night time traffic safety. This project also introduces the capability of color changing using RGB LEDs. The SSLS can use the readings from the Infrared Sensors to dynamically adjust its color temperature in response to the surrounding temperature. Imagine welcoming streets that glow in the evening, smoothly changing to a cooler, more energizing light in the day's heat, and streets painted a warm hue during low visibility conditions due to fogging on the roadway. Dynamic color adaptation has the potential to enhance not only the visual aesthetic appeal of urban environments but also the safety of pedestrians and the well-being of drivers.

In essence, this study investigates the concept of creating and implementing a state-of-the-art Smart Street Light System. In addition to addressing the energy inefficiencies associated with traditional street lighting, this system aims to provide an era of dynamic, responsive, and user-centric city lighting.

II. LITERATURE REVIEW

SSLS (Smart Street Light System) are being utilized more by cities as a more efficient way to simplify lighting control. With the utilization of this technology, cities can save a lot of resources and lessen the need for manual maintenance. Nevertheless, many street lighting systems still use the traditional light sources, therefore, it may conventionally reduce the human effort for the maintenance of the technology but the energy wastage and light pollution still exist.

In their study, Abhishek et al [1] devised a solar-powered, traffic-aware street lighting system that used a microcontroller (8052) to control LED lamps; it saved a considerable amount of energy as compared with conventional incandescent bulbs. Energy consumption was reduced by three times when lights were made to turn on only upon detection of vehicles by sensors located on either side of the road. Nevertheless, this method does not cater for the safety and security needs of pedestrians during the night. Turning off all lighting completely throughout darkness may expose soft traffic participants to danger especially in unfavorable weather conditions.

According to Haans et al. [3], pedestrians feel safer with a descending light distribution on a roadway. In this design, LED brightness varies based on the movement registered in the sensor created by the pedestrian; the brightest light is illuminated by the pedestrian closest to the streetlight, resulting in a clear and well-lit area around the individual. The streetlights will become less bright the farther the pedestrian and street light sensors are from one another. This results in a gentle softening that eases the eye of the pedestrian or driver and reduces reflections, enabling them to move about their environment without being blasted by the over illumination caused by a streetlight. Besides being cost-effective both in terms of energy consumption and maintenance staff required, it also ensures an ideal system for drivers' and pedestrians' safety.

Controlling the Correlated Color Temperature (CCT) of a light source allows one to exactly meet certain lighting requirements by adjusting the light source's color appearance, measured in kelvins (K). In addition to controlling color perception and visual comfort, a light source's CCT can affect people's circadian rhythms. Lower CCT values are preferable for residential spaces; they add a cozy warmth to the environment and improve vision in foggy conditions. Typically, these values range from 3000 K to 4000 K. according to Jin et al. [4], Lower CCTs may provide greater dark adaptation, and longer visibility ranges according to Park et al. [5], and a reduced propensity to contribute to light pollution, according to studies. Conversely, Peña-García et al. [6] suggested that higher CCT values, between 5000 K and 6000 K, are preferred for use in outdoor areas and roadways because they can improve safety and visibility, especially in clear conditions. According to research, they can also help with facial recognition and make evening activities easier [7]. High CCT values can lead to increased glare and light pollution, therefore aside from these benefits it comes with tremendous risk. In order to achieve optimal performance and energy efficiency within lighting systems, this control methodology is still being refined and investigated.

The limits of using only locally installed sensors are overcome by these systems, which may gather substantial real-time information across vast geographical areas by combining publicly available data via online APIs with sensors put on streetlights (SLs). Both Satrya et al. [8] and Daeley et al. [2] integrated micro-services into street light monitoring and control systems to access real-time weather information in order to adjust to changing weather conditions. Furthermore, in bad weather, Satrya et al. [8] recommended lowering the color temperature (CCT) of LED lamps from 5000 K to 3000 K, and Daeley et al. [2] talked about brightness and CCT management in foggy situations. Daeley et al. suggested using two LED arrays—one rated at 3000 K and the other at 5000 Kin—to automate CCT transitions on the Streetlight Web server side. It is stated in Rami et al. [9]. Combining these two elements might result in even more energy savings. Therefore, real-time data availability on online services has excellent prospects for smart street lighting.

III. METHODOLOGY

Research Approach:

After conducting a thorough literature evaluation and analysis, the researchers have developed a strong research approach to direct this work. This well defined methodology serves as a guide, detailing the set of procedures and regulations that guarantee an organized and effective workflow. The researchers have meticulously chosen a methodology that exactly complements their goals, enabling a successful conclusion.

System Design:

The proposed Smart Street Light System (SSLS) leverages a combination of hardware and software components to achieve its functionalities. Here's a breakdown of the key elements:

Hardware:

- Power Supply: A 5V power source will provide the system with the necessary operational voltage for it to function..
- Temperature Sensor: Integrating infrared sensor for real-time monitoring of the surrounding ambient temperature. The data from the sensor will be transmitted to the Arduino UNO microcontroller for processing.
- Motion Detection: Integrating HR-SR04 ultrasonic sensor for the detection of vehicles followed by the appropriate level of light brightness.
- Microcontroller: An Arduino UNO microcontroller will serve as the central processing unit of the SSLS. It will act as the receiver of sensor data, perform necessary calculations based on the chosen algorithm (described below), and provide the appropriate output accordingly.
- RGB LED Light: The system will utilize a high-efficiency RGB LED street light for illumination. Depending on the temperature reading, it will display the appropriate color of illumination. In addition, the brightness level of the RGB LED will be dynamically adjusted based on the algorithm's output.
- ESP8266 Wi-Fi Module: The ESP8266 is a low-cost Wi-Fi microcontroller that enables wireless communication capabilities for the SSLS. With the help of it, the device will be able to connect to the wifi and utilize the ThingSpeak.
- LCD Screen: Integrating a Liquid Crystal Display (LCD) screen to display real-time feedback on the system's operation. The LCD will display information such as:
    - Ambient temperature reading from the infrared sensor.
    - Current color of the LED light (if color adjustment is implemented in the algorithm).
    - Light intensity level (high brightness or low brightness).

- Padlock: The system will implement a physical security to secure its hardware components.

Software and Communication:

- Algorithm: The central core functionality of the SSLS relies on a well-defined algorithm. This algorithm will process the incoming sensor data (temperature and motion detection) and determine the optimal lighting response. The following are the detailed overview of the algorithm:
    - Continuous collection of real-time temperature data from the infrared sensor.
    - The HR-SR04 sensors will detect the vehicle.
    - Based on the temperature and presence of vehicles, the algorithm will determine the appropriate lighting level (high brightness or low brightness) and LED color (Orange, White, Blue, Red).
    - It will then display on the LCD the result such as Light Intensity, Color, and Ambient Temperature.
    - The Arduino UNO microcontroller will then transmit the calculated lighting level signal to the RGB LED driver.
    - The data from the sensors will be transmitted to the ThingSpeak by utilizing the WiFi module and providing real-time data.
- IoT and Web Interface: To facilitate remote management and monitoring, the SSLS will make use of IoT technologies. Sensor information and system status will be sent via the proper communication protocol (Wi-Fi) to a cloud platform. Real-time sensor readings will be seen using ThingSpeak, an online interface that also enables possible changes to the system design.
- Software Security: To secure the original source code of the software, the researchers compressed the code into a zip file and embedded it with a strong password to avoid unauthorized access.
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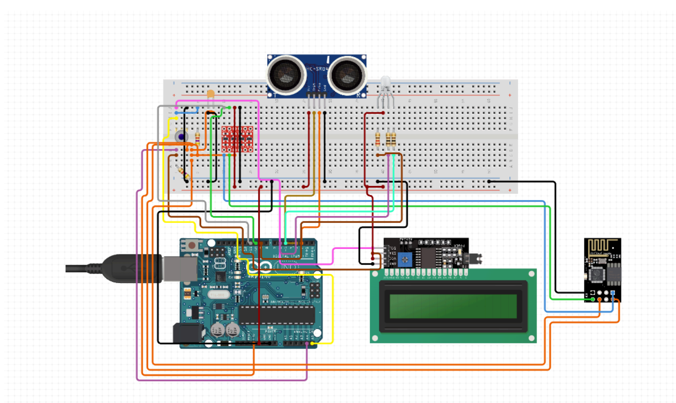


Figure 1. Model Circuit Design

Block Diagram of the System:

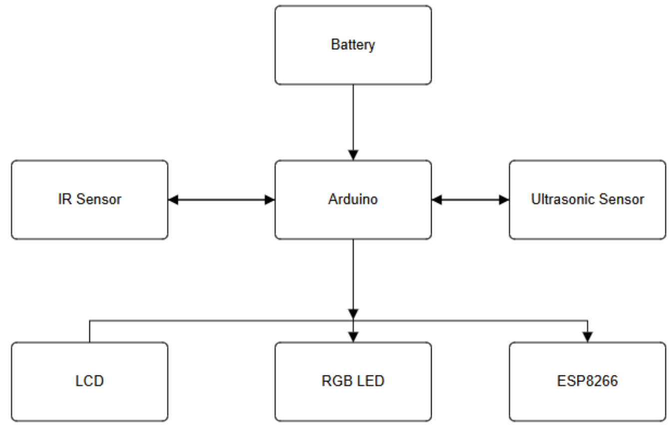


Figure 2. IoT based Smart Street Light System Block Diagram

This block diagram describes the working function of the project:

- A battery supplies power to the entire system.
- An infrared (IR) sensor detects the ambient temperature.
- An ultrasonic sensor detects the presence of a vehicle.
- An Arduino microcontroller controls the entire system and processes data from the sensors and provides the appropriate output based on the algorithm.
- An LCD screen displays information about the system, including temperature, light color, and light intensity.
- An RGB LED that can change colors, light intensity depending on the data from the two sensors and functions as the street light.
- An ESP8266 module, a Wi-Fi microcontroller, enables communication with a network to ThingSpeak for remote real-time monitoring and control.
- A padlock to secure physical components of the system.
- Zip file was utilized in the original code file of the system and embedding it with a strong password to secure the original source code.

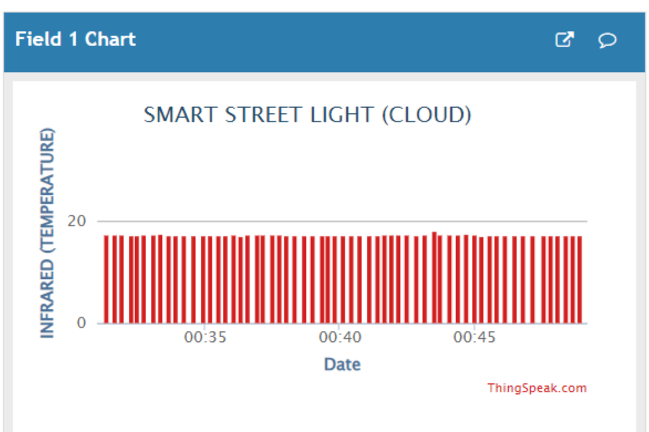
IV. RESULT AND ANALYSIS

The project aims to provide an IOT based Street Light System that is capable of conserving energy, display the appropriate intensity of illumination and the color of the light depending on the data from the sensors and well-defined algorithm, and it is capable of connecting to the internet for real-time monitoring using the online platform ThingSpeak. Moreover, it is integrated with a padlock for physical security and zip file for software security of the original source code.

Figure 3 shows the implementation of the proposed project. The infrared and ultrasonic sensors as well as the ESP8266 Wi-Fi module and LCD are all integrated with the arduino UNO. The color and intensity of the LED depends on its corresponding level of ambient temperature and distance to the object. Moreover, the sensed data is displayed over the LCD and transmitted to ThingSpeak in real-time for monitoring. It is embedded with a padlock for physical security of the physical components.

Figure 3. Implementation Model

Figure 4 and 5 illustrates the real-time data monitoring of the temperature and distance from the infrared sensor and HR-SR04, respectively. Such as the value, time, and date. In the graph, the x-axis represents the time while the y-axis represents the temperature and distance value. By hovering the pointer on the red line in the graph, it will also show more details about the date, day, time, and value at that specific time.



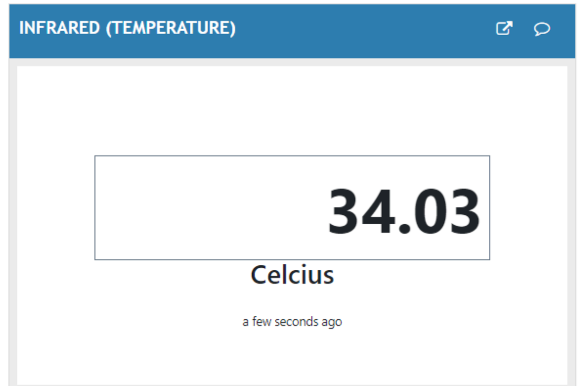
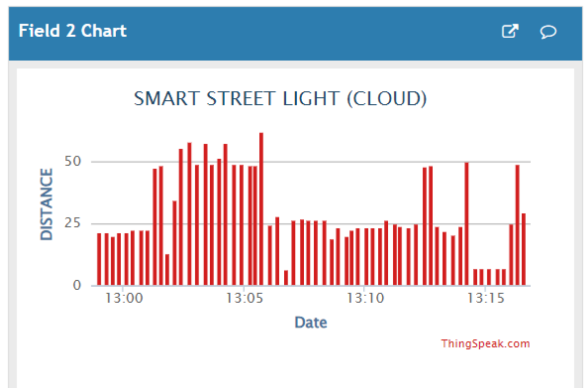


Figure 4. Infrared (Temperature) Dashboard



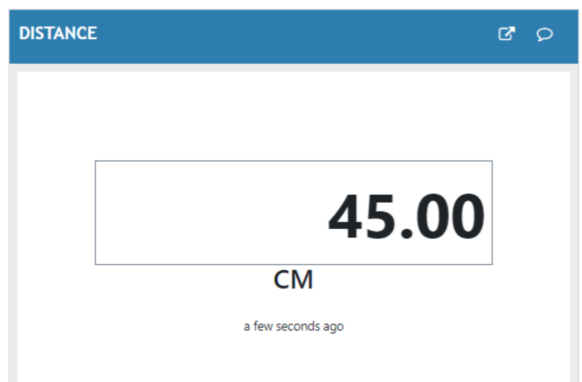


Figure 5. Ultrasonic (Distance) Dashboard

V. CONCLUSION

This study presents an innovative approach to street light automation using the platform ThingSpeak, infrared sensor, HR-SR04 ultrasonic sensor, ESP8266 Wi-Fi Module, RGB LED, and LCD. ThingSpeak offers enhanced data visualization, data management, and security. Energy cost is reduced by utilizing lighting distribution. Visual enhancement is achieved through RGB light such that the color of light corresponds to the ambient temperature, accordingly. Real-time display is also achieved with the use of LCD. The system does not require manpower and periodic check instead, by utilizing the ESP8266 Wi-Fi Module, the data from the sensors are reflected on the platform ThingSpeak for real-time monitoring. A physical security was embedded with the system to secure the physical components as well as software security of the original code by utilizing the zip file and embedding it with a strong password. A working prototype is implemented to illustrate the performance and functionality of the proposed system.

In future, the researchers will improve this system by reducing the time delay and improving its security features.

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