Kulliyyah of Engineering

Department of Mechatronics Engineering

Mechatronics Control And Automation Lab

MCTA 3104

Lab Project : Smart Street Light

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Section 2

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INTRODUCTION

In today's world, the development of intelligent and efficient systems has become paramount, especially in the field of urban infrastructure. One such system is the Smart Street Light, which is designed to improve energy efficiency and enhance automation by adjusting the brightness of street lights based on ambient lighting conditions. This project implements a closed-loop control system that uses sensors and control algorithms to monitor and optimize street lighting, thus ensuring that lights are bright enough for safety and energy-efficient when natural light is available.

A closed-loop system works by continuously measuring the output of a system (in this case, the street light brightness) and comparing it with the desired setpoint (the ideal brightness level). Any deviation between the actual and desired brightness is corrected through feedback, allowing the system to adjust automatically. This is achieved using a PID (Proportional-Integral-Derivative) controller, a type of feedback loop that calculates the difference (error) between the desired and actual outputs and adjusts the system accordingly. A visual representation of this is seen in Fig. 1.

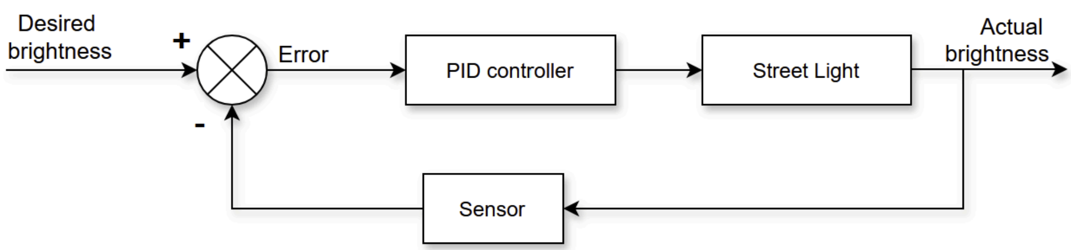

Figure 1: Closed-loop system for a street light.

This Smart Street Light project integrates Light Dependent Resistors (LDRs), which measure both the ambient light and the street light's current brightness, providing data to the PID controller. The system then adjusts the light output (via an LED) based on this feedback, creating a dynamic response to changing environmental conditions, such as the time of day or weather changes. Through this innovative approach, the project contributes to the broader field of smart cities, where automation and energy efficiency play a vital role in sustainable urban development.

OBJECTIVES

1. Automatically adjusts brightness based on ambient light conditions.
2. Implements a closed-loop control system for optimal performance and efficiency.

PROCEDURE

Components:

1. 1 x Arduino Uno
2. Jumper Wires
3. 1 x LED
4. 2 x LDR
5. 1 x Breadboard
6. 1 x Resistor
7. MATLAB and Simulink

Experimental Setup:

1. Connect GND and 5V pins of the Arduino to the breadboard.
2. Connection of LED
    a. Left pin → GND
    b. Right pin → D3
3. Connection of LDR 1
    a. - pin → GND

b. S pin → 5V

c. Middle pin → A0

4. Connection of LDR 2

    a. Left pin → Resistor → GND

    b. Left pin → A1

    c. Right pin → 5V

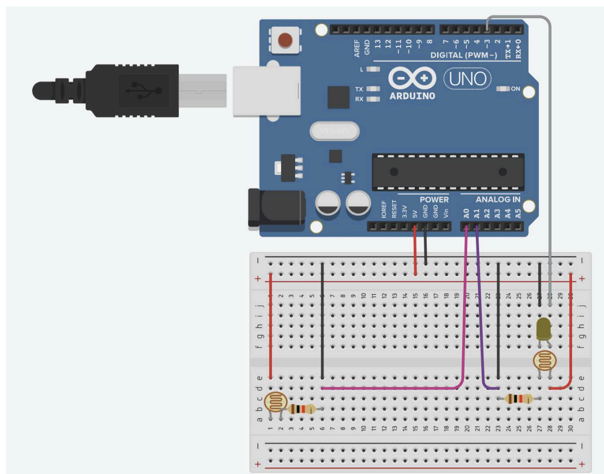

Figure 2: Connections of the components to the Arduino.

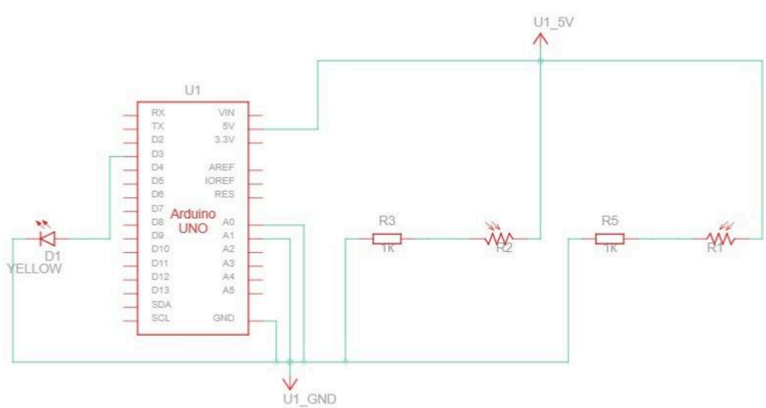

Figure 3: Circuit diagram.

Methodology:

1. Working principle of the smart street light prototype:
    a. LDR 1 measures the amount of sunlight.
    b. Brightness of the LED changes according to LDR 1.
    c. LDR 2 measures the brightness of the LED.
    d. Error of LDR 1 and LDR 2 is measured and goes through the PID controller.
    e. PID controller outputs the optimal LED brightness.
2. Connect each component as stated in the experimental setup.
3. Use Simulink/Matlab to make the program needed to implement the closed-loop system.
4. Upload the program to the Arduino.
5. Test prototype.

Simulink program:

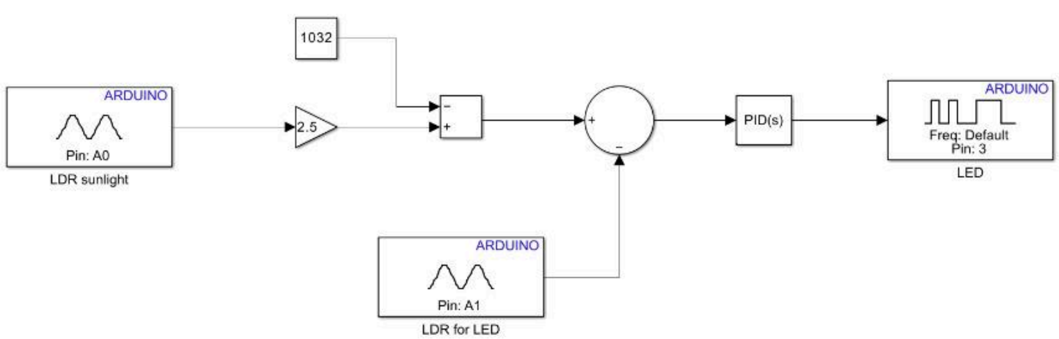

Figure 4: Program uploaded to Arduino in Simulink.

RESULTS

The results were that when the room was bright the LED would be off however as we gradually covered the first LDR to mimic the sun setting, the LED would slowly brighten up, reaching the maximum brightness when the LDR was completely covered up. Below we can see in Fig. 5 the LED is off when the LDR is not covered then in Fig. 6 the LED is at full brightness as the LDR is covered.

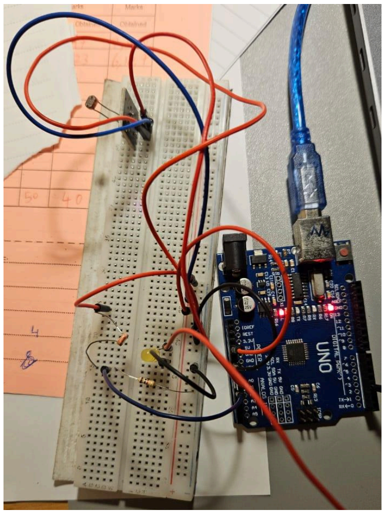

Figure 5: Prototype in a bright room.

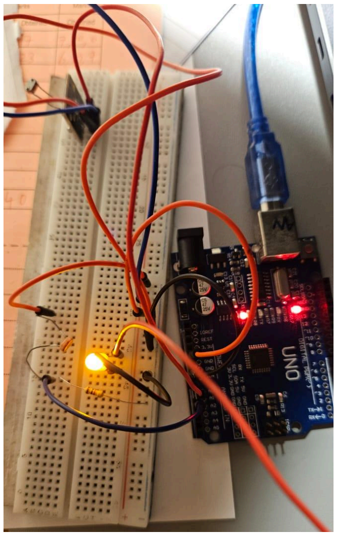

Figure 6: Prototype in a dark room.

DISCUSSION

The street lighting system's performance was greatly improved with the implementation of a closed-loop control system. Real-time feedback was made possible by the second LDR, which made sure that even in different environmental circumstances, the LED brightness matched the desired levels. Simulink and MATLAB made it easier to construct and test the PID controller, demonstrating the system's dynamic brightness adjustment capabilities. In order to further maximise energy savings by dimming lights when no movement is detected, future advancements could include the use of motion sensors.

IMPROVEMENTS

The Smart Street Light project can be significantly enhanced by integrating advanced features to improve energy efficiency and adaptability. Adding motion sensors, such as PIR or ultrasonic sensors, would allow the system to detect vehicles or pedestrians, enabling brightness adjustments or turning off lights in unused areas. Combining this with dimmer controls for partial brightness during low-traffic hours would further optimize energy consumption. Advanced sensors like photodiodes or weather sensors could replace LDRs for more precise light and environmental detection, ensuring accurate brightness adjustments during fog, rain, or other weather conditions. Additionally, integrating solar panels and rechargeable batteries would make the system self-sustaining and reduce reliance on grid electricity, contributing to sustainability efforts.

On the control side, incorporating an adaptive PID algorithm or machine learning would enhance the system's responsiveness and predictive capabilities. Adaptive control could dynamically tune parameters based on environmental changes, while machine learning could predict light intensity needs using historical and real-time data. IoT integration and mesh networking between streetlights would enable centralized monitoring, remote control, and collaborative adjustments for area-wide optimization. Data logging could be added to track sensor readings, brightness levels, and energy usage over time, helping identify areas for further performance improvements and fine-tuning the system.

Finally, the robustness and scalability of the project can be improved by using weatherproof enclosures, fail-safe mechanisms, and a compact design suitable for real-world street light fixtures.

CONCLUSION

The Smart Street Light project effectively illustrates a useful and creative way to improve street lighting systems. The system accomplishes dynamic brightness adjustment by combining real-time feedback mechanisms with light-dependent resistors (LDRs) and employing a closed-loop control system. This ensures optimal illumination and significant energy savings.

Stable and accurate system control was made possible by the use of a PID controller, which was created and implemented using MATLAB and Simulink. This improves adaptation to changing ambient light conditions in addition to reliability.

To sum up, this research demonstrates how contemporary management systems may be used to create sustainable and energy-efficient street lighting options, opening the door for more intelligent cities.