Highway Lighting System Using Ultrasonic Sensors, LDR, and Arduino

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***Abstract*— This project presents a Smart Highway Lighting System designed to conserve energy while ensuring night traffic visibility. The system uses ultrasonic sensors to detect approaching vehicles and automatically turns on the street lights only when needed. An LDR detects ambient light and ensures the system works only during nighttime. The system was implemented using Arduino, LEDs, ultrasonic sensors, and LDRs. This low-cost solution can reduce power consumption and enhance road safety.**

Keywords*— *Smart lighting, Arduino, Ultrasonic sensor, LDR, Energy-efficient highway system, Automated streetlight control.

I. Introduction

In modern cities, street lighting consumes a significant portion of electrical energy. Most lights remain on all night, regardless of whether any vehicles are on the road. This causes energy wastage and increases costs. This project aimed to develop a smart lighting system that operates only when vehicles are detected and remains off otherwise, especially during the daytime.

The idea was inspired by real-life observations of empty roads being fully lit throughout the night. This inefficiency led us to explore how sensor technology could be integrated with lighting systems to automate and optimize their use.

II. Theory

A. Ultrasonic Sensors

Ultrasonic sensors operate by emitting sound waves at a frequency above human hearing. These waves travel until they encounter an object and reflect back to the sensor. The sensor measures the time it takes for the sound to return, which is then used to calculate the distance.

The sensor has four pins: Vcc, Trig Pin, Echo Pin, and Gnd. The Trig Pin sends a 10-microsecond pulse, and the Echo Pin receives the reflected pulse. The distance ddd is calculated using the formula:

$$D = (t \times 0.034) / 2$$

Where:

- d is the distance in cm.
- t is the time in milliseconds for the pulse to return.

This is used in the system to detect the presence of vehicles and control the lighting accordingly.

B. Light Dependent Resistor (LDR)

An LDR is a resistor whose resistance decreases with an increase in light intensity. In dark conditions, the resistance is high, while it decreases in bright light.

The LDR in this project detects whether it's day or night. During the day, the resistance is low, and the system keeps all lights off. At night, the resistance increases, and the lights are activated. The relationship between light intensity I and resistance R of the LDR is typically inverse, meaning as light increases, resistance decreases:

$$I = 1/R$$

This allows the system to automatically switch between day and night modes based on ambient light.

C. Arduino Microcontroller

The Arduino Uno microcontroller controls the system by processing input from the ultrasonic sensors and the LDR. It decides when to turn the lights on and off based on the proximity of vehicles and the ambient light conditions.

The Arduino uses simple logic to keep the lights off during the day, dimly light the road at night, and activate full lighting when a vehicle is detected.

III. Components Used

- Arduino Uno
- 4 x Ultrasonic Sensors (HC-SR04)
- 4 x LEDs
- 1 x LDR
- Breadboard & Jumper Wires
- Power Supply

IV. Circuit Diagrame

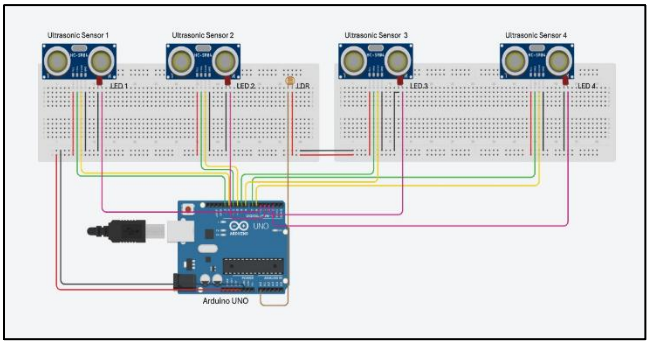

Fig. 1: *Digital circuit created using TinkerCad.*

V. Working Logic

The Smart Highway Lighting System operates based on real-time environmental and object detection inputs. The control logic implemented in the Arduino microcontroller can be summarized as follows:

1. LDR Value Detection
   The system continuously monitors ambient light using a Light Dependent Resistor (LDR) to determine whether it is day or night.
2. Daytime Condition
   If the LDR value indicates daytime, all streetlights remain OFF, as additional lighting is unnecessary.
3. Nighttime Condition
   When the LDR value confirms nighttime:
   - Idle State – Alternate Dim Lighting
     To maintain minimal visibility on the road even in the absence of vehicles, alternate lights are set to glow at a low brightness using PWM (Pulse Width Modulation).
   - Active State – Vehicle Detection using Ultrasonic Sensors
     For each ultrasonic sensor positioned along the road:

a. The sensor continuously measures the distance of any approaching object.

b. If a vehicle is detected within a specified range:

- The corresponding LED light and the next one ahead are immediately switched ON at full brightness.
- These lights remain ON as long as the vehicle remains within range.

c. If no vehicle is detected:

- The lights return to their default dim mode with alternate pattern.

VI. ARDUINO CODE SNIPPET

```
void loop() {
    int ldrValue = analogRead(ldrPin);

    if (ldrValue > 800) { // Bright light, daytime
      for (int i = 0; i < 4; i++)
        analogWrite(ledPins[i], 0); // All lights OFF
    }
    else { // Nighttime logic
      for (int i = 0; i < 4; i++)
        analogWrite(ledPins[i], (i % 2 == 0) ? 50 : 0); // Alternate dim lights

      for (int i = 0; i < 4; i++) {
        long duration = getUltrasonicDistance(trigPins[i], echoPins[i]);

        if (duration > 0 && duration < 30) { // Vehicle detected
          analogWrite(ledPins[i], 255); // Full brightness
          if (i < 3)
            analogWrite(ledPins[i + 1], 255); // Turn on next light as well
        }
        else {
          analogWrite(ledPins[i], (i % 2 == 0) ? 50 : 0); // Return to dim/off
        }
      }
    }

    delay(200); // Delay for stability
  }
```

Fig. 2: *Main logic implementation in Arduino IDE*

VII. RESULTS AND OBSERVATIONS

- System works reliably in the dark and responds instantly to vehicle movement.
- Flickering was resolved by maintaining lights ON for a fixed duration after detection.
- Lights turn off after a few seconds as the vehicle leaves the zone so that the driver has a clear view of the back as well.
- During daytime, all lights remain off, saving energy.

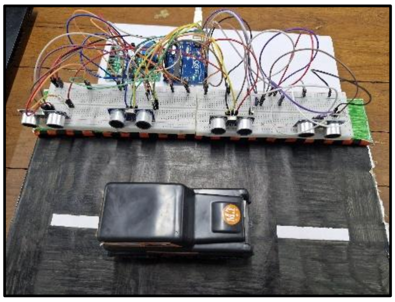

Fig. 3: *System state during daytime: All lights remain off as detected by the LDR sensor.*

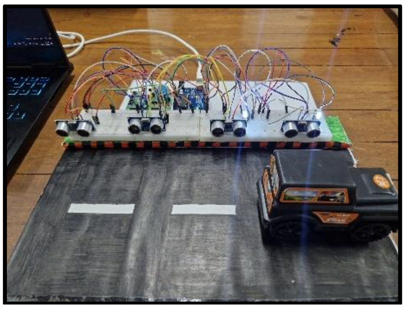

Fig. 4: *System behavior at night: Only required lights turn on upon vehicle detection, as the LDR sensor is covered to simulate darkness.*

VIII. FUTURE IMPROVEMENTS

This prototype uses just 4 LEDs, but the concept is easily scalable to hundreds or thousands of lights.

- Solar Power: Use of solar panels for self-sustaining operation.
- Real Streetlights: Controlled via relays for high-power switching.
- IoT Integration: Remote monitoring and control via the internet.
- Better Detection: Use of motion or camera sensors for accuracy.

IX. REFRENCES

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