DYNAMIC OPTICAL TRACKING IN LI-FI SYSTEMS

Li-Fi (***Light Fidelity***) is an ***optical wireless communication*** technology that uses ***visible light*** instead of radio waves for ***data transmission***. It offers ***ultra-fast speeds*** (up to 100 Gbps), enhanced ***security*** since light cannot penetrate walls, ***EMI-free operation*** suitable for hospitals and aircraft, and a ***massive available spectrum***. This project focuses on ***dynamic optical tracking***, where the ***transmitter automatically follows the receiver's movement*** to maintain ***stable, high-speed communication*** and prevent ***signal dropouts***.

The main objective is to design a ***smart, Arduino-based Li-Fi prototype*** that ***auto-adjusts*** the LED transmitter's direction according to the receiver's position, ensuring ***uninterrupted optical data transfer*** in a ***simple and affordable setup***. The system uses an ***Arduino Uno***, ***four LDR sensors***, an ***LED transmitter***, a ***servo motor*** for tracking, and basic ***resistors and wiring***. The communication process involves four stages — ***Transmission*** (LED signal), ***Reception*** (LDR detection), ***Tracking*** (servo alignment), and ***Decoding*** (Arduino processing). The software continuously ***reads light intensities***, ***compares values***, and ***adjusts servo angles*** for smooth and responsive alignment.

As the receiver moves, ***variations in light intensity*** are detected by the LDRs, prompting the servo to ***reposition the LED*** for optimal illumination and ***stable data flow***. This system has applications in ***high-speed indoor communication***, ***autonomous robots and drones***, ***smart lighting***, ***underwater data transmission***, ***interactive displays***, and ***secure point-to-point communication***. References include ***Wikipedia***, ***GeeksforGeeks***, ***pureLiFi***, ***tech@gov***, ***TinkerCad***, and ***OpenAI/Gemini*** for design, simulation, and visualization support.

DYNAMIC OPTICAL TRACKING IN LI-FI SYSTEMS

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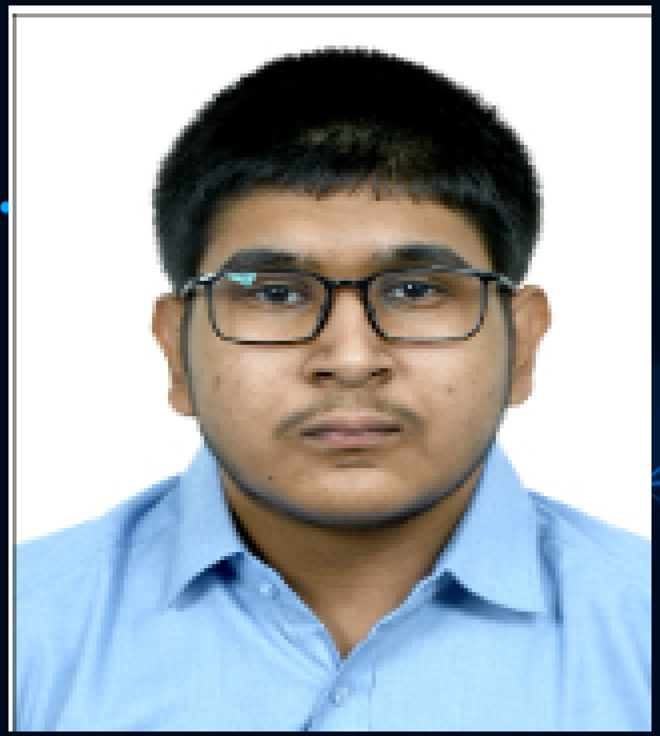

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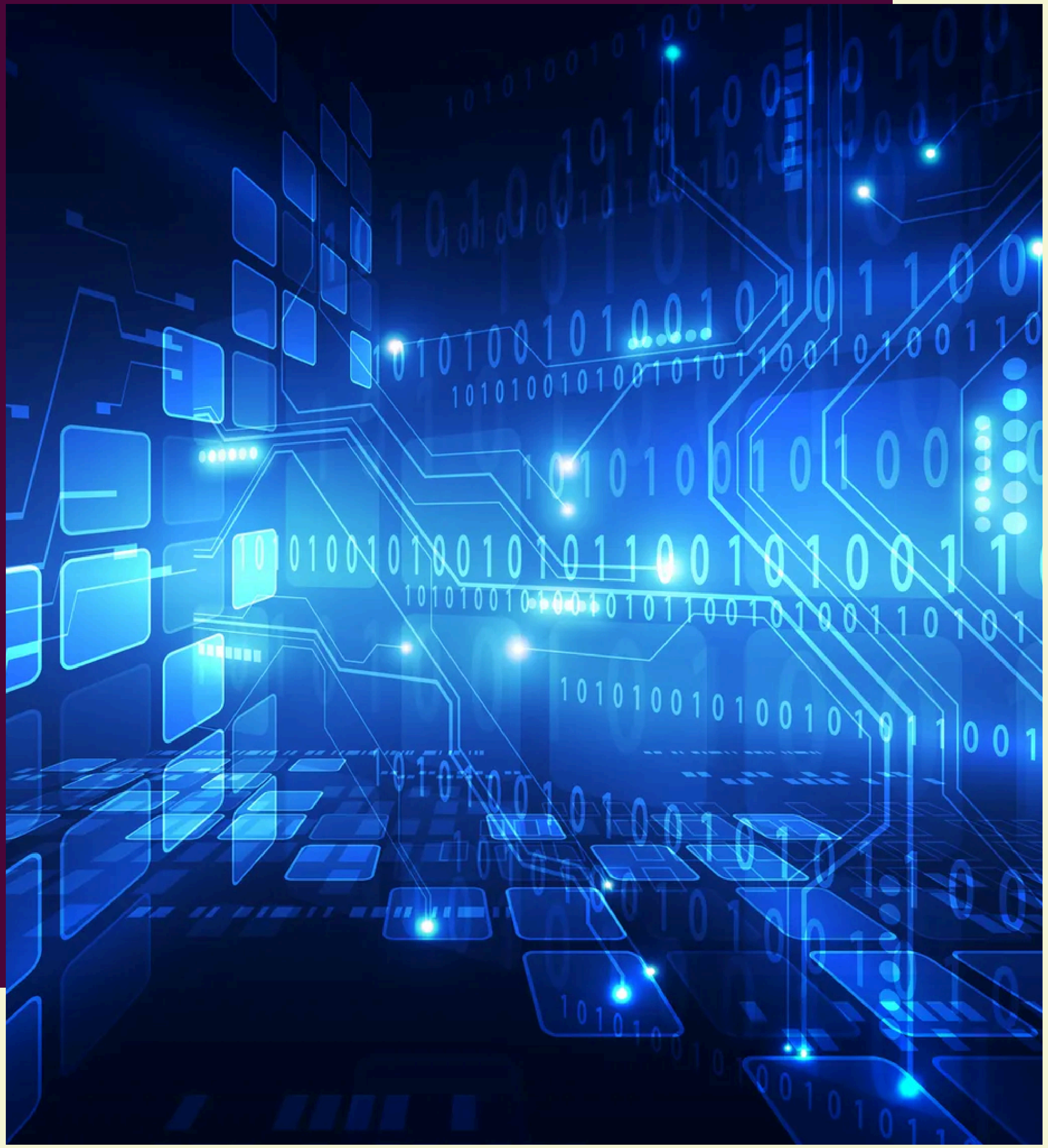
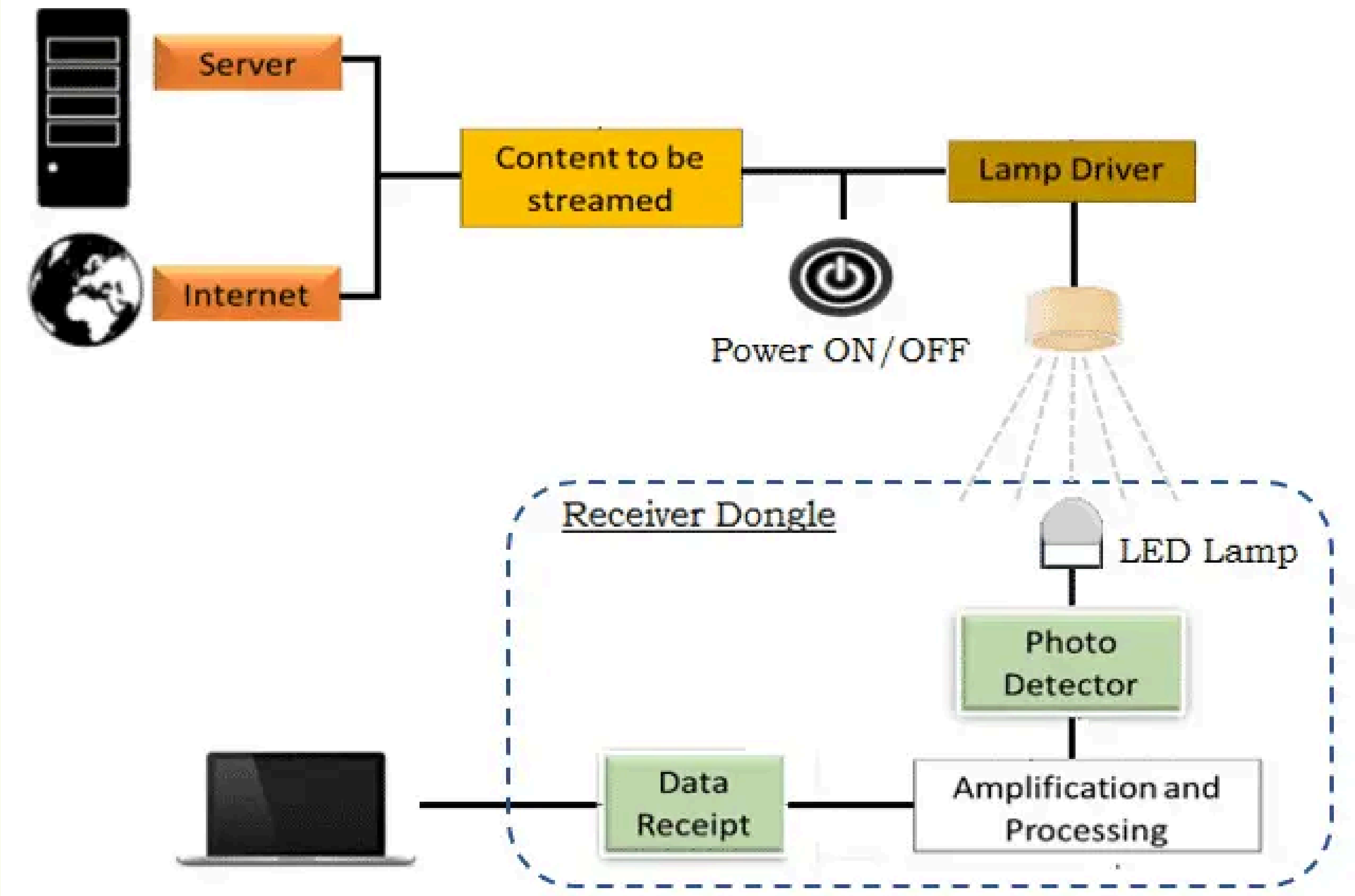


INTRODUCTION

- **WHY LI-FI ?**

1. Ultra-Fast Speeds (Up to 100 Gbps)
2. Highly Secure (Can’t penetrate walls)
3. EMI-Free (Safe in hospitals, aircrafts)
4. Massive Spectrum (10,000x RF)



- **DYNAMIC TRACKING**

1. Follows receiver movement
2. Reduces signal dropouts
3. Allows uninterrupted, high-speed communication, even if you're walking or moving.

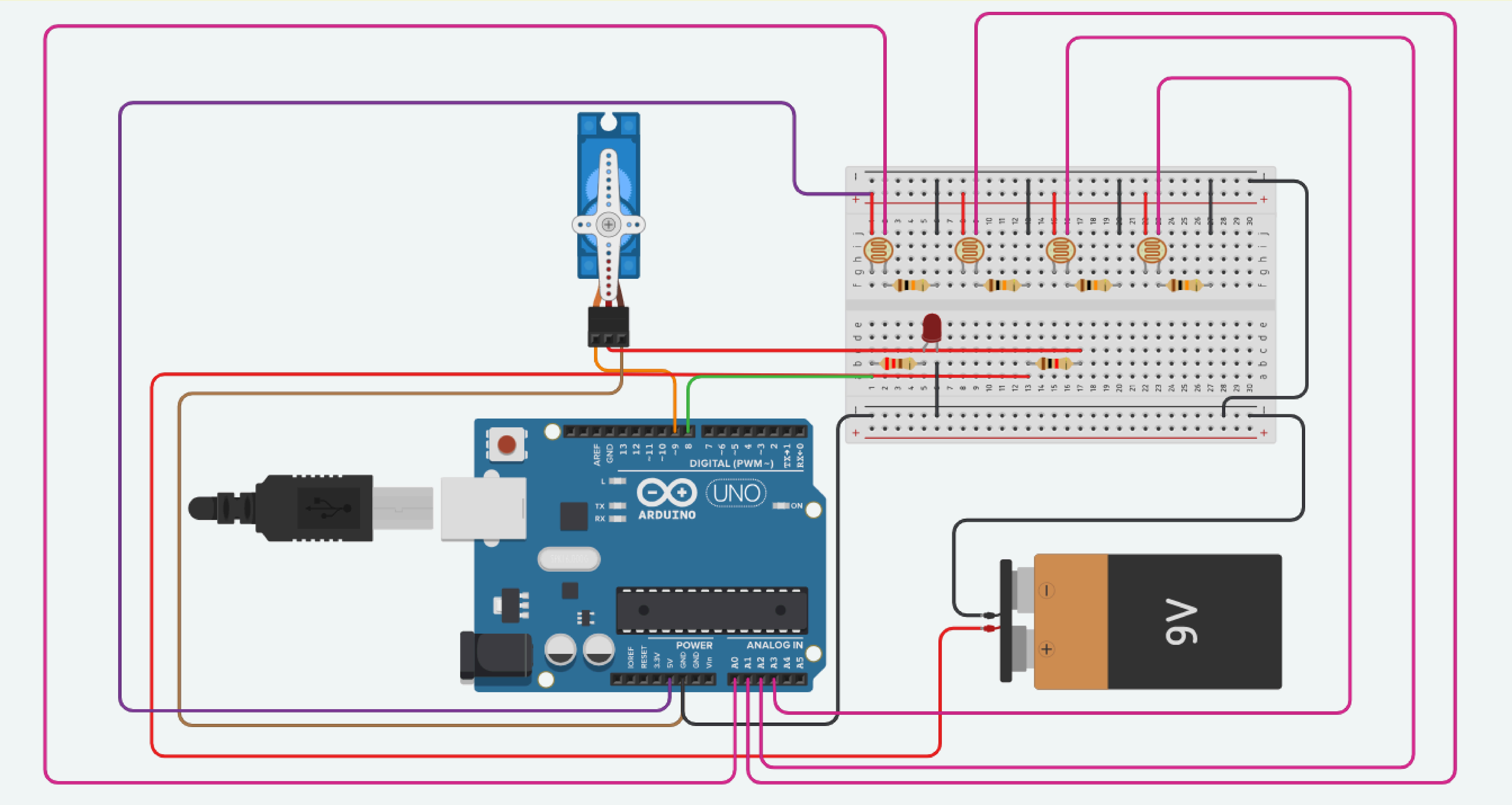
OBJECTIVE

- Create a smart Li-Fi system prototype that auto-adjusts based on receiver movement.
- Maintain continuous light-based communication without manual alignment.
- Negates the limitations of static Li-Fi systems.
- Simple, affordable, Arduino-based setup.

COMPONENTS

1. Arduino Uno R3 (Microcontroller)
2. 4 × LDRs (Light Dependent Resistors) — LDR1, LDR2, LDR3, LDR4
3. 4 × 10 kΩ resistors (for LDR voltage divider)
4. 1 × LED (for Li-Fi transmitter)
5. 1 × 220 Ω resistor (for LED current limiting)
6. 1 × Servo motor (for movement tracking)
7. Breadboard
8. 9V DC power supply (for servo motor)
9. 1 × 1 kΩ resistor (for servo motor current limiting)
10. Jumper Wires

CIRCUIT DIAGRAM

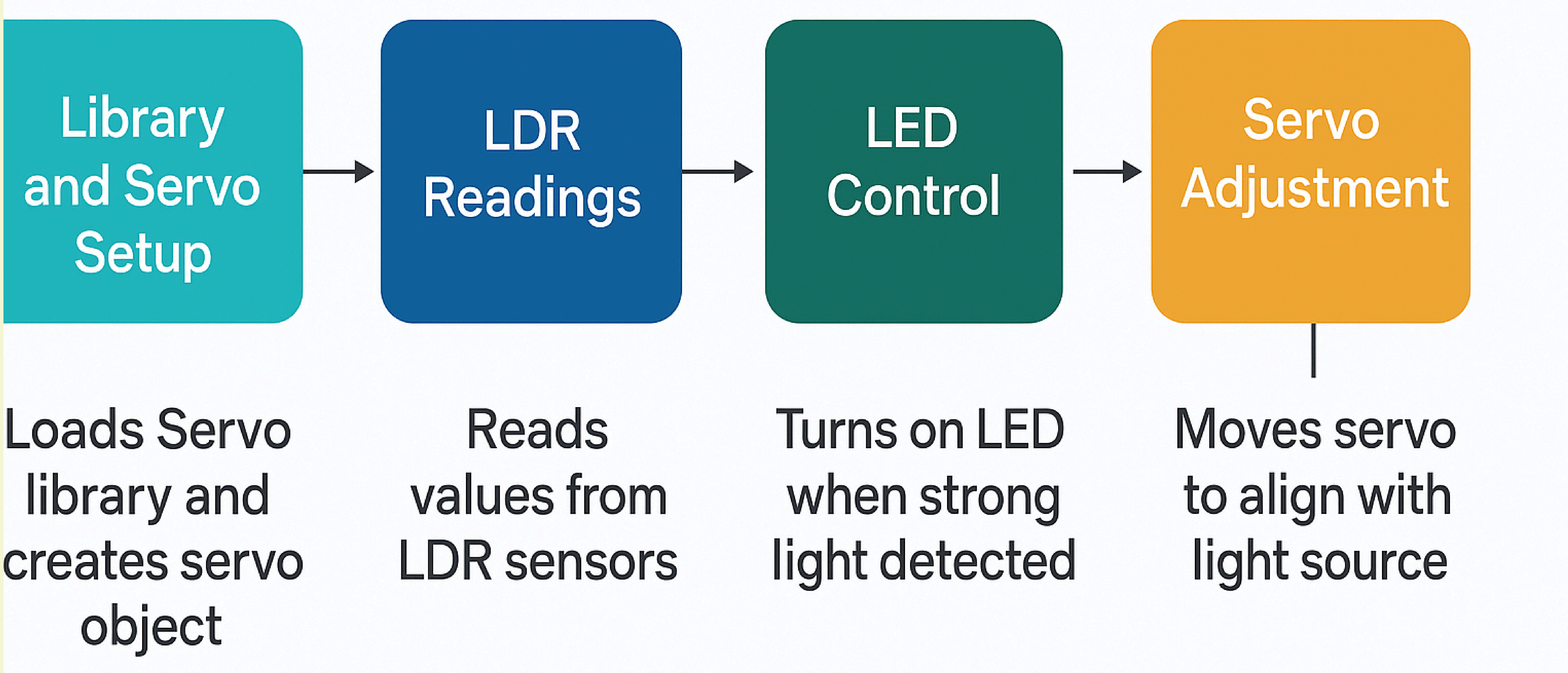


TRANSFER OF INFORMATION

FOUR Major Processes

1. **TRANSMISSION (LED : LIGHT SIGNAL)**
2. **RECEPTION (LDR : ELECTRICAL SIGNAL)**
3. **TRACKING (SERVO : ALIGNMENT)**
4. **DECODING (ARDUINO : USABLE DATA)**

REPRESENTATION OF CODE AS A FLOWCHART



CODE BLOCK I

- LIBRARY AND SERVO SETUP
- PIN ASSIGNMENT OF LEDs
- INITIALISATION OF SERVO POSITION (90 degrees)
- SETTING OF LED AS OUTPUT
- INITIALISATION OF LDRs IN ANALOG PWM PINS

```
#include <Servo.h>

Servo trackerServo;

// LDR analog pins
const int LDR1 = A0;
const int LDR2 = A1;
const int LDR3 = A2;
const int LDR4 = A3;

const int LED_PIN = 8;
int servoPos = 90; // Start at middle

void setup() {
  Serial.begin(9600);
  pinMode(LED_PIN, OUTPUT);
  trackerServo.attach(9);
  trackerServo.write(servoPos);
}
```

CODE BLOCK II

- ANALOG READ OF INTENSITY OF LIGHT
- SENSOR READINGS ON SERIAL MONITOR
- COMPARING OF INTENSITY OF LDRs
- CONVERSION FROM CANDELA TO NUMERICAL VALUE (0-123).

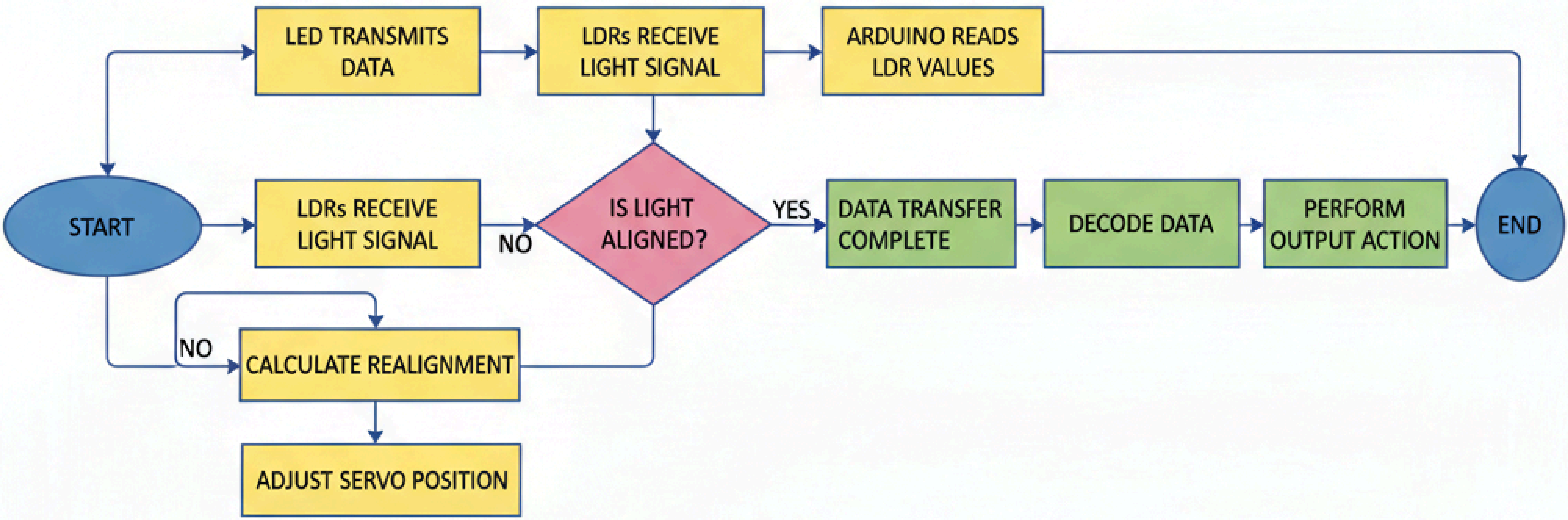
```
void loop() {
  // Read LDR values
  int val1 = analogRead(LDR1);
  int val2 = analogRead(LDR2);
  int val3 = analogRead(LDR3);
  int val4 = analogRead(LDR4);

  // Debug output
  Serial.print("LDR1: "); Serial.print(val1);
  Serial.print(" | LDR2: "); Serial.print(val2);
  Serial.print(" | LDR3: "); Serial.print(val3);
  Serial.print(" | LDR4: "); Serial.println(val4);

  // Average top and bottom readings
  int topAvg = (val1 + val2) / 2;
  int bottomAvg = (val3 + val4) / 2;

  // Average left and right readings
  int leftAvg = (val1 + val3) / 2;
  int rightAvg = (val2 + val4) / 2;
```

CODE BLOCK III

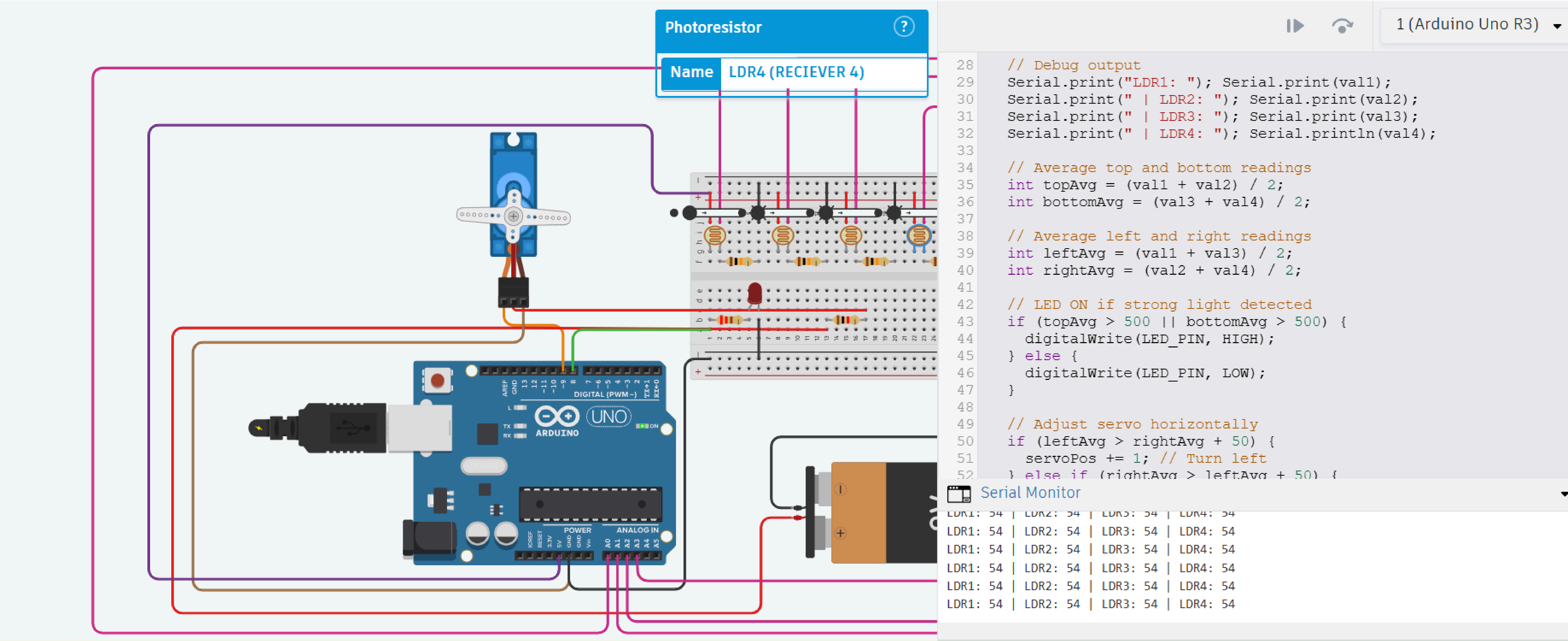
- INDICATION OF STRENGTH OF INTENSITY
- CONFIRMS THE OPTICAL SIGNAL
- ADJUSTMENT OF SERVO ANGLE BASED ON BRIGHTNESS
- OPERATION WITHIN SAFE LIMITING ANGLE
- SMALL DELAY (reduces jitter, smoothness)

```
  // LED ON if strong light detected
  if (topAvg > 500 || bottomAvg > 500) {
    digitalWrite(LED_PIN, HIGH);
  } else {
    digitalWrite(LED_PIN, LOW);
  }

  // Adjust servo horizontally
  if (leftAvg > rightAvg + 50) {
    servoPos += 1; // Turn left
  } else if (rightAvg > leftAvg + 50) {
    servoPos -= 1; // Turn right
  }

  // Constrain servo position
  servoPos = constrain(servoPos, 0, 180);
  trackerServo.write(servoPos);

  delay(50);
}
```

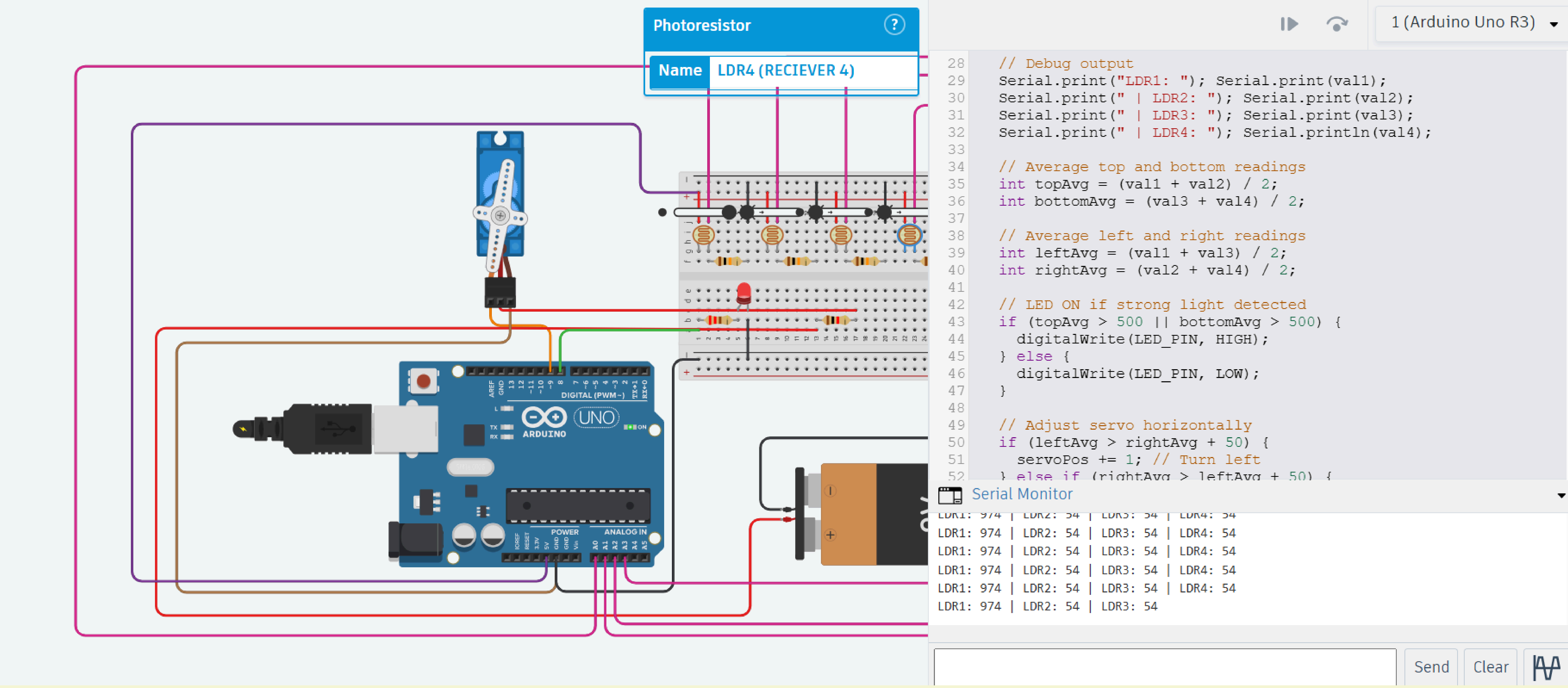
WORKING MECHANISM



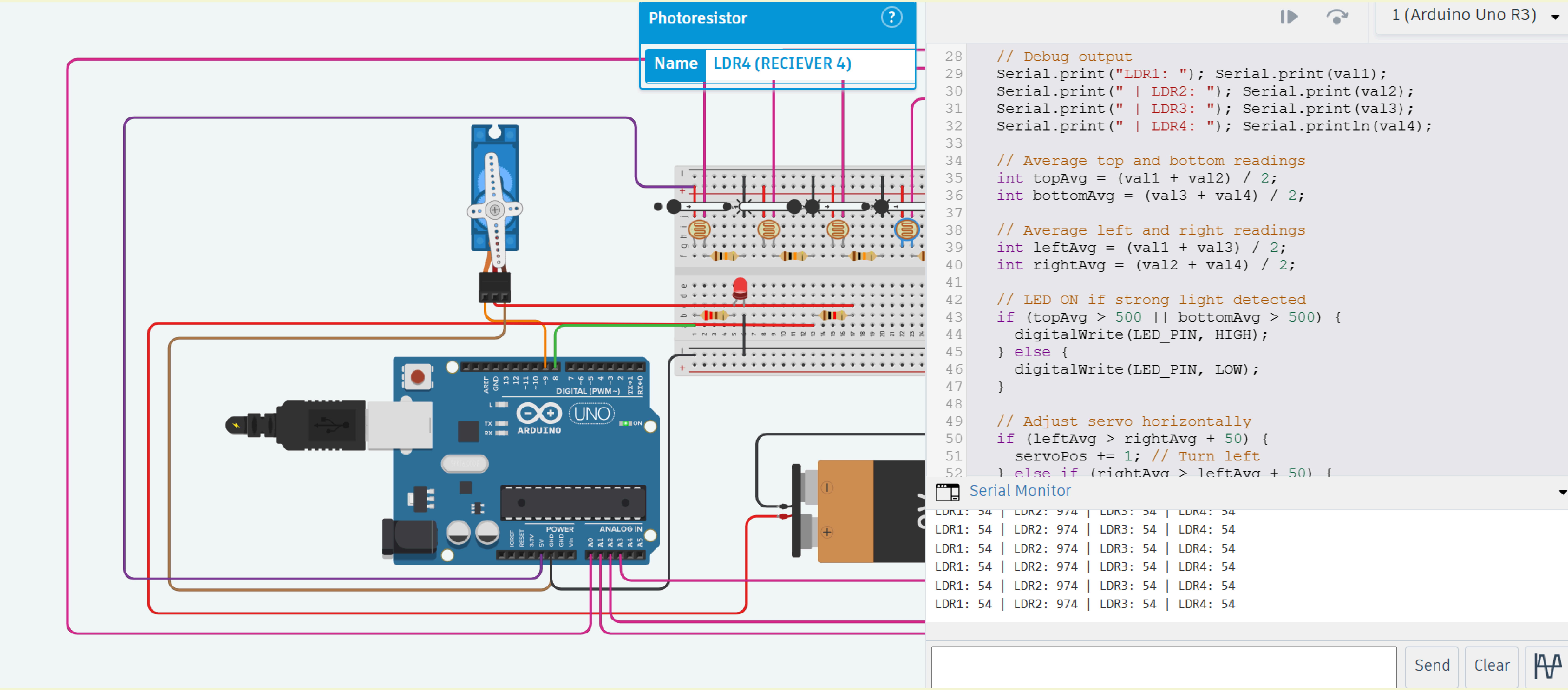
SIMULATION I



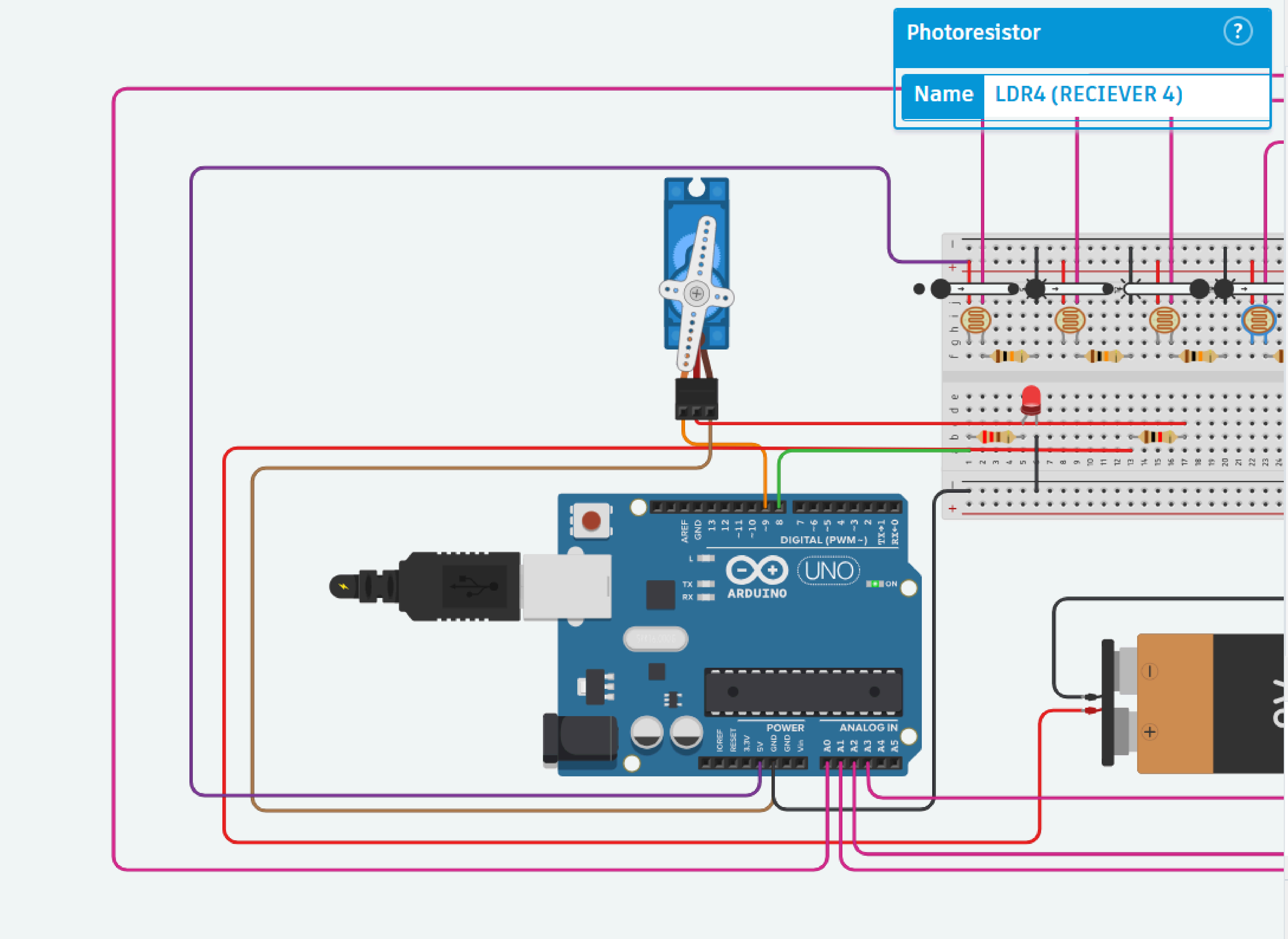
SIMULATION II



SIMULATION III



SIMULATION IV



1 (Arduino Uno R3)

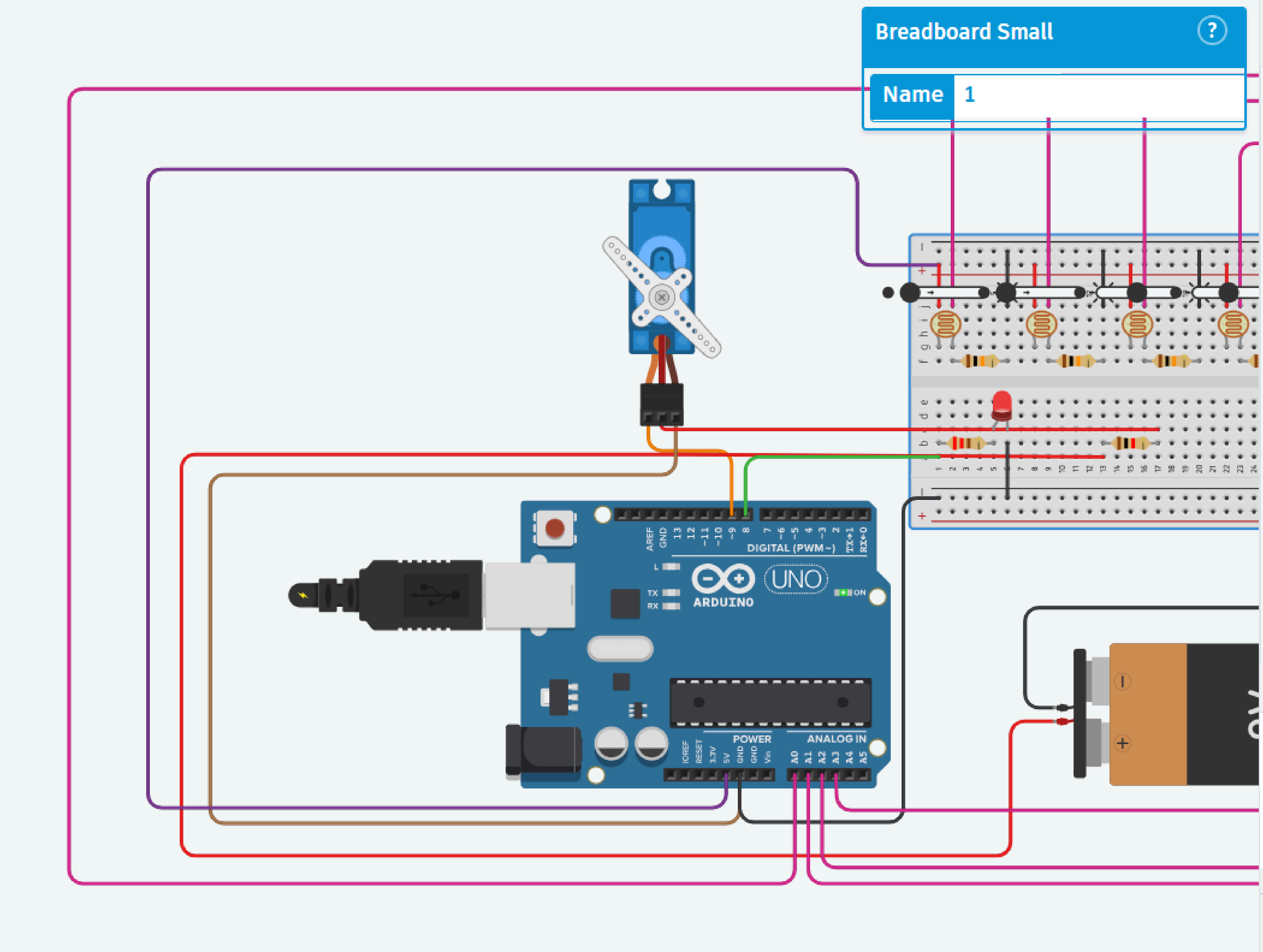
```
  // Debug output
  Serial.print("LDR1: "); Serial.print(val1);
  Serial.print(" | LDR2: "); Serial.print(val2);
  Serial.print(" | LDR3: "); Serial.print(val3);
  Serial.print(" | LDR4: "); Serial.println(val4);

  // Average top and bottom readings
  int topAvg = (val1 + val2) / 2;
  int bottomAvg = (val3 + val4) / 2;

  // Average left and right readings
  int leftAvg = (val1 + val3) / 2;
  int rightAvg = (val2 + val4) / 2;

  // LED ON if strong light detected
  if (topAvg > 500 || bottomAvg > 500) {
    digitalWrite(LED_PIN, HIGH);
  } else {
    digitalWrite(LED_PIN, LOW);
  }

  // Adjust servo horizontally
  if (leftAvg > rightAvg + 50) {
    servoPos += 1; // Turn left
  } else if (rightAvg > leftAvg + 50) {
```

Serial Monitor

```
LDR1: 54 | LDR2: 54 | LDR3: 974 | LDR4: 54
LDR1: 54 | LDR2: 54 | LDR3: 974 | LDR4: 54
LDR1: 54 | LDR2: 54 | LDR3: 974 | LDR4: 54
LDR1: 54 | LDR2: 54 | LDR3: 974 | LDR4: 54
LDR1: 54 | LDR2: 54 | LDR3: 974 | LDR4: 54
LDR1: 54
```

Send Clear

SIMULATION V



1 (Arduino Uno R3)

```
    // Debug output
    Serial.print("LDR1: "); Serial.print(val1);
    Serial.print(" | LDR2: "); Serial.print(val2);
    Serial.print(" | LDR3: "); Serial.print(val3);
    Serial.print(" | LDR4: "); Serial.println(val4);

    // Average top and bottom readings
    int topAvg = (val1 + val2) / 2;
    int bottomAvg = (val3 + val4) / 2;

    // Average left and right readings
    int leftAvg = (val1 + val3) / 2;
    int rightAvg = (val2 + val4) / 2;

    // LED ON if strong light detected
    if (topAvg > 500 || bottomAvg > 500) {
      digitalWrite(LED_PIN, HIGH);
    } else {
      digitalWrite(LED_PIN, LOW);
    }

    // Adjust servo horizontally
    if (leftAvg > rightAvg + 50) {
      servoPos += 1; // Turn left
    } else if (rightAvg > leftAvg + 50) {
```

Serial Monitor

```
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
LDR1: 54 | LDR2: 54 | LDR3: 937 | LDR4: 929
```

Send Clear

APPLICATIONS I

1. **HIGH SPEED INDOOR COMMUNICATION**

- Fast wireless internet using LED
- Keeps the receiver aligned

2. **AUTONOMOUS ROBOTS & DRONES**

- Navigate by tracking light.
- Useful in warehouses, manufacturing plants, search-and-rescue operations.

3. **SMART LIGHTING SYSTEM**

- Adjust direction, brightness.
- Saves energy, improves comfort.

APPLICATIONS II

1. **UNDERWATER DATA TRANSMISSION**

- Keep divers or underwater vehicles aligned with transmitters.

2. **INTERACTIVE DISPLAYS & EXHIBITS**

- Museums or exhibitions.
- Location-based information

3. **SECURE POINT-TO-POINT COMMUNICATION**

- Ensures strong links even with slight movements.

REFERENCES

- Wikipedia
- YouTube (Diversify Club Channel)
- GeeksforGeeks *https://www.geeksforgeeks.org/computer-networks/introduction-of-light-fidelity-li-fi/*
- pureLiFi *https://www.purelifi.com/about-lifi/*
- tech@gov *https://tec.gov.in/pdf/Studypaper/lifi%20study%20paper%20-%20approved.pdf*
- OpenAI, Gemini (images, flowchart designs)
- TinkerCad (running the simulations and designing the circuit)

THANK YOU