Light-Following Robotic Car

Supervisor: Dr. Esam Qaralleh

Embedded Systems Final Design Project, Fall 2024/2025

King Abdullah || School of Engineering

Princess Sumaya University for Technology

R.Amer 20201088

M.Rowad 20200726

J.Tutanji 20200247

Table of Contents

Abstract

The light-following robotic car is an embedded systems project developed to implement navigation and real-time decision-making. This car will be able to follow a light source by detecting light with the help of LDRs, while an ultrasonic sensor enables safe operation by avoiding obstacles. The system is powered by the PIC16F877A microcontroller, integrating sensor data and driving the servo motors through an H-Bridge motor driver. During operation, the car will stop at the detection of an obstacle, compute the best path by using some pre-programmed maneuvers, and then continue light tracking smoothly. This project represents embedded systems as an integration of electrical, software, and mechanical design. With its steady performance, the light-following car serves as a low-cost prototype of advanced robotics applications and demonstrates real-world sensor fusion and automation.

Introduction and Background

The light-following robotic car is a system designed for autonomous navigation and obstacle avoidance. Utilizing LDR light sensors, the car tracks and moves toward a light source while ensuring safe operation through an ultrasonic sensor that detects obstacles in its path. The car halts upon detecting an obstacle and intelligently navigates around it by executing predefined right and left movements. By integrating a PIC16F877A microcontroller with servo motors, an H-Bridge motor driver, and a robust power supply system, this project highlights the practical applications of embedded systems in autonomous vehicles and automation.

Design (Mechanical, Electrical, Software)

The project aims to develop an autonomous car capable of detecting and following a light source while avoiding obstacles in its path. This is achieved by integrating light-dependent resistors (LDRs) to detect light intensity and ultrasonic sensors to measure distances from nearby obstacles. A microcontroller processes the input data and sends signals to the motors to adjust the car's movement accordingly.

The system is divided into three main designs: electrical, software, and mechanical. The electrical design focuses on connecting and configuring all components such as sensors, motors, and the microcontroller. The software design ensures the car responds correctly to environmental changes by using real-time data to make decisions. The mechanical design involves a robust chassis and strategic placement of components, allowing efficient functionality and maneuverability.

Software:

```
//Ultrasonic  Trig  RC6 ,, Echo RC7
// SERVO PIN RC2
// PWM  EN MOTORS RC1
// DiRECTION PINS RB0 , RB1 , RB2 , RB3
// LDR RD0 , RD1 , RD2
// Analog LDR RA0
//Start  Buttno RD3
//LEDS Pin RD6, RD7

int tick;
int tick1;
unsigned int sensor_voltage;
unsigned char H_L;
unsigned int angle;
int distance;
int a;
int b;



void initialize();
void interrupt();
```

```
void stop_moving();
void move_left();
void move_right();
void move_forward();
void move_backwards();
void adjust_position();
void ENDD();
int dist();



void check_start(){
if(PORTD & 0B00001000){
     b++;
   }
   if(b%2==0){
   b=0;
   }else{b=1;}



}
```

```
void CCPPWM_init(){              // Configure and CCP2 at 2ms period with 50% duty cycle
    T2CON = 0x07;                // Enable Timer2 at Fosc/4 with 1:16 prescaler (8 uS percount 2000uS to count 250 counts)
    CCP2CON = 0x0C;              // Enable PWM for CCP2
    PR2 = 250;                   // 250 counts = 8uS *250 = 2ms period
    CCPR2L = 125;                // Buffer where we are specifying the pulse width (duty cycle)
}



void Speed(int p){
    CCPR2L = p;              // PWM from RC1
}

void mymsDelay(int x);

void ATD_init_A0();
unsigned int ATD_read_A0();

void check_front_right();
void check_front_left();
void check_front();
```

```
void main() {

    initialize();
    ATD_init_A0();
    CCPPWM_init();
    b=0;
    a=0;
    while(1){
      PORTD=PORTD & 0B11011111;
      check_start();

          while(b){
          PORTD=PORTD | 0B00100000;
          check_front_right();
          check_start();
          check_front_left();
          check_start();
          check_front();
          check_start();
          adjust_position();
          check_start();
          ENDD();
```

```
        check_start();
}               }
}
```

```
void initialize(){
TRISA=0X01;
TRISB=0X00;
TRISC=0B10000000;
TRISD=0B00001111;

PORTA=0X00;
PORTB=0X00;
PORTC=0X00;
PORTD=0X00;


  OPTION_REG= 0x87;//Use internal clock Fosc/4 with a prescaler of 256
  TMR0=248;// will count 8 times before the overflow (8* 128uS = 1ms)
  INTCON = 0b11100000; //GIE and , T0IE, peripheral interrupt

  T1CON=0x01;
```

```
  TMR1H=0;
  TMR1L=0;

  CCP1CON=0x08;
  PIE1=PIE1|0x04;// Enable CCP1 interrupts
  CCPR1H=2000>>8;
  CCPR1L=2000;

  H_L = 1;
}




void interrupt(){
   if(INTCON & 0x04){// TMR0 Overflow interrupt, will get here every 1ms
     TMR0=248;
     tick++;
     tick1++;
     check_start();
     INTCON = INTCON & 0xFB;//Clear T0IF
     }
```

```
if(PIR1&0x04){//CCP1 interrupt
  if(a==1){                          // CCP1 interrupt
        if(H_L){                     // high
              CCPR1H = angle >> 8;
              CCPR1L = angle;
              H_L = 0;               // next time low
              CCP1CON = 0x09;        // compare mode, clear output on match
              TMR1H = 0;
              TMR1L = 0;
        }
        else{                        //low
              CCPR1H = (40000 - angle) >> 8;     // 40000 counts correspond to
20ms
              CCPR1L = (40000 - angle);
              CCP1CON = 0x08;        // compare mode, set output on match
              H_L = 1;               //next time High
              TMR1H = 0;
              TMR1L = 0;
        }

        PIR1 = PIR1&0xFB; }else{
```

```
          PIR1 = PIR1&0xFB;
         }
     }

}
```

```
void ATD_init_A0(){
ADCON0 = 0x41; // ATD ON, Dont go, channel 0, fosc/16
ADCON1 = 0xCE; // All channels are digital except A0 , 500 khz , right justified
}
```

```
unsigned int ATD_read_A0(){
ADCON0 = ADCON0 | 0x04; // GO
while(ADCON0 & 0x04);
return ((ADRESH<<8) | ADRESL);
}
```

```
void mymsDelay(int const x){
```

```
    tick=0;
    while(tick<x);
}

void check_front_right(){
// read port D0 : right sensor
if(!(PORTD & 0b00000001)){
  tick1 = 0;
  // read port D2 : front sensor
  while((PORTD & 0b00000100)){
  // if it turns more than the turning_th stop (turning_th is time)
  if (tick1 >= 4000) break;
  // move right
  move_right();

  }
  mymsDelay(100);
// stop moving
stop_moving();
}
}
```

```
void check_front_left(){
// read port D1 : left sensor
if (!(PORTD & 0b00000010)){
    tick1 = 0;
   // read port D2 : front sensor
   while((PORTD & 0b00000100)){
     // move left
     if (tick1 >= 4000) break;
     move_left();
     }
// stop moving
stop_moving();
}
}

void check_front(){
while(!(PORTD & 0b00000100)){
sensor_voltage = ATD_read_A0();

while(sensor_voltage <= 70 || sensor_voltage >= 100){
  sensor_voltage = ATD_read_A0();
move_forward();
distance=dist();
```

```
if(distance<20){
move_right();
mymsDelay(2000);
move_forward();
mymsDelay(2000);
move_left();
mymsDelay(2000);
move_forward();
}else{move_forward();}
  if(PORTD & 0b00000100){break;}
}
if(sensor_voltage <= 100) {break;}
if(PORTD & 0b00000100){break;} }

  mymsDelay(100);
  stop_moving();
}



void stop_moving(){
    PORTB = PORTB & 0b11110000;
}
```

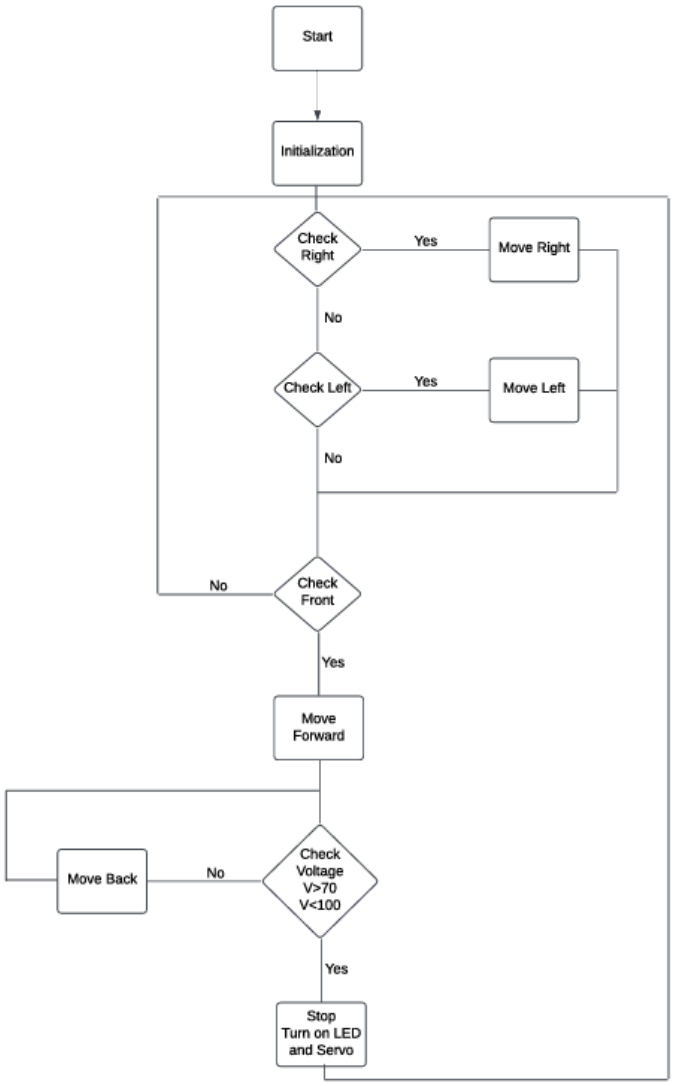
```
void move_left(){

    Speed(90);
    PORTB =(PORTB & 0b11110000)| 0b00001001;
}

void move_right(){
   Speed(90);
   PORTB = (PORTB & 0b11110000) | 0b00000110;
}

void move_forward(){
   Speed(140);
   PORTB = (PORTB & 0b11110000)| 0b00000101;

}

void move_backwards(){
   Speed(90);
   PORTB = (PORTB & 0b11110000)| 0b00001010;
}
```

```
void adjust_position(){
while(!(PORTD & 0b00000100)){
    sensor_voltage = ATD_read_A0();
    while(sensor_voltage < 70){
    move_backwards();
    sensor_voltage = ATD_read_A0();
}

if( sensor_voltage>=70) {break;}
if(PORTD & 0b00000100){break;}
}
mymsDelay(100);
stop_moving();
}




void ENDD(){

sensor_voltage = ATD_read_A0();
```

```
while (!(PORTD & 0b00000100))
{
    if(sensor_voltage <70 || sensor_voltage > 100) break;
    stop_moving();
    a=1;
    angle = 1000;
    PORTD=PORTD | 0B11000000;
    mymsDelay(2000);
    angle = 3500;
    PORTD=PORTD & 0B00111111;
    mymsDelay(2000);
    angle = 1000;
    PORTD=PORTD | 0B11000000;
    mymsDelay(2000);
    angle = 3500;
    PORTD=PORTD & 0B00111111;
    mymsDelay(2000);
    angle = 1000;
    PORTD=PORTD | 0B11000000;
}
PORTD=PORTD & 0B00111111;
angle =  2250;
a=0;
```

```
}

int dist(){
   int d = 0;
   T1CON = 0x10; // Use internal clock, no prescaler
   mymsDelay(200);

   T1CON = 0x10;
   TMR1H = 0;              // Reset Timer1
   TMR1L = 0;

   PORTC = PORTC | 0b01000000; // Trigger HIGH
   delay_us(10);            // 10 µs delay
   PORTC = PORTC & 0b10111111; // Trigger LOW

   while (!(PORTC & 0b10000000));


   T1CON = T1CON | 0b00000001; // Start Timer


   while (PORTC & 0b10000000);
```

```
    T1CON = T1CON & 0b11111110; // Stop Timer

    d = (TMR1L | (TMR1H << 8)); // Read Timer1 value
    d = d / 58.82;          // Convert time to distance (cm)

    mymsDelay(10);
    T1CON = 0x01;
    return d;
}
```



Mechanical design

1. Power Supply System

The power supply system supplies power to the car's components. It provides the regulated voltage levels required by the PIC16F877A microcontroller, sensors, and motors. It consists of 3 batteries, 3.7v each.

2. Microcontroller: PIC16F877A

The PIC16F877A microcontroller is the central processing unit of the system. It processes data from sensors, executes control algorithms, and generates signals for motor control. The GPIO pins of the microcontroller are configured as follows:

Digital Inputs: Ultrasonic sensor's Echo signal and start button.

Analog Input: LDRs for measuring light intensity by using ADC pins.

PWM Outputs: Speed control of motors using the H-Bridge driver.

3. Light Sensors: LDRs

three LDRs attached with analog pins of the microcontroller are used for detecting the direction of the strongest light. Voltage output from each of the LDRs is proportional to the light intensity it gets. The microcontroller processes the resultants and selects a direction to move based on which LDR had a greater amount of light. The LDR that gets the highest amount of light, lights up.

4. Ultrasonic Sensor

Distance Calculation: It employs an ultrasonic sensor that detects the distance to the obstacle.

5. Motor Control

Four DC motors drive the wheels of the car, and are controlled by:
H-Bridge Motor Driver: The driver enables both the forward and backward motion through which the speed and direction of the motors are controlled.

There are 2 DC motors connected together on each side, therefore, each two work together accordingly.

6. Servo Motor

A servo motor, connected to RC2, changes the orientation of the car to make precise navigation. The position of the servo is determined by a PWM signal provided by the microcontroller.

7. LEDs and Indicators

Two LEDs, RD6 and RD7, are used for indication purposes, showing the system's status. They can give indications when the car is on track, to avoid hurdles, or at rest.

8. User Interface: Start Button

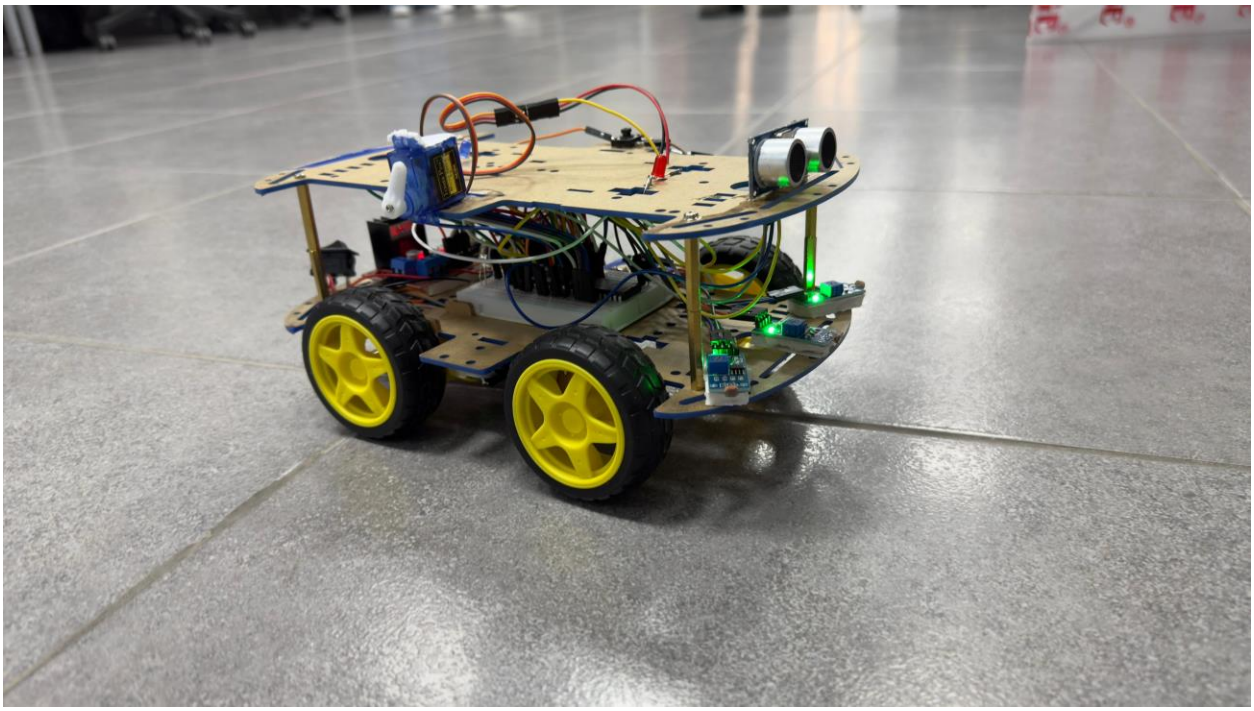
There is a start button, RD3, which starts the operation of the car. The microcontroller monitors the press of the button and switches the car between an active and idle state

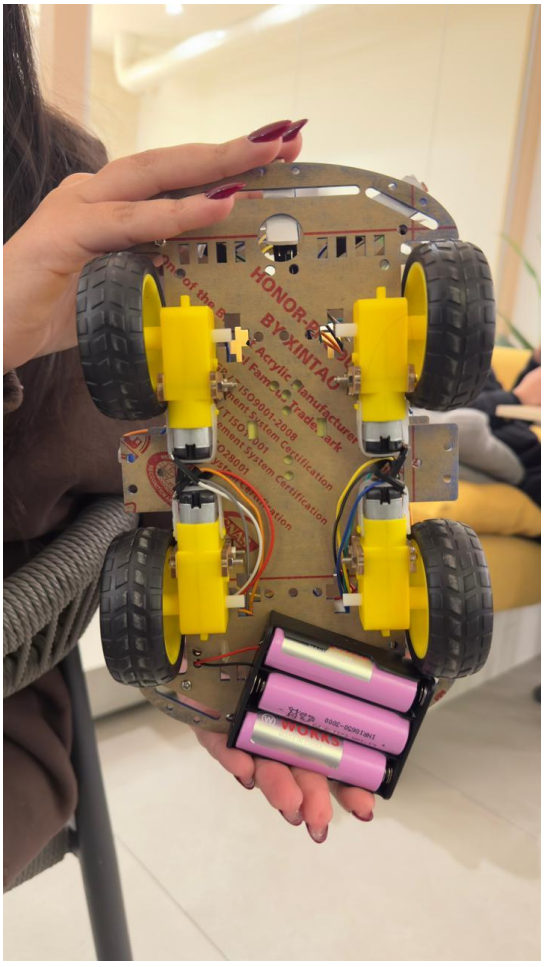
9. System Interconnections

Sensor Integration: The inputs from LDRs and the ultrasonic sensor are fed to the microcontroller, which does real-time processing.

Motor Driver Control: Digital and PWM signals from the microcontroller drive the H-Bridge to actuate the motors.

Power Distribution: Proper wiring ensures that all components have sufficient and stable power.





Eelectrical design:

1-power supply system

A regulated 5V supply for the **PIC16F877A microcontroller** and sensors.

A higher voltage supply (11.1V) for driving the **DC motors** via the H-Bridge motor driver.

2- microcontroller: PIC16F877A

The PIC16F877A microcontroller acts as the central controller, managing data from sensors and generating control signals for actuators. The GPIO pins are configured as follows:

Analog Input (RA0): Reads voltage from the analog LDR to measure light intensity.

Digital Inputs (RD0, RD1, RD2): Receives signals from digital LDRs to determine the direction of the strongest light source.

PWM Output (RC1): Controls the speed of the DC motors via an H-Bridge motor driver.

Direction Control (RB0, RB1, RB2, RB3): Sets the direction of motor rotation (forward, backward, left, or right).

Ultrasonic Sensor Pins (RC6 and RC7):

RC6 (Trigger): Sends pulses to the ultrasonic sensor to initiate distance measurement.

RC7 (Echo): Receives the reflected signal from the ultrasonic sensor to calculate distance.

Servo Motor (RC2): Outputs a PWM signal to control the orientation of the servo motor.

LED Indicators (RD6 and RD7): Indicate system status during operation.

Start Button (RD3): Allows the user to toggle the system's active state.

3. Light Detection System

Three LDRs (Light-Dependent Resistors) are used to detect light intensity and direction:

Analog LDR (RA0): Measures light intensity with higher resolution using the ADC module.

Digital LDRs (RD0, RD1, RD2): Detect light presence and directional cues.

The microcontroller processes the LDR readings to decide the car's movement.

4. Ultrasonic Sensor for Obstacle Detection

The ultrasonic sensor uses:

RC6 (Trig): Sends high-frequency pulses.

RC7 (Echo): Captures the reflected signal to calculate the distance to an obstacle.

Timer1 Module: Measures the time interval between sending and receiving the signal. The distance is then calculated using the time difference.

5. Motor Control System

The system uses:

H-Bridge Motor Driver (Direction Pins: RB0, RB1, RB2, RB3):

Enables forward and backward motion for each motor.

Facilitates left and right turns by controlling the rotation of individual motors.

PWM Signal (RC1): Adjusts the speed of the motors, allowing precise control of the car's movement.

6. Servo Motor

A servo motor connected to RC2 adjusts the car's orientation. The position is controlled by generating a PWM signal with varying duty cycles.

7. User Interface

Start Button (RD3): A simple push button toggles the system between active and idle states. Its state is monitored continuously to enable or disable the car's operation.

8. LED Indicators

RD6 and RD7: Two LEDs provide visual feedback during operation. For example, one LED might indicate active light tracking, while the other signals obstacle avoidance.

9. System Timing

Timer0: Generates periodic interrupts (every 1ms) for time-based functions such as delays and task scheduling.

Timer1: Used for precise distance measurements from the ultrasonic sensor.

Problems & Recommendations

- ## Inconsistent Ambient Lighting Detection

  Problem: The LDRs could give spurious readings in changing ambient light conditions, for example, outdoors where the sun changes position or shade, or indoors where shadows may be present. Instead of placing only one LDR at first, we placed 3 LDRs to be able to detect light from different angles

- ## Obstacle Detection Blind Spots

  Problem: The ultrasonic sensor is unable to detect obstacles at certain angles or when the surface material is not a good reflector of ultrasonic waves, such as soft or angled surfaces. We placed it at the roof of the car to be able to detect and sense obstacles more accurately

Conclusion

The light-following car with obstacle avoidance demonstrates the practical application of embedded systems in autonomous navigation. By integrating LDR sensors, an ultrasonic sensor, and a PIC16F877A microcontroller, the project achieves a cost-effective yet efficient design capable of real-time decision-making. This project serves as a stepping stone for more advanced systems, showcasing how sensor fusion and programming can solve real-world challenges. It has potential applications in robotics, automation, and smart mobility solutions, providing a foundation for future exploration in autonomous vehicle technologies. The success of this project highlights the importance of interdisciplinary collaboration between hardware, software, and mechanical design, proving that embedded systems are a cornerstone for innovation in modern engineering