SMART TRAFFIC DIVERSION SYSTEM FOR ROAD CONGESTION MANAGEMENT SYSTEM

Team Members

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EXECUTIVE SUMMARY:

This project entails the development of a smart traffic management system using Arduino, ultrasonic sensors, and a seven-segment display in a 2-way traffic control system. The primary goal is to efficiently monitor and control traffic flow at intersections to enhance safety and reduce congestion.

Key Components and Functionality

1. Hardware Components:
   - **Arduino Microcontroller:** Central unit for system control.
   - **Ultrasonic Sensors:** Detect vehicle presence and measure distances.
   - **Seven-Segment Display:** Displays the count of detected vehicles.
   - **LEDs and Speaker:** Provide visual and auditory alerts for traffic conditions.
   - **Buttons:** Allow manual adjustment of the vehicle count.
   - **IR :** Detect the presence and count of vehicles waiting to take a U-turn, enhancing system reliability and responsiveness.

2. Software Implementation:
   - The system initializes by configuring pins and preparing all components.
   - It continuously monitors two ultrasonic sensors to detect vehicles within a specified range (less than 200 cm).
   - If the distance remains the same, it indicates that the vehicle is waiting to make a U-turn. Therefore, IR can count the number of vehicles waiting to take a U-turn.
   - Traffic lights are controlled dynamically, changing states (green, yellow, red) based on traffic conditions.
   - LEDs and a speaker provide visual and auditory alerts when necessary.

Key Findings and Results

- **Real-Time Monitoring:** The system effectively detects vehicles in real-time using ultrasonic sensors.
- **Dynamic Traffic Control**: Traffic light timings are adjusted based on real-time vehicle detection, enhancing traffic flow and safety.
- **Visual and Auditory Alerts:** LEDs and the speaker ensure clear communication of traffic conditions through visual and auditory signals.

Conclusions

The project successfully demonstrates the feasibility of using sensors and microcontroller-based logic to manage traffic at intersections. Key achievements include:

- ❖ Real-time vehicle monitoring and counting.
- ❖ Dynamic adjustment of traffic light timings based on real-time data.
- ❖ Effective communication of traffic conditions through visual and auditory alerts.

Recommendations

1.**Scalability:** Extend the system to cover multiple intersections for broader traffic management.
2. **Data Analysis:** Implement data logging to analyze traffic patterns and optimize light timings.
3. **User Interface:** Develop a more user-friendly interface for easier control and monitoring, potentially with wireless remote management.
4. **Additional Sensors:** Incorporate other types of sensors (e.g., infrared or cameras) to improve accuracy and handle various conditions.

Our project provides a solid foundation for a comprehensive traffic management system with potential for significant enhancements to further improve urban traffic efficiency and safety.

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Project Objective

This project aims to address urban traffic congestion by developing a smart traffic management system using Arduino, ultrasonic sensors, IR sensors and a seven-segment display. The system will detect real-time vehicle presence and dynamically adjust traffic light timings to improve traffic flow at intersections. By integrating visual and auditory alerts, it ensures clear communication of traffic conditions to drivers. The project also allows for manual adjustments to vehicle counts, enhancing flexibility. Overall, it seeks to reduce delays, emissions, and driver frustration, paving the way for a more efficient urban traffic system.

Scope:

This project focuses on developing a prototype for an intelligent traffic management system aimed at optimizing traffic flow at urban intersections. The scope includes the design, implementation, and testing of a system that uses Arduino, ultrasonic sensors, IR sensors and a seven-segment display to monitor and manage vehicle traffic.

Assumptions

- The system assumes that vehicles can be accurately detected within a range of 200 cm using ultrasonic sensors.
- It is assumed that traffic flow at intersections can be significantly improved by dynamically adjusting traffic light timings based on real-time vehicle detection.
- Manual adjustments to vehicle counts will be infrequent but necessary for testing and calibration purposes.

Boundaries

- The project is limited to a single intersection and does not include integration with other intersections or broader traffic management systems.
- It focuses on vehicle detection and traffic light control, excluding pedestrian traffic management.
- The prototype will operate in a controlled environment, and real-world variables such as weather conditions, sensor obstructions, and varying traffic patterns are not within the scope.
- Data logging and long-term analysis of traffic patterns are not included in this phase but are considered for future enhancements.

Methodology:

Overall Approach

The methodology for this project involves a systematic approach to designing and implementing an intelligent traffic management system using an Arduino microcontroller, ultrasonic sensors, IR sensors and a seven-segment display. The key steps in the approach include sensor integration for vehicle detection, real-time traffic light control, and user interaction through manual adjustments. This ensures a comprehensive solution to dynamically manage traffic flow at intersections.

Detailed Methodology

1. System Initialization:

The project begins with initializing all hardware components, including setting up pins for the ultrasonic sensors, IR sensors and seven-segment display, LEDs, and speaker. This ensures that all components are configured correctly before the system starts monitoring traffic.

2. Real-Time Vehicle Detection:

Ultrasonic sensors are used to detect the presence of vehicles at a distance of up to 200 cm. These sensors emit sound waves and measure the time it takes for the echo to return, which is then converted to distance. The use of ultrasonic sensors is justified as they are cost-effective and provide reliable distance measurements. Then, IR can count the number of vehicles waiting to take a U-turn.

3. Dynamic Traffic Light Control:

Based on the data from the ultrasonic sensors, the traffic light timings are dynamically adjusted. When a vehicle is detected within the specified range, the system counts the number of vehicles and adjusts the traffic light states (green, yellow, red) accordingly. This approach ensures that traffic lights respond to real-time conditions, reducing congestion and improving flow.

4. Visual and Auditory Alerts:

LEDs and a speaker are integrated to provide visual and auditory alerts. When certain traffic conditions are met (e.g., a high number of detected vehicles), the system activates the red LED and the speaker to alert drivers. This ensures that drivers are aware of changes in traffic signals, enhancing safety.

5. User Interaction:

Buttons are included to allow manual adjustments of the vehicle count. This is particularly useful for testing and calibration purposes. By enabling manual overrides, the system remains flexible and user-friendly.

6. Display of Vehicle Count:

A seven-segment display shows the current count of detected vehicles which is detected by the IR sensors. This provides a visual representation of traffic conditions at the intersection, aiding both the system operators and drivers.

7. Iteration and Testing:

The system undergoes continuous iteration and testing to ensure accuracy and reliability. Each component is tested individually and as part of the integrated system to confirm proper functionality and response to traffic conditions.

Justification for Methodology

- Reliability and Accuracy: Ultrasonic sensors are chosen for their reliability and accuracy in detecting vehicle presence, crucial for real-time traffic management.
- Cost-Effectiveness: The use of readily available components like Arduino, LEDs, and ultrasonic sensors, IR sensors makes the system affordable and scalable.
- Dynamic Control: The methodology emphasizes dynamic adjustment of traffic light timings, which is essential for managing varying traffic volumes effectively.
- User-Friendliness: Including manual controls and clear visual/auditory alerts ensures that the system is easy to operate and understand, even for non-technical users.

Artifacts used:

Research Insights:

"Understanding Smart Traffic Management Systems" - Provided an overview of current technologies shaping smart traffic management.
"Exploring IoT Applications in Urban Traffic Control" - Delved into the application of IoT for enhancing traffic management in urban areas.
"Insights into Real-Time Traffic Monitoring through Sensor Networks" - Offers a comprehensive examination of utilizing sensor networks for real-time traffic monitoring.

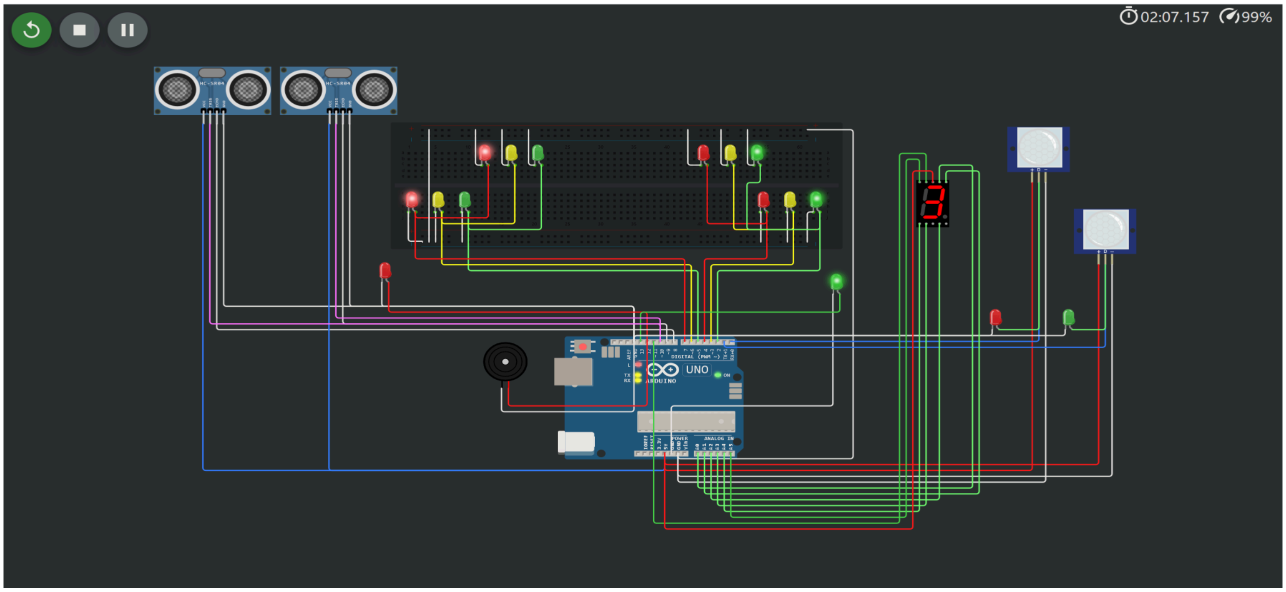
Data Collection Activities:

Driver Feedback Surveys: Gathered insights on driver behavior and opinions regarding existing traffic systems.
Conversations with Urban Planners: Engaged urban planners in discussions to understand the feasibility and potential impact of proposed traffic management systems.

Tools Explored:

1. **Arduino IDE**:
   - The Arduino Integrated Development Environment (IDE) was used for writing, testing, and uploading code to the Arduino microcontrollers. Its comprehensive libraries and user-friendly interface were crucial for the project's development.
2. **MATLAB/Simulink**:
   - MATLAB and Simulink were employed to simulate traffic scenarios and analyze data. These tools helped in modeling traffic patterns and evaluating the system's performance under different conditions.
3. **Sensor Modules**:
   - Various sensor modules were tested for their accuracy and reliability in detecting vehicles. These tests ensured that the chosen sensors would provide consistent and precise data for real-time traffic monitoring.

Technical coverage :
1. Prototypes



Component	Description
Pins and Initializations	Set up pins for LEDs, speakers, and ultrasonic sensors, IR sensors. Initialize serial communication and display initial setup messages.
Main Loop	Continuously executes the main logic of the program. Controls LED lights, handles button presses, triggers ultrasonic sensors, and updates system status based on sensor readings.
Display Green Light	Sets the LEDs to display the green light for Set 1.
Loop for delay_time	Executes the loop for the duration specified by delay_time.
Handle Button Presses	Monitors and responds to button presses, updating the motion number accordingly.
Trigger Ultrasonic Sensors	Sends signals to trigger ultrasonic sensors and reads distance measurements.
IR Sensors	IR could count the number of vehicles waiting to take a U-turn.
Update Count	Updates the count based on distance conditions from the sensors.
Update LED and Speaker Status	Controls the status of LEDs and speakers based on count and motion number.
Display Yellow and Red Lights	Sets the LEDs to display yellow and red lights for Set 1 and Set 2, respectively.
Delay for delay_time	Delays the program execution for the specified duration.

1. Code snippets

```
#include "SevSeg.h"
SevSeg sevseg;
#define LedRed  12
#define LedGreen  13
#define speaker 12

const int pingPin_1_2 = 10;
const int echoPin1 = 8; // Echo Pin of Ultrasonic Sensor
const int echoPin2 = 9; // Echo Pin of Ultrasonic Sensor
long long int delay_time = 60000;

int motion_number = 0;
bool motion0 = false;
bool motion1 = false;


int a = A0;
int b = A1;
int c = A2;
int d = A3;
int e = A4;
int f = A5;
int g = 11;

const int digitSegments[10][7] = {
  {LOW, LOW, LOW, LOW, LOW, HIGH, LOW},  // 0
  {HIGH, LOW, LOW, HIGH, HIGH, HIGH, HIGH},      // 1
  {LOW, LOW, HIGH, LOW, LOW, LOW, HIGH},   // 2
  {LOW, LOW, LOW, LOW, HIGH, LOW, HIGH},   // 3
  {HIGH, LOW, LOW, HIGH, HIGH, LOW, LOW},    // 4
  {LOW, HIGH, LOW, LOW, HIGH, LOW, LOW},   // 5
  {LOW, HIGH, LOW, LOW, LOW, LOW, LOW},  // 6
  {LOW, LOW, LOW, HIGH, HIGH, HIGH, HIGH},     // 7
  {LOW, LOW, LOW, LOW, LOW, LOW, LOW}, // 8
  {LOW, LOW, LOW, LOW, HIGH, LOW, LOW}    // 9
};
```

```
  void displayNumber(int num) {
  digitalWrite(a, digitSegments[num][0]);
  digitalWrite(b, digitSegments[num][1]);
  digitalWrite(c, digitSegments[num][2]);
  digitalWrite(d, digitSegments[num][3]);
  digitalWrite(e, digitSegments[num][4]);
  digitalWrite(f, digitSegments[num][5]);
  digitalWrite(g, digitSegments[num][6]);
}

void setup() {
  pinMode(a, OUTPUT);
  pinMode(b, OUTPUT);
  pinMode(c, OUTPUT);
  pinMode(d, OUTPUT);
  pinMode(e, OUTPUT);
  pinMode(f, OUTPUT);
  pinMode(g, OUTPUT);


  pinMode(2, OUTPUT);
  pinMode(3, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(5, OUTPUT);
  pinMode(6, OUTPUT);

  pinMode(echoPin1, INPUT);
  pinMode(echoPin2, INPUT);
  pinMode(LedRed, OUTPUT);
  pinMode(LedGreen, OUTPUT);
  pinMode(speaker, OUTPUT);
  digitalWrite(LedRed, HIGH);
  digitalWrite(LedGreen, HIGH);
  Serial.begin(9600);
  delay(250);
  digitalWrite(LedRed, LOW);
  digitalWrite(LedGreen, LOW);
  Serial.println("starting ...");
}
```

```
void handleButton(int buttonPin, bool &motionFlag, int &value) {
  if (digitalRead(buttonPin) == HIGH && !motionFlag) {
    value += (buttonPin == 1) ? 1 : value == 0 ? 0 : -1;
    motionFlag = true;
    if(buttonPin == 1) Serial.println("VR on");
    else Serial.println("VR Off");
  }

  if (digitalRead(buttonPin) == LOW && motionFlag) {
    motionFlag = false;
  }
}

void loop() {
  int duration, duration2, cm, cm2, count;
  int next_signal = 0;

  // Green light for set1
  digitalWrite(2, HIGH);
  digitalWrite(7, HIGH);
  digitalWrite(4, LOW);
  digitalWrite(6, LOW);

  for(int i = 0; i < (delay_time / 1000) ; i++){
    displayNumber(motion_number);
    delay(1);

    handleButton(1, motion1, motion_number);
    handleButton(0, motion0, motion_number);
    // Trigger ultrasonic sensor 1
    digitalWrite(pingPin_1_2, LOW);
    delayMicroseconds(2);
    digitalWrite(pingPin_1_2, HIGH);
    delayMicroseconds(10);
    digitalWrite(pingPin_1_2, LOW);
    duration = pulseIn(echoPin1, HIGH);
    cm = microsecondsToCentimeters(duration);
    Serial.print("cm 1 = ");
    Serial.println(cm);
```

```
  // Trigger ultrasonic sensor 2
  digitalWrite(pingPin_1_2, LOW);
  delayMicroseconds(2);
  digitalWrite(pingPin_1_2, HIGH);
  delayMicroseconds(10);
  digitalWrite(pingPin_1_2, LOW);
  duration2 = pulseIn(echoPin2, HIGH);
  cm2 = microsecondsToCentimeters(duration2);
  Serial.print("cm 2 = ");
  Serial.println(cm2);

  if (cm < 200 || cm2 < 200) {

   count += 1;
   Serial.print("Count: ");
   Serial.println(count);

   if (count > 1 && motion_number > 2) {

    digitalWrite(LedRed, HIGH);
    digitalWrite(LedGreen, LOW);
    tone(speaker, 1000);
    delay_time = 100000;
    next_signal = 10;

   } else {
    digitalWrite(LedRed, LOW);
    digitalWrite(LedGreen, HIGH);
    noTone(speaker);
   }
  } else {
   count = 0;
   digitalWrite(LedRed, LOW);
   digitalWrite(LedGreen, HIGH);
   noTone(speaker);
  }
 }
 if(next_signal == 0){
  delay_time = 60000;
 }
```

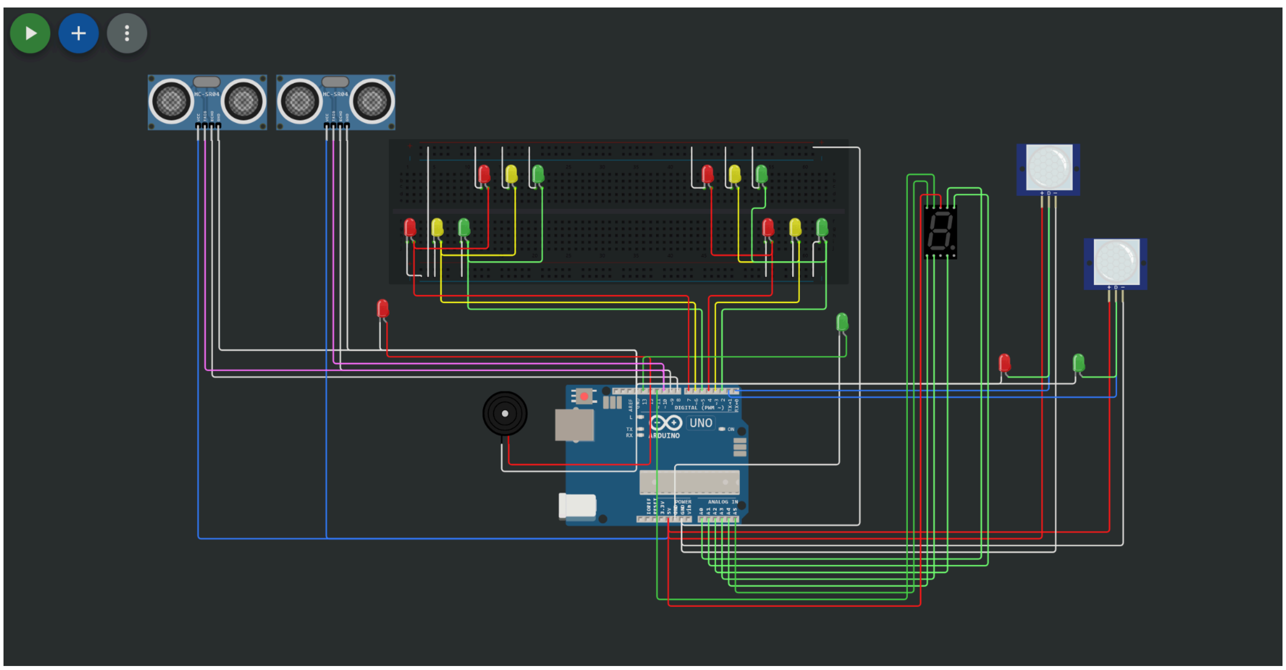
```
else{
    next_signal -= 1;
  }

// Yellow light for set1

  digitalWrite(3, HIGH);
  digitalWrite(7, HIGH);
  digitalWrite(2, LOW);
  delay(1000);

// Red light for set2

  digitalWrite(4, HIGH);
  digitalWrite(5, HIGH);
  digitalWrite(2, LOW);
  digitalWrite(3, LOW);
  digitalWrite(7, LOW);
  delay(delay_time);

// Yellow light for set2

  digitalWrite(6, HIGH);
  digitalWrite(4, HIGH);
  digitalWrite(5, LOW);
  delay(1000);
}

long microsecondsToCentimeters(long microseconds) {
  return microseconds / 29 / 2;
}
```

LINK : https://wokwi.com/projects/399178205622497281

3. Output and Testing concepts

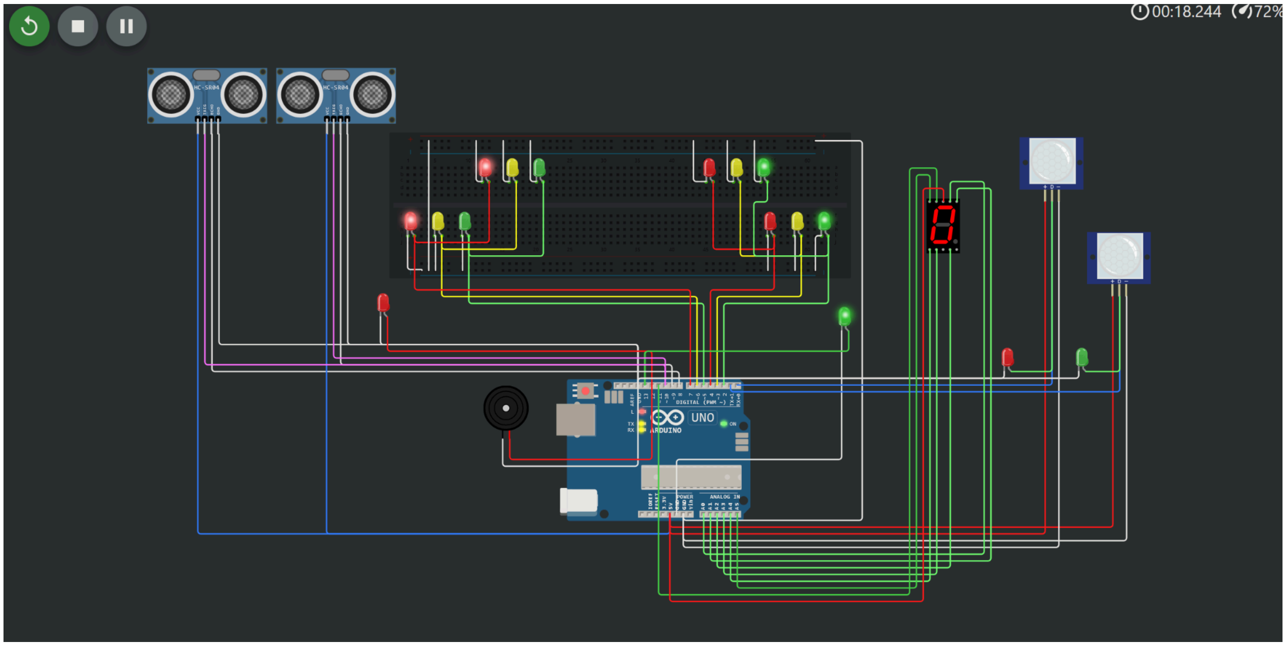
Components Involved

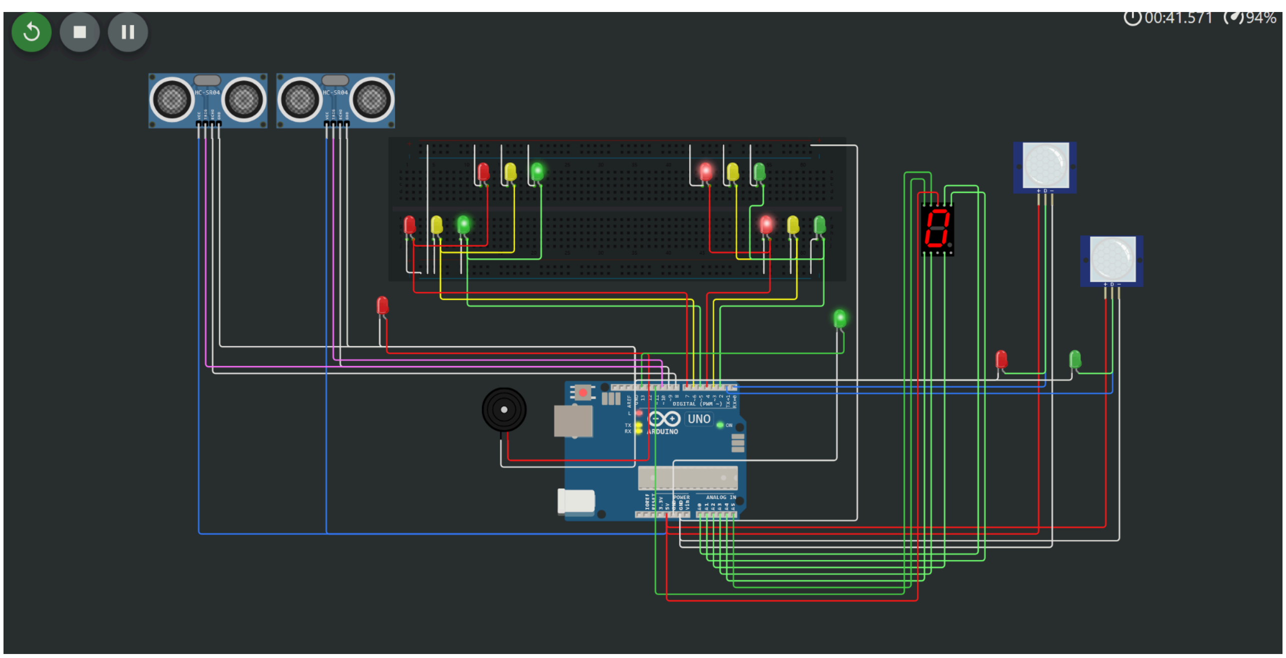
- **Seven-Segment Display**: Shows the current count of detected motions.
- **Ultrasonic Sensors**: Measure the distance of approaching objects and detect motion.
- **IR Sensors :** Count the number of vehicles which are waiting to take a U-turn.
- **LEDs (Red and Green)**: Indicate the status of the traffic light.
- **Speaker/Buzzer**: Emits sound when certain conditions are met.
- **Traffic Lights**: Operate in a sequence of green, yellow, and red.



Traffic Light Simulation

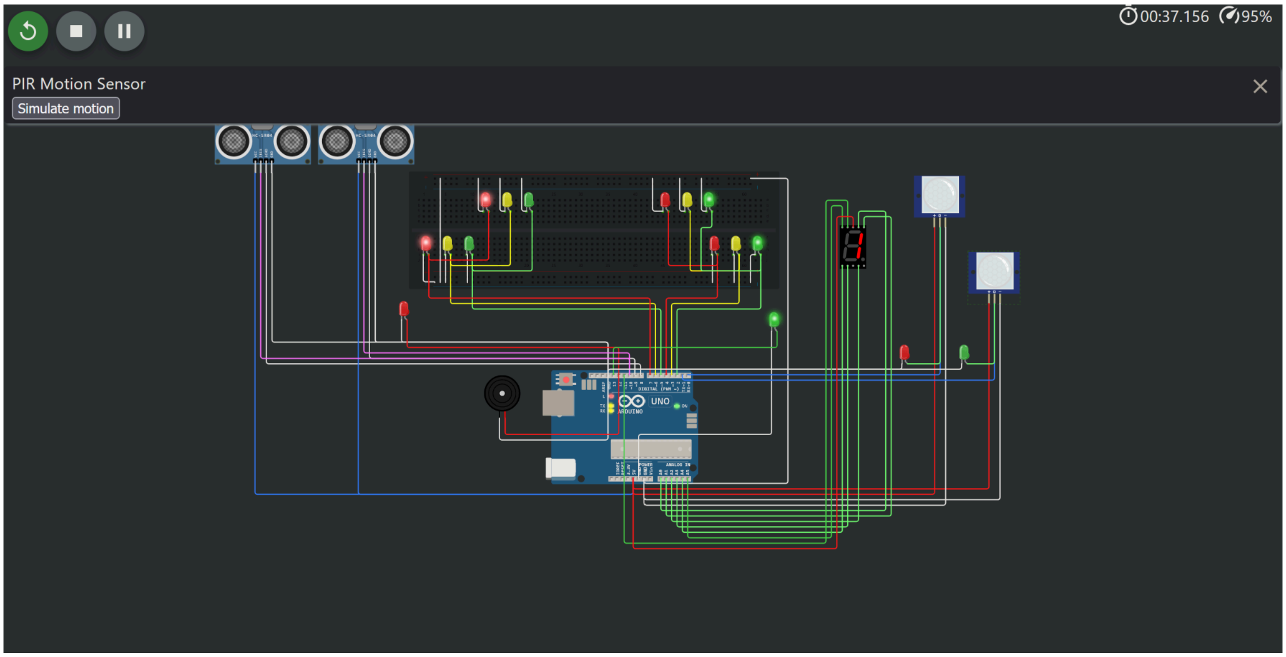
1. A two way traffic light simulation





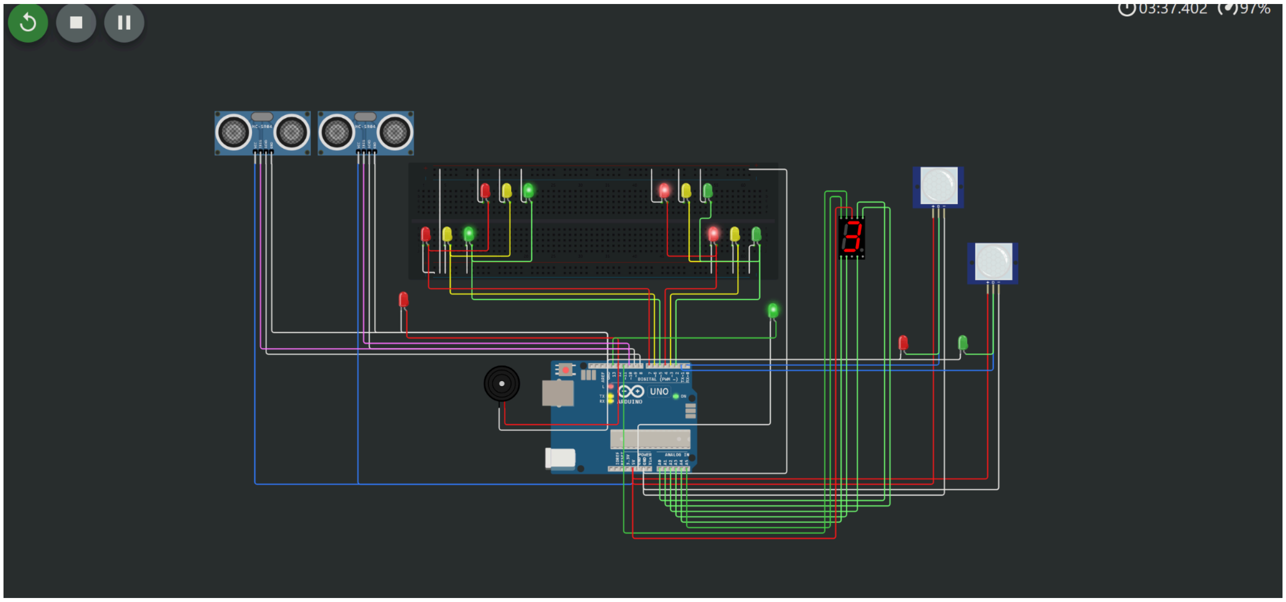
2. **At the Count of One**

- Seven-Segment Display: Displays the number 1.
- LEDs: The green LED is on, indicating that the green light is active.
- Speaker/Buzzer: Remains off as the motion count is low.
- Traffic Light Status: The green light is on, allowing vehicles to pass.



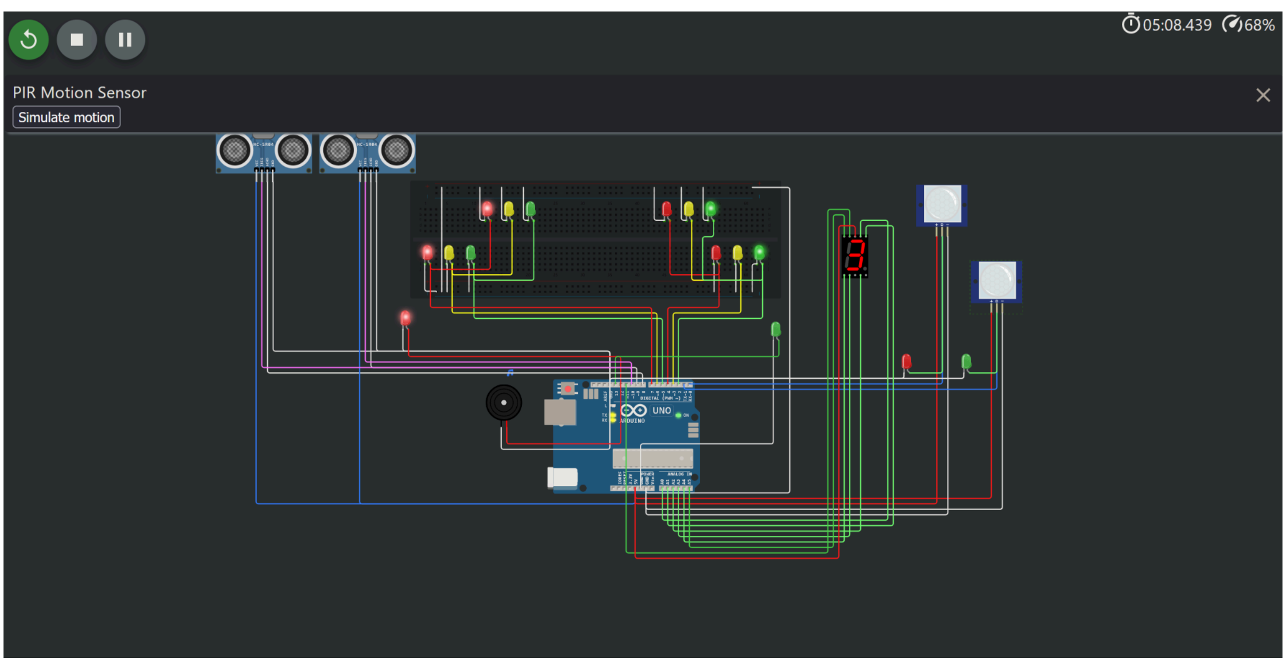
3. **While Green Light is Off at the Count of Three**

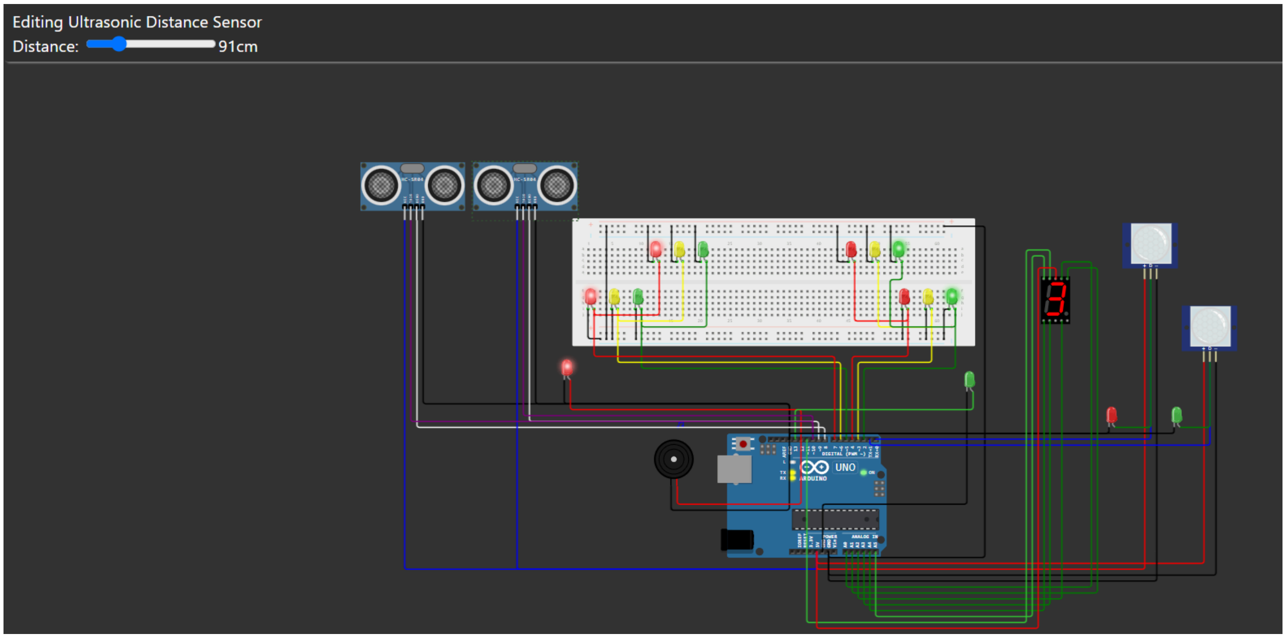
- **Seven-Segment Display**: Displays the number 3.
- **LEDs**: The red LED turns on, indicating that the red light is active.
- **Buzzer**: Turns off, as the green light is no longer active.
- **Traffic Light Status**: The red light is on, stopping vehicles from passing.



4. At the Count of Three While Green Light is On

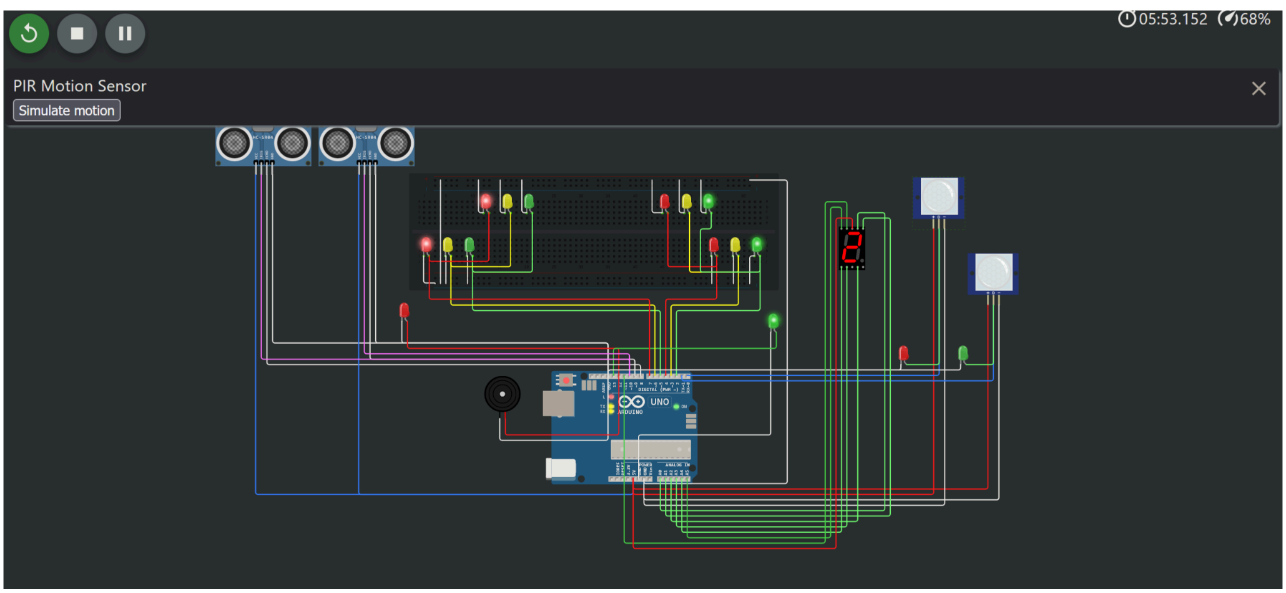
- ➢ **Seven-Segment Display**: Displays the number 3.
- ➢ **LEDs**: The green LED remains on.
- ➢ **Buzzer**: Turns on, emitting a sound to indicate the motion count has reached 3 while the green light is on.
- ➢ **Traffic Light Status**: The green light continues to be on, allowing vehicles to pass.
- ➢ **Vehicle distance**: UR detects the distance which is near and distance remains same for some time.





5. Vehicle Count Decrement

- ➢ **Seven-Segment Display**: Reflects the decremented vehicle count.
- ➢ **LEDs:** Adjust according to the traffic light status.
- ➢ **Buzzer:** Remains off or turns off if the condition for sound is no longer met.
- ➢ **Traffic Light Status:** Changes as per the traffic light sequence, adjusting to green, yellow, or red as needed.



Results:

Our project aimed to develop a traffic light control system that uses ultrasonic sensors and a seven-segment display for traffic management and feedback. The key findings and results are presented below.

Key Findings

1. **Ultrasonic Sensor Accuracy:**
    - Detects vehicle presence and measures distances.
    - IR Sensors: Detects the presence and count of vehicles waiting to take a U-turn, enhancing system reliability and responsiveness.
2. **Traffic Light Management:**
    - The traffic lights operated in a set sequence: green, yellow, and red, with configurable durations.
    - The green light duration was modifiable based on sensor input, with default and extended times.
3. **Display and Feedback:**
    - A seven-segment display showed the current count of detected motions.
    - LEDs provide visual feedback, switching between red and green based on sensor data.
    - The speaker emitted a sound under certain conditions, such as when the motion count exceeded a threshold.

Results Presentation

Traffic Light Sequences

The system followed a predefined traffic light sequence with adjustable durations:

Light Colour	**Duration**
Green	60 seconds
Yellow	1 second
Red	Variable(depends on condition)

Sensor Readings and System Response

The following table outlines how the system responded to sensor readings:

Distance (cm)	**vehicle count (IR)**	**LED Status (Red/Green)**	**Speaker (On/Off)**
< 200	>2	Red	On
> = 200	<=2	Green	Off

Motion Detection and Display

The seven-segment display showed the number of detected motions. The response to the motion count is summarized:

Motion Count	LED Status (Red/Green)	Speaker(On/Off)	Delay Time(seconds)
> 2	Red	On	100
< = 2	Green	Off	60

Challenges and Resolutions:

1. Sensor Accuracy Optimization:

- ➢ Challenge: Ensuring consistent and accurate readings from ultrasonic sensors and IR sensors across various environmental conditions.
- ➢ Resolution: Fine-tuning sensor parameters, such as sensitivity and sampling rates, and implementing error-handling mechanisms to filter out noise and erroneous readings.

2. System Responsiveness Enhancement:

- ➢ Challenge: Balancing system responsiveness while maintaining a smooth user interface and real-time performance.
- ➢ Resolution: Optimizing code structure and sensor reading algorithms to minimize processing delays and improve overall system responsiveness.

3. User Interaction Complexity:

- ➢ Challenge: Integrating user interaction through button inputs, necessitating reliable functionality and intuitive operation.
- ➢ Resolution: Implementing robust button handling routines and user interface designs, coupled with iterative testing and refinement to ensure seamless user interaction.

4. Resource Management:

- ➢ Challenge: Efficiently managing hardware resources such as pins and memory to accommodate the system's requirements.
- ➢ Resolution: Employing resource-efficient coding practices, such as pin multiplexing and memory optimization techniques, to maximize hardware utilization without compromising performance.

5. Debugging and Testing Iterations:

- ➢ Challenge: Identifying and resolving bugs and issues through rigorous testing and debugging iterations.
- ➢ Resolution: Utilizing comprehensive testing methodologies, including unit testing and simulation, to systematically identify and address software bugs and system inconsistencies.

Conclusion:

In this project, we embarked on a journey to create a Smart Traffic Diversion System aimed at alleviating urban traffic congestion and enhancing road safety. Leveraging Arduino microcontrollers, ultrasonic sensors and IR sensors, our system dynamically manages 2 way traffic flow by intelligently adjusting traffic signals in real-time.

Throughout the development process, we encountered various challenges and complexities. From calibrating sensor readings to fine-tuning signal control algorithms, each hurdle presented an opportunity for learning and innovation. Through perseverance and iterative refinement, we overcome these obstacles, resulting in a robust and effective traffic management solution.

The culmination of our efforts yielded promising outcomes. By deploying our Smart Traffic Diversion System, we observed significant improvements in traffic flow efficiency and congestion reduction. Real-time data analysis enabled the system to adapt swiftly to changing traffic conditions, ensuring optimal signal control and smooth vehicle movement.

Beyond its technical achievements, our project carries broader implications for urban infrastructure and transportation management. The successful implementation of IoT-based solutions demonstrates the potential for technology to reshape city landscapes and address pressing societal challenges. By harnessing the power of data and automation, our system paves the way for smarter, safer, and more sustainable urban environments.

Looking ahead, the impact of our project extends far beyond the confines of this endeavor. As cities continue to grapple with the complexities of urbanization, our Smart Traffic Diversion System serves as a beacon of innovation, offering a scalable and adaptable solution for modern transportation challenges. Through collaboration, innovation, and a commitment to progress, we are shaping the future of urban mobility, one intersection at a time.

References:

1. Wokwi Simulator, Available at: www.wokwi.com/simulator,
2. Arduino Official Website, Available at: www.arduino.cc,
3. UltraSonic Sensor: https://www.arduino.cc/reference/en/libraries/hcsr04-ultrasonic-sensor/
4. IR Sensor: https://www.arduino.cc/reference/en/libraries/infrared/
5. Course Link: https://www.projectcademy.com/courses/iot-projects/intelligent-traffic-management-system/