Department of Computer Science and Engineering

BRAC University

Course Title: Internet of Things

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Mehrab Mohsin Khan

19101378

Abstract

The Internet of Things (IoT) represents an emerging area of research, and its body of knowledge is still developing. A key feature of IoT is its ability to create smart environments that respond quickly to support human decisions and operations. IoT-based systems are being proposed for various applications. This project focuses on designing a dynamic traffic signal system that automatically adjusts signal timings based on traffic density at intersections. Traffic congestion is a major issue in cities worldwide, and it is essential to move from manual or fixed timer systems to automated systems with decision-making capabilities. The increase in the number of cars is not the sole reason for traffic problems; poor planning to manage the vehicle load also contributes significantly. For instance, it is common for vehicles to wait at a red light even when no other cars are present, exacerbating traffic jams and often requiring manual intervention by police. Modern societies can benefit from traffic management systems to reduce congestion and its negative impacts. These systems comprise a set of applications and management tools to enhance overall traffic efficiency and safety. The Smart Traffic Light Control System operates dynamically, adjusting the timing of lights based on vehicle concentration in specific areas. It intelligently modifies the delay between light changes as needed to address arising issues.

Introduction

In cities, the number of vehicles is growing faster than the traffic infrastructure can support, making congestion a significant issue, especially during car accidents. This congestion reduces individual productivity and, consequently, societal efficiency, as many work hours are lost at traffic signals. The primary causes of these chaotic traffic jams are the high volume of vehicles, inadequate infrastructure, and poor distribution of signaling systems. This problem impacts many aspects of modern society. Traditional traffic management systems use inefficient traffic lights with predefined timers and manual control by police officers. Without considering real-time traffic data, these systems often grant green lights to empty lanes while other lanes with heavy traffic wait at red lights, as the same green light intervals are applied to all lanes. The Smart Traffic Light Control System operates dynamically based on the vehicle concentration in a specific area. This system benefits from local workstations with regional processing units that receive data from each vehicle within a certain radius. Each IR sensor functions as an eye, transmitting traffic data, while the communication between IR sensors and traffic signals is established through an Arduino connection, with IR sensors acting as both mouth and ear for sending and receiving information. This persistent collection and transmission of traffic data is nearly impossible with manual communication. Additionally, this inefficiency contributes to increased pollution, as engines often remain on, consuming significant amounts of petrol and diesel without any productive outcome. To mitigate these issues or reduce them significantly, it is necessary to implement new schemes that incorporate sensor-based automation techniques in traffic signaling systems.

Hardware and Software Requirements

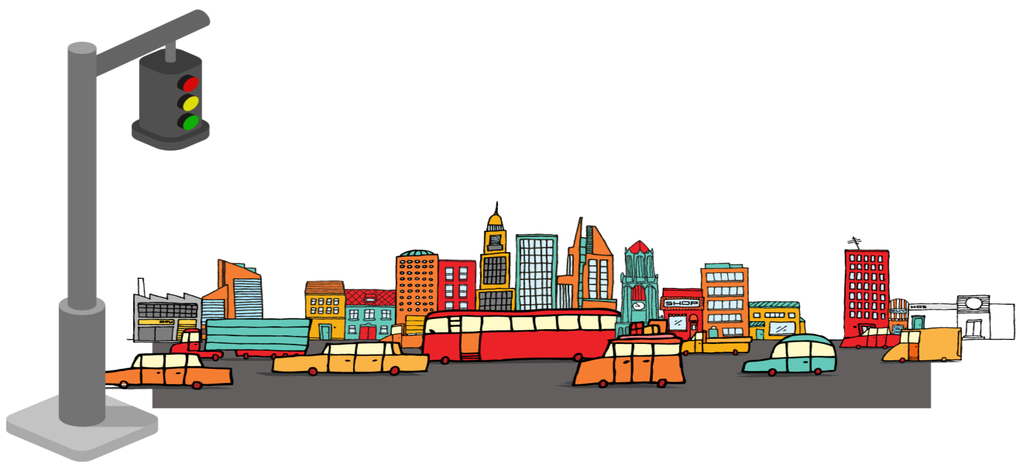
The design and implementation of a Density-Based Traffic Signal Control System necessitate a blend of hardware and software components, each playing a vital role in ensuring the system operates efficiently and adapts to real-time traffic conditions.

Hardware Components:

- **Arduino UNO (or compatible board):** Acts as the central microcontroller, processing data from sensors and controlling the traffic lights.
- **IR Sensor Module:** Detects the presence and density of vehicles in each lane approaching the intersection.
- **LEDs (for traffic signals):** Serve as the traffic signals for each lane.
- **Breadboard and Jumper Wires:** Facilitate the connection of all electronic components.
- **Power Supply for Arduino:** Provides the necessary electrical power to the Arduino and other components.

Software Components:

- **Arduino IDE:** Utilized for programming the Arduino board.
- **C/C++ Code:** Interfaces with the sensors, processes data, and controls the LEDs based on traffic conditions.
- **Traffic Signal Control Algorithm:** Core logic that determines the traffic light timings based on vehicle density data from the IR sensors.



Objectives of the Project

The goal of our traffic signal monitoring system project is to design and implement a Density-Based Traffic Signal Control System using Arduino and IR Sensors to efficiently manage traffic flow based on vehicle density. This system aims to achieve several key objectives:

- **Enhance Traffic Flow:** By optimizing traffic signal timings, the system reduces congestion and improves traffic flow at intersections. This minimizes waiting times for vehicles, resulting in a smoother and more efficient traffic management system.
- **Improve Road Safety:** The system provides real-time traffic updates and adaptive signal control to reduce the likelihood of accidents.
- **Real-Time Data Collection:** Utilizing IR sensors and other devices, the system collects real-time traffic data to monitor vehicle density and traffic patterns. This ensures accurate and timely data collection for analysis and decision-making.
- **Reduce Environmental Impact:** By decreasing vehicle idling time at intersections, the system reduces fuel consumption and emissions, promoting environmentally friendly traffic management practices through efficient signal control.
- **Scalable and Cost-Effective Solution:** The system employs cost-effective hardware, such as IR sensors, Arduino, and traffic signal LEDs, to create an affordable solution for traffic monitoring.

Design

The design of the Density-Based Traffic Signal Control System combines multiple components to create an intelligent traffic management solution. By utilizing Arduino, infrared (IR) sensors, and LEDs, the system dynamically adjusts traffic signal timings based on real-time vehicle density. This adaptive approach aims to improve traffic efficiency, reduce waiting times, and enhance overall road safety.

System Architecture

The system architecture involves installing IR sensors at each lane approaching the intersection. These sensors continuously monitor the lanes, detecting the presence and number of vehicles. The data collected by the IR sensors is sent to the Arduino, which processes this information using a pre-programmed algorithm.

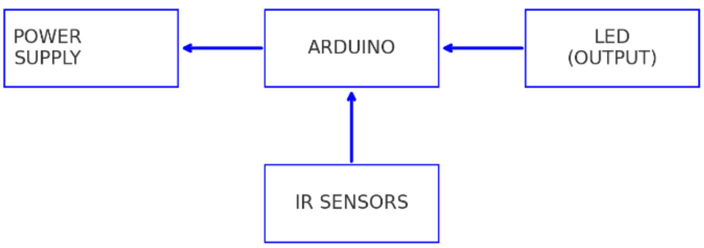
- **Sensor Data Collection:** IR sensors detect the presence of vehicles at the intersection and send signals to the Arduino board.
- **Data Processing:** The Arduino board processes the sensor data to determine the traffic density at the intersection.
- **Traffic Signal Control:** Based on the traffic density, the Arduino board controls the traffic signal LEDs to manage the flow of traffic.

System Operation

- **Placement of IR Sensors:** IR sensors are positioned at specific points on each lane approaching the intersection. These sensors detect the presence and count of vehicles.
- **Data Collection:** The IR sensors continuously monitor the lanes and send data about vehicle density to the Arduino.
- **Signal Control Logic:** The Arduino processes the input from the IR sensors using a programmed algorithm to determine the vehicle density on each lane. Based on the density, the Arduino decides the duration for which each traffic light (Red, Yellow, and Green) should be on for each lane. The logic prioritizes lanes with higher vehicle density, ensuring that lanes with more vehicles get a green signal for a longer duration.
- **Traffic Light Control:** The Arduino controls the LEDs connected to each lane. The LEDs represent the traffic signals, turning Red, Yellow, or Green based on the Arduino's decisions. When a vehicle is detected by the IR sensor, the Arduino board updates the traffic signal status accordingly. The system can be programmed to adjust signal timings dynamically based on real-time traffic conditions.

System Flowchart

- **Initialize System:** Start the Arduino and initialize the IR sensors and LEDs.
- **Read Sensor Data:** Continuously monitor and collect data from the IR sensors to determine the vehicle density in each lane.
- **Process Data:** Analyze the vehicle density data for each lane.
- **Determine Signal Timings:** Calculate the optimal green light duration for each lane based on the density data.
- **Control Traffic Lights:** Activate the green light for the lane with the highest density. After the green light duration, switch to the yellow light for a brief period, then turn on the red light and proceed to the next lane based on the density.
- **Repeat:** Continuously repeat this process to ensure effective real-time traffic management.



Documentation

Working of the Circuit

The model operates by changing traffic signals based on the detected density in a specific road section. Four sensors are placed at each corner of a four-way intersection to monitor the density of the area they cover. In this intelligent traffic control system, IR sensors are used to measure traffic density on each side. These IR sensors, consisting of an IR transmitter and receiver, are positioned on either side of the road at specific intervals. The IR transmitter sends out IR rays, and the receiver captures these rays. The entire system is controlled by a microcontroller, the Arduino, which interfaces with a Serial to Parallel IC (74HC595) and the IR sensors. As vehicles pass through these IR sensors, the sensors detect their presence and send this information to the Arduino.

A total of four IR sensors and twelve LEDs are required. The LEDs, in three sets of Green, Yellow, and Red, indicate the GO, Ready to Go, and WAIT states, respectively. The traffic signal is set with a default timing of 5 seconds for the green light, with all other signals being red. After 5 seconds, two signals turn yellow for 5 seconds, while the other two remain red. This sequence continues until all IR sensors are either receiving signals or none are detecting any vehicles. The LEDs (Green, Yellow, and Red) light up in the following sequence.

Arduino IDE Source Code

The Arduino code is designed to continuously monitor the IR sensors and adjust the traffic signals according to the detected vehicle density.

```
#define LEFT_IR 13

#define DOWN_IR 12

#define RIGHT_IR 11

#define UP_IR 10

#define LEFT_RED 9

#define LEFT_YELLOW 8

#define LEFT_GREEN 7

#define DOWN_RED 6

#define DOWN_YELLOW 5

#define DOWN_GREEN 4

#define RIGHT_RED 3

#define RIGHT_YELLOW 2

#define RIGHT_GREEN 1

#define UP_RED A1
```

```
#define UP_YELLOW A2
#define UP_GREEN A3

void setup() {
  pinMode(LEFT_IR, INPUT);
  pinMode(DOWN_IR, INPUT);
  pinMode(RIGHT_IR, INPUT);
  pinMode(UP_IR, INPUT);

  pinMode(LEFT_RED, OUTPUT);
  pinMode(LEFT_YELLOW, OUTPUT);
  pinMode(LEFT_GREEN, OUTPUT);
  pinMode(DOWN_RED, OUTPUT);
  pinMode(DOWN_YELLOW, OUTPUT);
  pinMode(DOWN_GREEN, OUTPUT);
  pinMode(RIGHT_RED, OUTPUT);
  pinMode(RIGHT_YELLOW, OUTPUT);
  pinMode(RIGHT_GREEN, OUTPUT);
  pinMode(UP_RED, OUTPUT);
  pinMode(UP_YELLOW, OUTPUT);
  pinMode(UP_GREEN, OUTPUT);

  Serial.begin(9600);
}

void loop() {
```

```
  allRedsHigh();
  defaultTraffic();
}

void allRedsHigh() {
  digitalWrite(LEFT_RED, HIGH);
  digitalWrite(RIGHT_RED, HIGH);
  digitalWrite(UP_RED, HIGH);
  digitalWrite(DOWN_RED, HIGH);
}

void defaultTraffic() {
  if (digitalRead(LEFT_IR)) {
    Serial.println("Left IR read");
    setLaneLights(LEFT_RED, LEFT_YELLOW, LEFT_GREEN, 3000, 5000);
  } else {
    Serial.println("Left IR read");
    setLaneLights(LEFT_RED, LEFT_YELLOW, LEFT_GREEN, 2000, 10000);
  }

  if (digitalRead(DOWN_IR)) {
    setLaneLights(DOWN_RED, DOWN_YELLOW, DOWN_GREEN, 3000, 5000);
  } else {
    setLaneLights(DOWN_RED, DOWN_YELLOW, DOWN_GREEN, 2000, 10000);
  }
```

```
  if (digitalRead(RIGHT_IR)) {
    setLaneLights(RIGHT_RED, RIGHT_YELLOW, RIGHT_GREEN, 3000, 5000);
  } else {
    setLaneLights(RIGHT_RED, RIGHT_YELLOW, RIGHT_GREEN, 2000, 10000);
  }

  if (digitalRead(UP_IR)) {
    setLaneLights(UP_RED, UP_YELLOW, UP_GREEN, 3000, 5000);
  } else {
    setLaneLights(UP_RED, UP_YELLOW, UP_GREEN, 2000, 10000);
  }
}

void setLaneLights(int red, int yellow, int green, int secondTimer, int thirdTimer) {
  digitalWrite(red, LOW);
  digitalWrite(yellow, HIGH);
  delay(secondTimer);
  digitalWrite(yellow, LOW);
  digitalWrite(green, HIGH);
  delay(thirdTimer);
  digitalWrite(green, LOW);
  digitalWrite(red, HIGH);
}
```

Conclusion

The Density-Based Traffic Signal Control System marks a significant advancement in urban traffic management by leveraging modern technology to address the ever-changing nature of traffic conditions. Using an Arduino microcontroller and infrared (IR) sensors, this system effectively monitors vehicle density in real-time and adjusts traffic signal timings to optimize traffic flow, reduce waiting times, and enhance road safety.

The project's hardware components, including the Arduino UNO, IR sensors, LEDs, and power supply, work seamlessly with the software components, such as the control algorithms and sensor processing code, to create an intelligent and responsive traffic management solution. This integration ensures that traffic signals adapt dynamically to real-time traffic conditions, prioritizing lanes with higher vehicle density and minimizing congestion.

There is a pressing need for efficient traffic management systems, especially in countries like Bangladesh, which experiences 384 road accidents daily. To reduce congestion and unwanted delays, this project introduces an advanced system. The prototype implementation in the laboratory yielded remarkable results, demonstrating good accuracy in vehicle detection and low relative error in road occupancy estimation. The successful implementation of this system offers numerous benefits, including reduced fuel consumption and emissions due to decreased idle times, improved traffic efficiency, and enhanced safety for all road users. Furthermore, the project highlights the potential of smart traffic control systems to contribute to environmental sustainability and better urban living conditions.

The proposed model can significantly save citizens' time, particularly during peak hours, and help avoid traffic congestion caused by accidents or other incidents. Overall, the Density-Based Traffic Signal Control System represents a promising step towards smarter and more efficient urban traffic management, paving the way for future innovations and improvements in the field.

Future Work

The Density-Based Traffic Signal Control System has demonstrated significant potential in improving urban traffic management. However, there are several areas where future enhancements can be made to further optimize the system and extend its capabilities.

- **Integration with IoT:** Connecting the traffic signal system to the Internet of Things (IoT) can enable remote monitoring and management of traffic signals. This would allow for real-time updates and control, making traffic management more efficient and responsive to changing conditions or emergencies.
- **Solar Power Integration:** Incorporating solar panels to power the system can reduce reliance on conventional power sources. This would promote sustainability by utilizing renewable energy and potentially lower operational costs.
- **Emergency Vehicle Priority System:** Implementing a priority system for emergency vehicles, such as ambulances and fire trucks, can improve response times during emergencies. This system would allow emergency vehicles to communicate with traffic signals, ensuring they receive green lights as they approach intersections.

- **Advanced Data Analytics:** Utilizing advanced data analytics can provide deeper insights into traffic patterns and behaviors. This data can be used to refine traffic algorithms and improve the overall efficiency of the traffic signal system.
- **Machine Learning Algorithms:** Implementing machine learning algorithms can enhance the system's ability to predict traffic conditions and adapt signal timings more accurately. These algorithms can learn from historical data and continuously improve their decision-making processes.
- **V2X Communication:** Vehicle-to-Everything (V2X) communication can be integrated to allow vehicles to communicate directly with traffic signals. This would enable more precise traffic management and enhance the system's ability to respond to real-time traffic conditions.
- **Scalability and Deployment:** Expanding the system to cover larger urban areas and testing it in different environments can validate its scalability and effectiveness. Deploying the system in various cities can provide valuable feedback and insights for further improvements.
- **Enhanced User Interface:** Developing a user-friendly interface for traffic management authorities can simplify the process of monitoring and controlling traffic signals. This interface could include real-time traffic data visualization, alert notifications, and manual override capabilities.
- **Environmental Impact Assessment:** Conducting comprehensive environmental impact assessments can quantify the system's benefits in terms of reduced emissions and fuel consumption. These assessments can help in promoting the system as an environmentally friendly solution.
- **Public Awareness and Education:** Educating the public about the benefits and functionalities of the smart traffic signal system can encourage acceptance and cooperation. Public awareness campaigns can highlight the system's role in improving traffic flow and safety.

By addressing these areas, the Density-Based Traffic Signal Control System can be further refined and enhanced, leading to even greater improvements in urban traffic management. The continued development and deployment of this system hold the promise of making cities smarter, safer, and more efficient.