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Traffic Monitoring System

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Abstract: - ***Traffic congestion remains a major challenge, particularly in developing countries. In response, numerous models and approaches have been proposed by researchers to create smarter, more reliable, and robust traffic systems. This paper reviews and compares various global initiatives aimed at enhancing traffic management. A comparative study of several key research efforts is presented, highlighting Intelligent Traffic Systems (ITS) as a crucial application area. The essential features of each study are summarized and evaluated, with a focus on their feasibility in developing countries such as India. Additionally, a new model is proposed, utilizing infrared proximity sensors, a centrally placed microcontroller, and vehicle length measurement to implement an intelligent traffic monitoring system.***

Keywords: Infrared proximity sensors, RF module, Bluetooth module, Intelligent Traffic System (ITS)

1. INTRODUCTION

Traffic congestion is a daily-life problem in almost every metropolitan city. With the rising standard of living, the number of vehicles is increasing at an exponential rate. In response to this, extensive research has been conducted toward developing Intelligent Traffic Systems (ITS)—traffic systems that closely interact with various components, including vehicles, drivers, and pedestrians. ITS not only enhances safety at intersections and prevents congestion but also manages the overall traffic flow more effectively.

Developed countries such as the United States, Japan, and the United Kingdom have already implemented ITS solutions on their roads, and ongoing research continues to refine and adapt these systems for use in developing countries as well. Beyond surveying various ITS research efforts, this paper proposes a model that employs a simple algorithm based on the length of traffic queues in each lane. The time allocated to each lane is dynamically adjusted according to the queue lengths detected on other lanes. Infrared proximity sensors, rather than Wide Area Networks (WANs), are utilized to measure traffic density.

The proposed model aims to proportionately reduce congestion across all lanes without relying on WANs, while also managing the priority passage of emergency vehicles such as ambulances and fire brigades. Furthermore, the system includes mechanisms to track vehicle routes. Once implemented, the system operates autonomously without the need for human assistance.

2. CLASSIFICATION OF ITS

Intelligent Traffic Systems (ITS) have been researched and implemented using various approaches, including wireless sensor networks (WSNs), Radio Frequency Identification (RFID), and graph theory applications for finding optimized paths. Broadly, ITS can be classified into two major domains:

- **I. Real-Time Systems**
- **II. Data Analysis Systems**

Real-Time Systems are further subdivided into:

- I.1 Path Optimization
- I.2 Traffic Density Analysis

Similarly, Data Analysis Systems are divided into:

- II.1 Green Light Optimization
- II.2 Information Chaining Systems

2.1 Real-Time Systems

Real-Time Systems acquire data from the current traffic situation through video surveillance or WSNs and respond immediately. Traffic signals are dynamically controlled based on vehicle presence, enabling automatic, real-time operation.

Dotolie et al. [1] developed a real-time optimization model that addressed urban traffic control, including pedestrian considerations, and validated it with real case studies. Wenjie et al. [2] focused on dynamically calculating the time required for a vehicle to reach an intersection, adjusting the green light duration accordingly.

Albers et al. [3] monitored real-time traffic flow at intersections to better manage traffic, emphasizing the role of short-term forecasting using CCTV cameras. Van Daniker [4] introduced the Transportation Incident Management Explorer (TIME) for real-time data collection.

Challal et al. [5] proposed a distributed vehicular sensor network combined with WSNs to monitor and manage traffic, although not in real-time. Chandak et al. [6] utilized video surveillance to reduce emergency vehicle response times by enabling communication between emergency vehicles and traffic lights.

Real-time data can be used to both estimate traffic density and optimize paths, which are discussed in the following sections.

2.1.1 Traffic Density

Measuring traffic density at intersections helps reduce congestion. This data can be used to adjust signal timings and manage vehicle flows.

Zhou et al. [7] proposed an adaptive traffic light control algorithm that adjusts both the sequence and duration of traffic lights based on real-time data such as waiting time and traffic volume. Sinhmar [8] implemented a system using IR sensors to gauge traffic density and update signal timings accordingly.

Hussain et al. [9] designed a centralized microcontroller-based system that uses data from road-embedded wireless sensors to manage traffic efficiently. Srivastava et al. [10] suggested the use of weight sensors to count vehicles, utilizing Programmable Logic Controllers (PLCs) to analyze data for automated parking and traffic management.

2.1.2 Path Optimization Techniques

Path optimization aims to guide vehicles along the shortest and least congested routes, minimizing overall traffic.

Gambardella [11] and Bertelle et al. [12] proposed using ant colony optimization techniques for finding efficient transportation paths. Ozkurt et al. [13] combined video surveillance and neural networks to alleviate traffic stress.

Xia [14] analyzed optimal road networks by studying car movements and statistical traffic properties. Kale et al. [15] developed a system that provides incoming ambulances with optimal routes based on real-time traffic information, evaluated by criteria such as average waiting time, travel distance, and green light switching frequency.

2.2 Data Analysis Systems

Data Analysis Systems collect real-time or statistical traffic data but do not make decisions dynamically; instead, they operate based on predefined algorithms.

Yousef et al. [16] proposed a method for reducing congestion based on minimizing average waiting time and queue length, improving global traffic flow across multiple intersections.

2.2.1 Information Chaining System

Information Chaining involves communicating traffic conditions from one junction to others or directly to vehicles, helping users reroute as necessary.

Malik et al. [17] described a real-time traffic light control system using wireless sensors to monitor vehicle counts and waiting times, sending data to nearby control centers. Blessy et al. [18] introduced a GSM-based system that transmits congestion information from one junction to adjacent ones and to drivers, forming an interconnected communication network.

2.2.2 Green Light Optimization

Optimizing traffic signal timings, especially green light durations, is critical for reducing congestion.

Chen et al. [19] addressed traffic light optimization using graph models and algorithms like Particle Swarm Optimization [25, 26], Ant Colony Optimization [27], and Genetic Algorithms. Soh et al. [28] presented a MATLAB simulation for a fuzzy traffic controller that dynamically adjusts light timings based on real-time flow conditions.

Jantan et al. [29] proposed an image-based monitoring system using associative memory to detect various traffic scenarios under different weather conditions. Placzek [30] designed a hybrid fuzzy cellular traffic model for adaptive traffic control simulations. Dakhole et al. [31] developed an ARM7- and ATmega16-based system to manage multiple traffic lights and reduce jams.

Jaiswal et al. [32] discussed optimizing traffic signals to prioritize ambulances and VIP vehicles, alongside managing lane-wise traffic density, ensuring smooth and congestion-free movement.

Table 1: Summarization of Classification of ITS

Name	Summarization	Remarks
Intelligent Traffic System	**Real-Time System**	
Traffic Density	Detecting vehicle density and dynamically adjusting signals	On-the-spot detection; requires significant financial investment
Path Optimization	Guiding vehicles based on real-time traffic data	Effective but limited by availability of alternative routes
Data Analysis System		
Information Chaining System	Sharing traffic conditions across junctions and vehicles	Useful for routing but requires highly reliable systems
Green Light Optimization	Adjusting signal timings using fuzzy logic and algorithms	Highly efficient but capital-intensive

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3. PROPOSED METHOD

The proposed model primarily addresses the following issues in existing traffic management systems:

- (i) **Unnecessary consumption of green light time** in lanes with fewer vehicles.
- (ii) **Delay of emergency vehicles** (e.g., ambulances), which must wait their turn despite urgency.
- (iii) **Uniform wait time** across lanes irrespective of traffic density.
-

In conventional systems, the green signal duration is fixed for all directions, leading to congestion when one lane has a higher vehicle count than others. The proposed method dynamically adjusts the traffic light based on real-time traffic density and emergency situations.

3.1 Hardware Implementation of the Method

The system uses **infrared proximity sensors**, an **ATMega 2560 microcontroller**, and **RF modules**.

- **Sensor Setup:**

  Each road approaching the intersection is equipped with **four infrared sensors** placed at strategic intervals, creating two zones:

  - **High-Density Zone**
  - **Low-Density Zone**

Each zone is monitored by two sensors positioned on opposite sides of the road. Proper placement ensures sensor ranges do not overlap, preventing erroneous data readings. This dual-side sensing captures a complete picture of traffic distribution across the road width.

- **Microcontroller Connections:**
  - Sensors are connected to the **analog pins** of the microcontroller.
  - Traffic lights are connected to the **digital pins**.

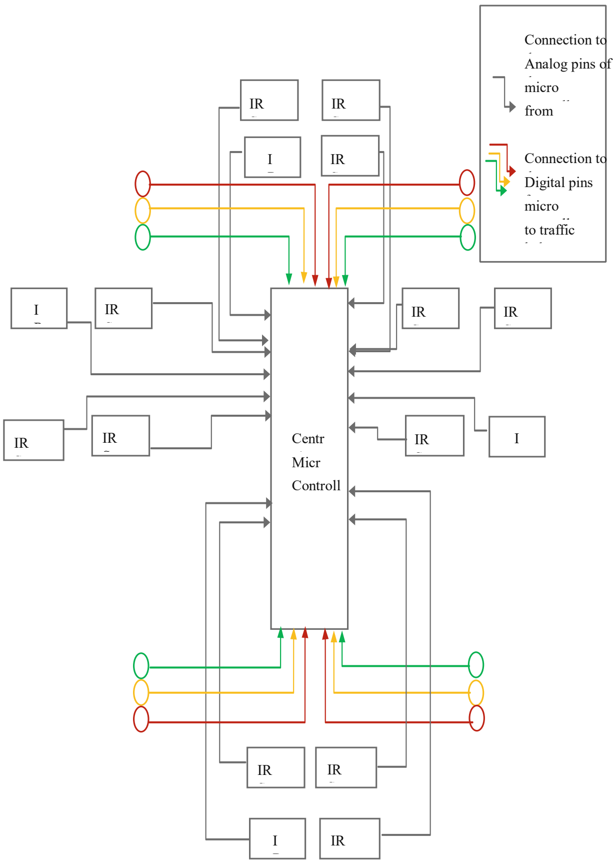

Figure 1: *Schematic Circuit Diagram of the Proposed Model.*

3.2 Prioritizing the Lanes

The system classifies lane density into **multiple priority levels** based on sensor input:

Condition	**Traffic Status**	**Priority**
All four sensors LOW	No traffic	0
One low-zone sensor HIGH, others LOW	Very light traffic	1
One side full (both zones)	Moderate traffic	2
Low-zone sensors HIGH, high-zone LOW	High traffic in low zone only	3
Low-zone HIGH, one high-zone HIGH	High traffic in low zone, moderate in high	4
All sensors HIGH	Heavy traffic in both zones	5

These priority assignments ensure that lanes with heavier traffic or emergency needs are prioritized

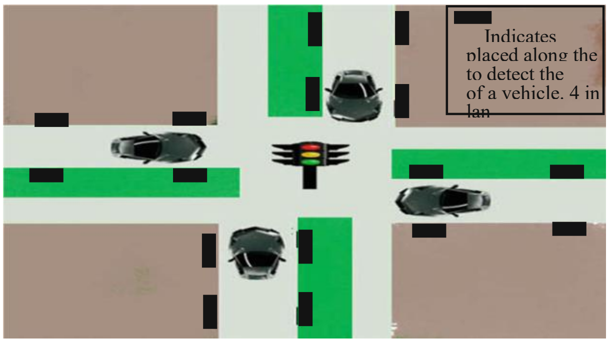

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Figure 2: *Conceptual View of the Proposed Traffic Model.*

3.3 Algorithm for the Control of Traffic Lights

The proposed **Control Algorithm** uses a **priority-based stack (P_STACK)** to manage lane execution.

Key Definitions:

- **P_STACK[4]**: Stack storing lane indices based on priority.
- **Ti**: Green light time assigned to the lane.
- **Pi, Pi-1**: Priorities of the current and next lanes in the stack.

Main Control Algorithm:

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Control_Algo:
 while (true):
   Sense_and_Push()
   while (P_STACK is not empty):
     Sense_and_Set(P_STACK)
     Execute(P_STACK, Ti)

Sense_and_Push():
 Sense each lane's density.
 Push lanes into P_STACK based on priority (highest at top).

Sense_and_Set(P_STACK):
 if (emergency vehicle detected):
   Move respective lane to the top.
   Set corresponding Ti.
 else:
   Read priorities Pi and Pi-1.
   Set Ti based on Pi.
   if (Pi < Pi-1):
     Update Ti to accommodate newly increased traffic.

Execute(P_STACK, Ti):
 Set green light ON for top lane in P_STACK for Ti seconds.
 Set yellow light ON for next lane indicating preparation.
 Red light remains ON for other two lanes.
 Pop the executed lane from P_STACK.
```

This dynamic system ensures optimal usage of time slices and prioritizes emergency vehicles efficiently.

4. CONCLUSION

This project reviews the existing methods and proposes an intelligent, priority-based traffic management system aimed at smoother traffic flow and better emergency handling, particularly beneficial for developing countries. The two major objectives achieved are: Real-time calculation of vehicle density for smooth traffic movement. Priority-based signalling to allow faster movement of emergency vehicles. Although sensor installation and wiring are labour-intensive, the system promises a smarter, more efficient urban traffic solution once deployed. The programmability of the microcontroller also leaves room for future algorithmic upgrades and refinements.

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