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Smart Movable Road Divider for Dynamic Traffic Management and Emergency Clearance

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Abstract - *The rapid urbanization and increasing traffic congestion in cities necessitate innovative solutions for efficient traffic management. This paper presents a Smart Movable Road Divider that dynamically adjusts traffic lanes based on vehicle density and emergency vehicle presence. The system employs RFID technology to detect approaching ambulances and a YOLO-based camera system to monitor traffic density. A miniature setup is demonstrated using Arduino Uno, toy cars, and a movable divider mechanism. The proposed solution aims to enhance road safety and optimize traffic flow*

***Key Words*: Traffic management, Movable Road divider, RFID, YOLO algorithm, Emergency vehicle clearance, Arduino Uno.**

1.INTRODUCTION

Urbanization and the rapid increase in vehicular concentration have more traffic congestion in urban areas, delaying emergency vehicle response times, inefficient road space utilization, and heightened commuter frustration. Traditional static road dividers cannot keep pace with such dynamic conditions often resulting in underutilized lanes on one side and too congestion on the other. These present challenges require innovative steps to ensure smoother traffic and improved emergency response. The proposed System uses sensors, cameras, and real-time monitoring machine learning algorithms traffic density. From the information, the movable divider adjusts lane assignments dynamically, balancing road use, reducing produced bottlenecks, and zero delay at peak periods and the system has top priority given to emergency cars such as ambulances. Equipped with RFID tags and real-time communication modules, the system detects emergency vehicles and adjusts the divider and traffic signals to create a clear route. This substantially reduces response latency to enable quicker access to health care facilities and improving patient safety.to health care facilities and improving patient safety.

2. LITERATURE SURVEY

Ravish et al. [1] proposed an automated movable road barrier traffic system to relieve traffic congestion and ensure safety issues. Traditional static barriers are limited in their adaptability during danger periods. The system uses computer vision for the monitoring of real-time traffic using traditional cameras and cloud computing-based data processing. A Python program handles vehicle density and establishes the best times to change the barrier to the busier lane, thus enhancing road space utilization. Comparative analysis shows improved traffic flow and reduced delays in dynamic situations. The system includes a potential RFID emergency vehicle detection feature and future directions for integration later with GPS for additional functionality. Laboratory test results assure the system's reliability in various circumstances, with suggestions directed towards scalability and deployment in different urban environments.

S. Agrawal et al. [2] proposed a system that integrates IoT, cloud computing, and deep learning to provide a responsive traffic control solution. Strategically positioned cameras capture real-time car density, and information is forwarded to a cloud platform for analysis. From this analysis, commands are passed to an embedded controller for dynamically controlling the position of the divider. The system is designed to alleviate congestion by moving dividers to more closely spaced lanes while also allowing emergency vehicles by default, providing a clear direction. RFID sensors provide protection by detecting other vehicles and preventing sudden divider shifts. This effective system avoids wasteful time, conserves fuel efficiency, and improves emergency response times.

S. Srikanth et al. [3] aims to decrease traffic congestion during rush hours using an Arduino Mega microcontroller and IR sensors. The divider is dynamically modulated based on traffic situations and red-light conditions. An emergency feature allows the system to detect ambulances equipped with RF transmitters and convert the signals to green, providing a seamless path. Traffic data are stored in ThingSpeak, enabling long-term urban planning analysis. The use of IR and RF sensors enables the system to efficiently minimize delays and optimize road use.

G. Manasa et al. [4] propose a system designed for urban traffic hotspots like Banjara Hills. It features IR sensors to continuously regulate traffic density and adjust divider positions in real time. By dynamically allocating lane space, the system enhances road efficiency and minimizes congestion. Location-based services support smart device compatibility for real-time traffic information. Prototype test results prove the system's ability to alleviate congestion and improve traffic flow. Future upgrades may include image processing and machine learning to handle complex, multi-way traffic conditions, making it versatile for different traffic zones.

S. Vastava et al. [5] employed Arduino UNO and NodeMCU microcontrollers and IR sensors to control lane arrangements based on traffic flow. The system efficiently alleviates congestion by offering extra lanes and safety devices such as buzzers to raise alertness. In a trial conducted on Moinabad road, the system ensured smoother traffic flow, faster emergency vehicle clearance, and reduced idle time, contributing to environmental sustainability. Its automated form removes the need for human involvement, making it a cost-effective option for urban dynamic traffic management.

3. PROPOSED SYSTEM

The proposed system is aiming to address challenges faced in urban traffic management. This includes emergency vehicle prioritization and dynamic reallocation of road lanes. The system integrates RFID-based emergency vehicle detection, YOLO-based traffic monitoring and divider movement to achieve efficient road systems.

3.1 Emergency Vehicle Detection and Lane Clearance

One of the main goals of the system is to provide a clear and uninterrupted route for emergency vehicles with decreased response time delays. Emergency vehicles are imbedded with RFID tags, which are received by RFID readers placed strategically along the road. When detected, the system will then automatically induce the movement of the road divider, displacing it laterally to form a dedicated emergency lane. This system obviates the need for manual traffic control or sirens, which could be ineffective in heavily populated areas. After the emergency vehicle has passed through the impacted area, the divider goes back to its initial position, and normal traffic flow is maintained without unnecessary disruptions. Automating lane movements, the system greatly decreases emergency response times and improves road safety by reducing delays in urgent medical and rescue missions.

3.2 Traffic Density Monitoring and Dynamic Lane Reallocation

To dynamically allocate lanes, the system continually tracks traffic density. Real-time traffic data captured by a camera module is handled with the YOLO (You Only Look Once) object detection system. This model counts vehicles precisely, which lets the system find traffic anomalies across lanes.

Should a notable difference in traffic density between adjacent lanes be found, the system automatically moves the divider's position to maximise road use. For example, the system adjusts the divider to provide extra space for high-density lanes if one lane suffers heavy traffic while another is underused during peak hours. By means of this adaptive lane reallocation, traffic congestion is minimised, travel time is lowered, and general road capacity use is improved.

3.3 System Design and Components

The system comprises hardware and software components that work together to facilitate real-time traffic regulation and emergency response.

- **Arduino Uno Microcontroller**: Serves as the central control unit, managing motorized divider movements based on RFID detection and YOLO-based traffic analysis.
- **RFID Sensors:** Connected with Arduino Uno for detecting RFID tagged vehicles.
- **Camera Module**: Captures live traffic footage, providing real-time data traffic density monitoring.
- **Motorized Road Divider**: Composed of modular sections, each equipped with independent motors, allowing precise lane adjustments.
- **YOLO Algorithm** (Processed on a Laptop): Runs on a dedicated processer or Laptop, analysing vehicle density and triggering lane reallocation commands.

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The algorithm of the proposed system is given below:

1. **Start**
2. **Ambulance Detection**

   → *Check if an ambulance is detected*

   - **Yes**

     a. Move the divider to create a clear path

b.Wait until the ambulance passes
c. Reset the divider to its original position
d. Go back to **Ambulance Detection**

- **No** → Go to **Traffic Density Monitoring**

3. **Traffic Density Monitoring**

→ *Check if lane density is uneven*

- **No**
a. Continue monitoring traffic density
b. Loop back to **Ambulance Detection**

- **Yes** →
a. Move the divider to balance traffic flow
b. Continue monitoring traffic density
c. Loop back to **Ambulance Detection**

4. **Repeat Continuously**

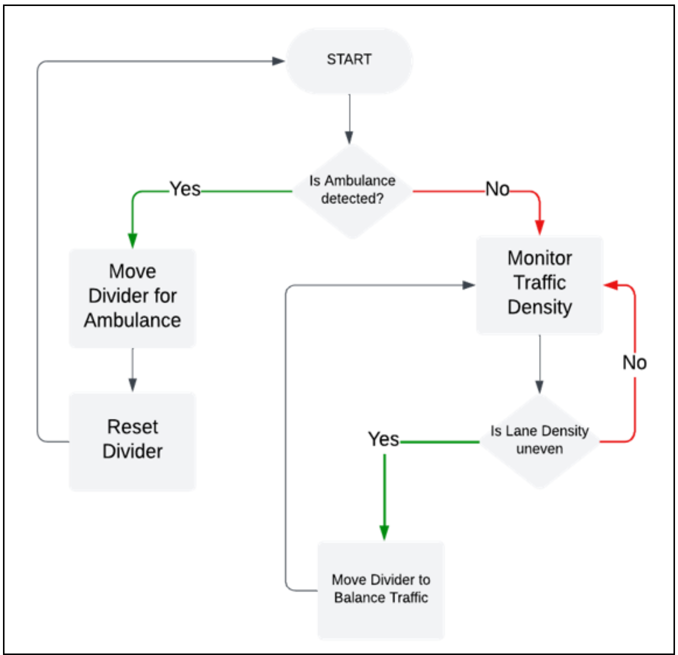

Fig -1: Flowchart

5. METHODOLOGY

To perform real-time traffic control and prioritize emergency vehicles, the proposed Smart Movable Road Divider system combines hardware and software components. Two main phases characterize the approach: hardware implementation and software integration.

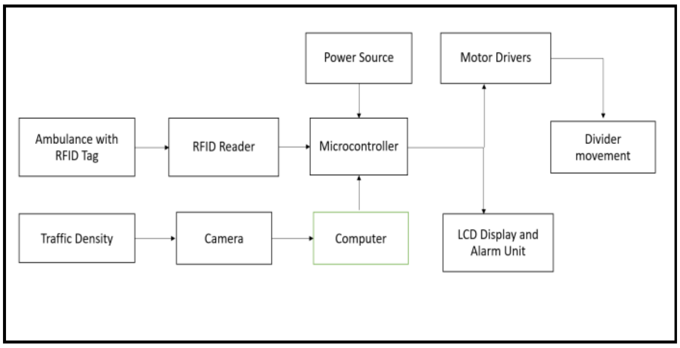

Fig-2: Block Diagram

5.1 Hardware Implementation

The hardware setup includes the following components:

- **Arduino Uno:** Acts as the control center, integrating the movement of the divider and the transmission of data between RFID.
- **RFID Sensors:** Identify and detect emergency vehicles with RFID tags for priority clearance.
- **Camera Module:** Supplies constant video stream for traffic density analysis.
- **Movable Divider Segments:** The road divider consists of segmented modules that move side-to-side to configure lanes.
- **Motors:** Separate motors operate the movement of every divider segment, with precise adjustments possible.

The hardware model was assembled on a scaled-down road model consisting of two lanes. RFID sensors were placed along the road and each segment of the divider was connected to a motor controlled by Arduino Uno.

The camera was set up in a overhead position to the miniature road.

5.2 Software Integration

The software component is very important in lane decision-making and real-time data processing modifications. Key components are:

- **YOLO Algorithm:** A pre-trained YOLO (You Only Look Once) model is run on a processing unit for detection and enumeration of vehicles.
- **Arduino Programming:** Arduino Uno is programmed to detect signals from RFID sensors and control motor functions related to the segment dividers.

- **Feedback Loop:** An assessment framework continuously monitors the working effectiveness of the system, tuning the motor movements based on real-time data to guarantee accuracy and reliability of the system in optimizing the traffic flow and emergency vehicle clearance.

5.3 System Workflow

The overall workflow of the system is as follows:

- RFID sensors pick up the arrival of an emergency vehicle and transmit a signal to the Arduino Uno.
- The Arduino shifts the divider segments with the motors to create a distinctive lane for the emergency vehicle.
- Meanwhile, real-time traffic information is recorded by the camera module, and the same is processed with the YOLO algorithm to detect and count automobiles.
- It employs traffic flow volumes to calculate the best position of the divider to achieve optimal lane usage.
- The system is always monitoring operations through the feedback loop, with the immediate response and error correction.

This modular and scalable design ensures adaptability for various road conditions and traffic patterns, making the system suitable for real-world applications.

6. RESULTS AND DISCUSSIONS

6.1 Emergency Vehicle Detection Accuracy

The system accurately detected emergency vehicles using RFID sensors with 93% average detection. The table below indicates the detection rate of the RFID-based emergency vehicle identification system in different experiments.

Table -1: Emergency Vehicle Detection Accuracy

Number of Trials	Successful Detections	Accuracy (%)
10	9	92
20	19	95
30	28	94

The RFID-based detection mechanism ensures that emergency vehicles are instantly recognized, allowing the system to prioritize lane reallocation and facilitate faster emergency response times.

6.2 Traffic Density Monitoring and Object Detection

YOLO object detection process was utilized for vehicle detection. Detection performance and classification accuracy were assessed using a confusion matrix, which verified the system for detecting actual detections and predicted ones, with number of tests done equal to 30.

- **True Positive (TP):** Vehicles correctly detected (9)
- **False Negative (FN):** Vehicles missed by the detection system (1)
- **False Positive (FP):** Non-vehicles wrongly classified as vehicles (1)
- **True Negative (TN):** Non-vehicles correctly ignored (19)

Table -2: Confusion Matrix for Vehicle Detection

	Predicted Positive	Predicted Negative
Actual Positive (Vehicle Present)	9(TP)	1(FN)
Actual Negative (No Vehicle)	1(FP)	19(TN)

6.3 Performance Metrics for Vehicle Detection

Key metrics were calculated to evaluate effectiveness of the system. These include accuracy, precision, recall, and F1-score, which measure how well the system detects and classifies vehicles.

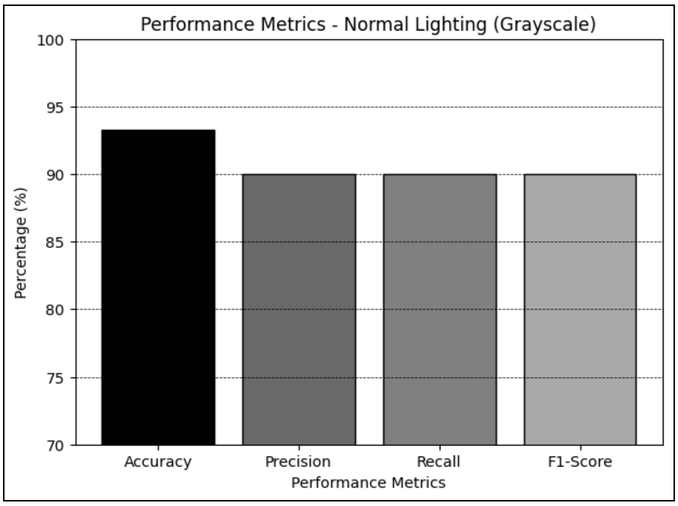

Chart -1: Performance Metrics

- **Accuracy** = (TP + TN) / (TP + TN + FP + FN) = (9 + 19) / (9 + 19 + 1 + 1) = 93.33%
- **Precision** = TP / (TP + FP) = 9 / (9 + 1) = 90%

- **Recall** = TP / (TP + FN) = 9 / (9 + 1) = 90%
- **F1-Score** = 2 * (Precision * Recall) / (Precision + Recall) = 90%

The results show that the YOLO vehicle detection system performs detection in a very reliable and accurate manner with very less error percentage and misidentification of the objects

6.4 Lane Shift Response Time

The time taken for the divider to move after detecting either an emergency vehicle or a high traffic density scenario was recorded.

Table -3: Lane Shift Response Time

Action Trigger	**Expected Response Time (sec)**	**Measured Response Time (sec)**
Emergency Vehicle Detection (RFID)	1.2 sec	1.2 sec
Traffic Congestion Detection (YOLO)	5 sec	4.3 sec
Lane Shift Activation	3 sec	2.5 sec

The system demonstrates low-latency response times, ensuring that lane reallocation occurs swiftly and efficiently.

thus, enabling efficient lane changing according to traffic flow and emergency requirements.

The successful installation and demonstration of the system proved its feasibility and practicality for real-world use. The modular divider design allows for scalability and flexibility of roads of varying lengths and traffic.

7. CONCLUSION

The proposed movable road divider system is found to optimize traffic flow and prioritize emergency vehicles with a combination of RFID technology, computer vision, and hardware modularity. The combination of an Arduino Uno microcontroller, RFID sensors, and the YOLO algorithm enabled real-time detection and adaptive reaction, thus enabling efficient lane changing according to traffic flow and emergency requirements.

The successful installation and demonstration of the system proved its feasibility and practicality for real-world use. The modular divider design that allows for scalability and flexibility of roads of varying lengths and traffic. Additionally, the installation of sophisticated algorithms for traffic analysis provides precision and consistency under different environmental conditions.

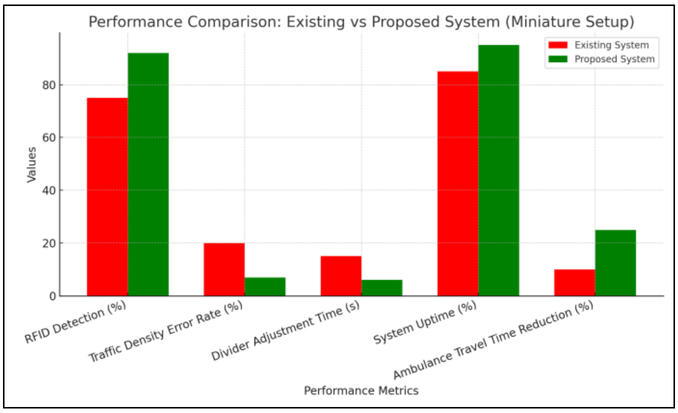

Chart -2: Comparison

8. FUTURE SCOPE

The potential applications of the Smart Movable Road Divider accommodate integration with the future generation traffic management systems, such as AI-driven traffic prediction and vehicle-to-infrastructure (V2I) communication, which are more efficient emergency routing and real-time traffic-based optimizations. The system can also be designed to integrate autonomous vehicles, IoT networks, and renewable sources of resources, hence becoming more environmentally friendly. With sensors such as LiDAR, and infrared cameras, and machine learning algorithms, the divider can provide more intelligent, adaptive traffic flow solutions, safe and efficient road networks for smart cities.

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