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Traffic Density Identification for Four-Way Intersection Using FPGA

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ABSTRACT: Time is a necessary key for everyone's life in traffic management because it plays a major role every day. In peak hours have heavy traffic, many intersections occur and make difficult situations in emergencies across the road. Most of the system works with fixed timing and without any priority. It is controlled by using RFID technology and FSM logic with FPGA. FSM logic utilizes a set of well-defined states and transitions to respond to corresponding sensor input from real-time traffic conditions. The system consists of various sensors, including density identification of traffic flow monitors and emergency vehicle detection, to gather input data for efficient decision making. Emergency vehicle management is designed and developed by using RFID with FSM states. RFID tags help to read the unique Id from emergency according to traffic signs. Overall, the proposed system ensures that efficient traffic flow, flexible and suitable for smart city applications.

Keywords: IR, RADAR, RFID, FPGA, FSM Logic, Traffic signal

1. Introduction

In traffic collision occurs due to the rapid increase of vehicles. Most existing traffic signal systems follow fixed time control methods, which do not adapt to real-time traffic conditions. These results provide an inefficient traffic system under various traffic conditions. Hence, it provides an intelligent system that can identify density and manage traffic flow effectively.

Traffic density identification helps in understanding the number of vehicles present in each lane and enables better control of traffic signals. By using appropriate sensors, real time vehicle detection can be achieved under different environmental and lighting conditions. Hardware-based solutions are preferred for such applications due to their speed, reliability, and real-time performance. This paper proposes a traffic density identification for a four-way intersection using an FPGA – based approach. This system uses radar sensors and IR sensors to detect vehicle presence and estimate traffic density in each lane. Light sensors are used to identify an emergency vehicle during traffic at each lane.

It can provide priority using RFID (Radio Frequency Identification) for emergency vehicle that are incorporated to identify authorized vehicles such as ambulances and fire track. All sensor inputs are processed using an FPGA, which allows for parallel processing and fast decision-making. FPGA Compared to microcontroller-based systems, it offers better real-time response and flexibility. The traffic density calculation and system output are displayed using LED indicators

and LCD; it also provides clear visual information to users.

The implemented system is to reduce traffic collision, waiting time, improve traffic flow efficiency. It also supports future intelligent traffic management, and smart city applications.

2. Recent Works

FPGA Based traffic monitoring system provides a real-time solution for monitoring and analysis of traffic conditions. It offers scalable, efficient solutions, and it addresses modern urban challenges. The system maintained real-time responsiveness, with average end to end processing latency below 100milliseconds even under high traffic loads[1].real time density based dynamic traffic controller using ultrasonic sensors and FPGA technology to dynamically manage traffic signals based on real-time vehicle demsity.in previous approaches often lacked adaptable timing ,integrated emergency vehicle handling or intersection synchronization[2].in FPGA based smart traffic light systems emergencies employed to implement intelligent traffic management algorithms, ensuring swift and safe ambulance navigation through congested urban traffic. These communication capabilities are further augmented by FPGA based encryption logic and security protocols [3].t in traffic signal control using discrete logic and FSM system managing traffic intersections designed to transition between various states baaed connections [4]. Simulation of an optimized traffic controller using Moore FSM was selected for its simplicity, reliability, and ability to manage state dependent outputs, which are essential for controlling traffic light cycles [5]. In enhanced energy efficiency by optimizing signal timings based on live data, thereby reducing unnecessary signal changes [6]. Traffic light controllers are classic examples of sequential systems, making them finite state machine design, clocked sequential logic timing, and control using counters [7]. In FSM based coordinated and automated traffic system incorporates various sensors, including vehicle detectors, pedestrians' sensors and traffic flow monitor gather input data for accurate decision making [8]. Automatic pathways for emergency vehicles using RFID technology provide automatic, uninterrupted pathways for emergency vehicles [9]. Emergency vehicle detection using RFID improves efficiency in traffic and decreases the waiting time, which enables better road clearance for emergency service vehicles [10]. Implementation of smart emergency vehicles prioritization includes the main tool RFID control system. RFID tags help verify the passage of emergency vehicles according to traffic signs [11]. Smart traffic RFID technology consists of sophisticated traffic moves and provides the lane for the ambulances using Arduino [12]. In FPGA based system incorporates advanced features of safe, efficient operation and hardware implementation demonstrate the proposed FPGA traffic control system [13].

3. Proposed Work Explanation

The paper concentrates on developing a traffic density identification and emergency vehicle prioritization for a four way intersection. If the traffic density identification shows how many vehicles present in each lane using LCD and it depends on the traffic lights ON such as green, red, yellow. The traffic control used for density identification uses FSM (Finite State Machine) control logic. It means when the density is reached a high green signal put the lane, and others give the signal based on the density at the time. It used to avoid traffic congestion and provide smooth traffic management.

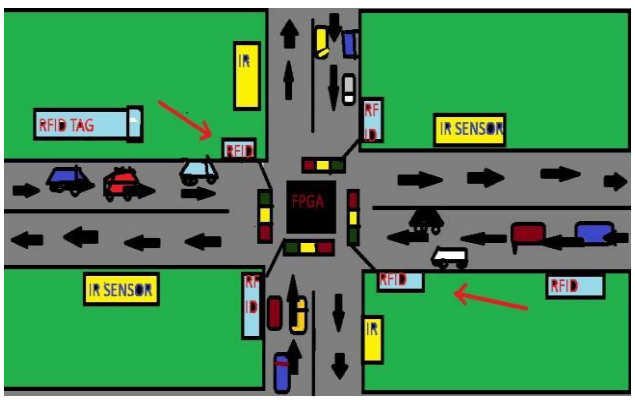

Figure 1: *Overview of the complete traffic system structure of a four- way junction with FPGA*

It also includes the major concept of emergency vehicle prioritization for using RFID (Radio Frequency Identification) technology. RFID technology considers two concepts for emergency vehicles presented in place that means it focuses in front of the lane or middle of the lane. Each lane has fixed RFID (2) that communicates the information to FPGA (Field Programmable Gate Array) using the I^2C protocol.

3.1 Block diagram

The block diagram represents the traffic density identification with emergency vehicle priority at a four-way intersection.IR (Infrared) sensors are used to detect vehicles present and vehicle counting and each road. Which is located near a traffic lane in four directions. If the IR transmitter emits infrared rays in front of the lane on each road. When the vehicle passes, the IR reflects. These interruptions are detected by the receiver and counted as a vehicle. Based on traffic density, which is classified at low, medium, or high, that information is passed to the sensor interface into FPGA, which uses it to decide the green signal duration for that road. In LIDAR is used to detect speed of the vehicles presents reflected in radio waves. If a vehicle is moving at high speed, frequency shift indicates a potential emergency vehicle. Similarly, when high speed detector uses radar, that information is sent to FPGA then makes a decision. It also indicates the vehicle counts using LCD in each lane. Dynamically adjust to manage to give that signal in Green, Yellow, Red.

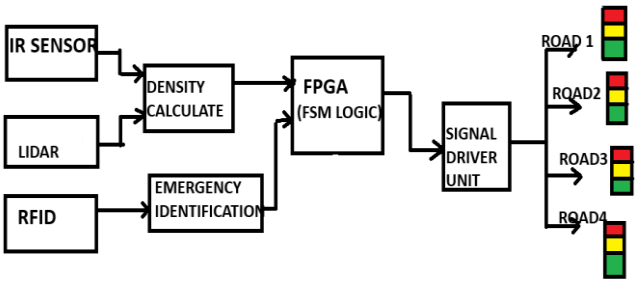

Figure 2: *Block diagram of traffic density system with emergency priority system*

FPGA makes decision to high density based that particular lane to get green signal in longer time and others are red. If the RFID used to detect emergency vehicles also that information sends to FPGA to make decisions inefficiently. In every emergency, a unique ID, which has been detected using RFID tags and receiver, is installed near the traffic signal. When a vehicle comes within a range, the reader detects the tag and verifies that it is an authorized emergency vehicle. Once the tag is detected, the digital signal is sent to FPGA to conform to emergency and make the decision to get a green signal.

3.1.1 RFID

RFID uses electromagnetic fields to automatically identify, and track tags attached to vehicles. It is commonly known as electronic toll collection or smart parking. It facilitates nonstop tolling, managers access to gated areas, prioritizes emergency vehicles, and provides real time data traffic flow optimization.

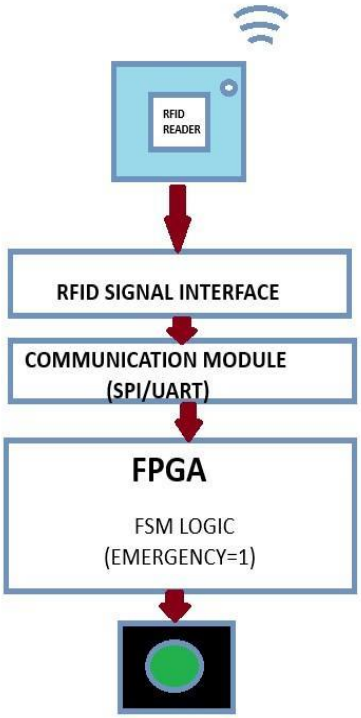

Figure 3: *RFID Working Flow Diagram.*

3.1.2 IR SENSOR

IR in traffic management detects vehicle presents to dynamically adjust traffic light timings based on real time density. This IR transmitter always emits IR rays from it. The operating voltage of this IR

transmitter is 2to 3v. It can be used for vehicle counting and detecting vehicle presence.

3.1.3 LIDAR

LIDAR is used to detect objects, measure distance, and determine speed using radio waves. It can be used to cover a long range and manage efficient traffic management. Identify speed using the Doppler Effect and avoid false triggering.

3.1.4 FPGA

FPGA is used to implement the finite state machine and make better decisions. it uses spartan-6 FPGA, and it can be used to parallel processing for read IR, LIDAR, and RFID signals simultaneously. It also generates signal timing control and timing accuracy is much higher.

Figure 4: *Xilinx spartan –6 FPGA Board*

3.1.5 Traffic light controller interface &wireless relay module

Input and output connectors: Type KF-128,1426AWG,250VAC@16A screw terminals, safety fuse for AC INPUT 8A, operating voltage range:100-240v AC /5060Hz,6w maximum per module.

A traffic controller interface is the communication link between the control unit and the traffic signal lights. It is responsible for receiving control signals and driving the red, yellow, and green lights. Traffic lamps operate at higher voltage levels and current levels. Driver circuits or relay units are used to safely interface with signal lights. The wireless relay module is used to control electrical loads.

3.2 FSM Logic

A finite state machine that has a computational model is used to describe systems with a limited number of states and the transition between those states. It is widely used for digital circuit design, control systems, and software development. Incorporating FSM is a design of traffic signal controllers that allows for a deterministic and structured approach to managing signal transitions. It consists of three main components.

States: represent different conditions in traffic signals such as red, green, and yellow.

Transitions: define how the state moves from one to another based on different events or inputs.

Inputs: information from sensors like vehicle counts and emergency detection.

3.2.1 State diagram

State diagram represents traffic density and emergency state. It consists of a total of 7 states such as S0, S1, S2, S3, S4, SY and SE. It follows emergency has highest priority then density decides which road gets green. It also dynamically adjusts based on current density traffic control using FSM states.

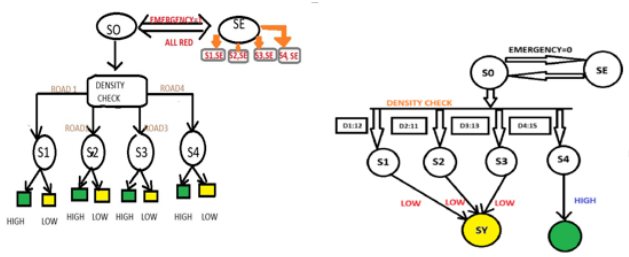

Figure 7: *State Diagram of Traffic Light Systems and Them Triggering Conditions*

s0’ is a density check state that means all signals are red and traffic density compared to all roads, finally ‘FSM’ select the current highest density road. S1, S2, S3, S4, represents road1, road2, road3, and road4 density calculation. It depends on only one road that gets green remaining as red then after green timer moves to yellow state ‘SY’. If ‘SY’ represents safety and prevents sudden signal

change to avoid collision. After the yellow timer moves to return S0. If an 'SE' emergency state concentrate to detect any emergency vehicle can be entered from that road, if it has highest priority to get green remains RED. When emergency conditions are clear, FSM moves back 's0' in normal density operation.

3.2.2 Transition Table

PRESENT STATE	CONDITION	OUTPUT
SO(ALL RED)	DENSITY CHECK	RED
S1(R1)	HIGH/LOW	GREEN/YELLOW
S2(R2)	HIGH/LOW	GREEN/YELLOW
S3(R3)	HIGH/LOW	GREEN/YELLOW
S4(R4)	HIGH/LOW	GREEN/YELLOW
SE	EMERGENCY=1	GREEN
S0	O	RED

Figure 6: *Transition table of state diagram*

Case 1: Traffic density identification

The state S0 checks the density on four lanes, such as S1, S2, S3, and S4. S0 gets the information from where high density presents in the road (S4), after that an emergency vehicle has not arrived on the road, then switched to red signals for the lane. Fig7.case 1 explain diagram.

Case 2: emergency vehicle prioritization

If state 'S0' checks density S1, S2, S3, and S4 normal density identification. The (emergency =1) condition is received by s3 then put to green signal that lane.

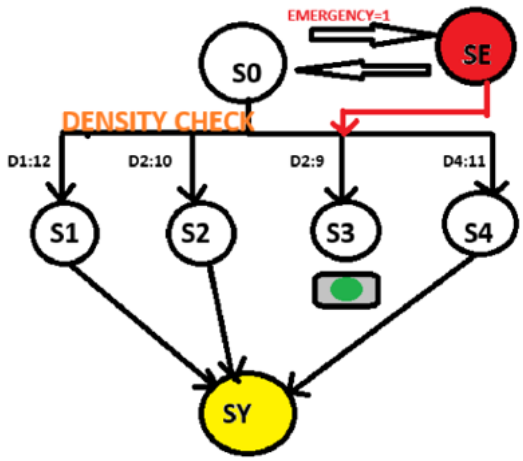

Figure 8: *Case 2 explaining diagram.*

4. Results and Discussion

The proposed system of traffic density identification and emergency vehicle prioritization was successfully implemented. If the system is tested under different traffic density conditions to evaluate its performance. The density is also detected using sensors, then FPGA makes efficient decisions. It has adjusted dynamically in the real-time traffic density-based outputs and reduced traffic

In comparison to conventional fixed time traffic light systems, the proposed system improved smooth traffic management and decreased waiting time at intersections. FSM logic with priority condition ensures that proper function prevents signal conflicts and accidents. Overall, the project results ensure that efficient traffic using FSM logic, flexible and suitable for smart traffic management

5. Conclusion

The proposed traffic density identification and emergency vehicle priority system can be further enhanced some advances such as;

A) Camera based traffic monitoring

If the technology is added to replace basic sensors and involves image processing techniques. It can accurately analyze vehicle count, lane occupancy, and traffic flow in real time under complex traffic conditions.

B) Artificial intelligence and machine learning algorithms

It can be implemented to predict traffic patterns and automatically adjust signal timings and helps to decreased congestion during peak hours and improve efficiency.

C) Vehicle to communication

V2I can be integrated to allow traffic to communicate directly with vehicles. Used to priority control for emergency vehicles and increasing public safety.

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