Smart Traffic Management System

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Certificate

This is to certify that the Project work titled "Smart Traffic Management System" is being submitted by ***Sparsh Raj*** **(19BPS1028)** and ***Hande Atharrva Devendra*** **(19BPS1086)** for the course **Context-Aware Computing**, is a record of bonafide work done under my guidance. The contents of this project work, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University.

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1. ABSTRACT

The rapid growth in the number of vehicles on the road and the increasing size of cities have created many problems for road traffic management authorities, including traffic congestion, accidents, and air pollution. The existing obsolete traffic management model with a fixed timer for changing the signal light is inefficient in managing the current level of high-value road traffic. Along with this obsolete system, the issue of the rising number of road accidents, and irresponsible citizens' action of wrong lane driving is increasing the concern of the authorities as well as the common citizen to improve the road traffic security and improve the traffic management efficiency.

As per the existing system, many traffic accidents aren't reported to authorities which hamper the delivery of proper justice to the victim and this also makes the problem to worsen as authorities don't get the problem for analysis and to take the required actions against it. This also obstructs the legal traffic measures to be implemented in a well-structured manner.

In order to provide a solution to this problem of inefficient traffic management, our effort put forward an intelligent and intelligent traffic management system with the addition of a GPS module to all the vehicles, which acts as the primary context provider. The proposed approach makes the traffic signal decision based on the timer and the local traffic density.

2. INTRODUCTION

The proposed system adds an intelligent behaviour to the existing timer-based traffic light system using a Radar camera or CORDON multi-target Photo Radar System at every intersection. Each intersection is equipped with a Radar camera that continuously measures the contextual information of the vehicle, including average speed and absolute mean acceleration on a road segment during a specific period. Afterwards, it estimates the local traffic congestion level based on this contextual information.

It is a hybrid approach that makes the traffic signal decision based on the timer as well as the local traffic density. Majorly it works on timer-based traffic lights, but it also takes the local traffic congestion in the corresponding road into consideration obtained from the context provider, i.e. Radar camera, here.

The leading edge of this system over the existing systems is the rules for the transition of the traffic light. It changes from Red ⇒ Yellow ⇒ Green ⇒ Yellow ⇒ Red mainly on a fixed timer, but until this timer is active, it continuously keeps the context data from the next lanes. So, for example, if the system detects the vehicle density of the current lane is low and current light status is GREEN while there is a lane with HIGH traffic density having current light status RED, then it automatically makes the light status with HIGH traffic density to GREEN and LOW traffic density to RED and reset the timer.

This system is an object-oriented context model which executes on an event-triggered context-aware mechanism. The timer value and the minimum vehicle density value will be predefined in the system, which can be set manually depending upon the observations made from the existing vehicle density. As the timer has an intelligent system to assist it with the vehicle density, so the behaviour of the system varies as per the busy hours and the free hours on the road, which makes it a proper context-based model.

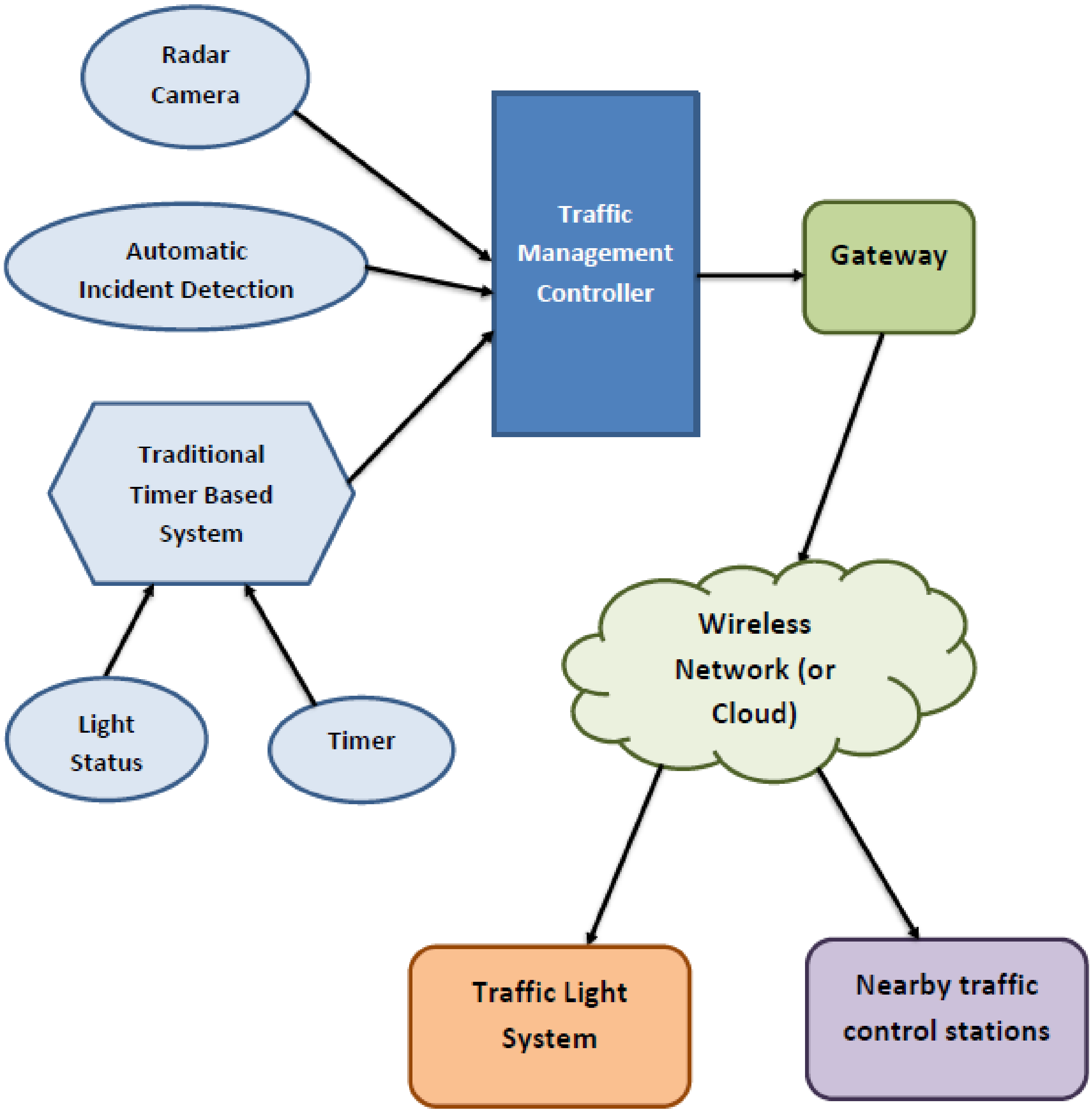
Our proposed system does not require any network infrastructure for collecting and processing data, which decreases the expenses effectively. In addition, we propose a new context-aware traffic estimation system, which uses fuzzy logic to estimate traffic state.

3. CHALLENGES TO BE ADDRESSED

- Developing a context-aware based smart traffic system.
- Improvising the existing timer-based traffic control system with the addition of radar cameras in order to make the operational behaviour dynamic, depending upon the average traffic density of the corresponding lane.
- Making the system smarter to address any accidents properly with smarter traffic management in such situations and also enabling it to inform the local authorities about the same.
- Handling unprecedented traffic systems which arise due to case-based uncertainties and hardware or software failure issues.

4. CONTEXT-AWARE MANAGEMENT SYSTEM

(with architecture diagram)



The architecture of the context-aware management system for the Smart Traffic Management System is shown above. Various context providers feed information to the Traffic Management Controller. Here the context providers are the Radar Camera which provides the average speed and average acceleration of the vehicles, the Automatic Incident Detection (AID) which informs if an accident took place or not, and the Traditional Timer Based System which provides light status and timer status. This controller then interacts with this data and finds the set of actions to take place in real-time according to the defined context behaviours. Now the action to be taken is finalised. This information is then uploaded to the cloud with the help of gateways. The finalized information is then updated in the Traffic Light System and also notified to the nearest traffic control station with the help of a wireless network (or through Cloud).

5. ALL PHASES (Context acquisition, context modelling, context-aware adaptation, reasoning, service dissemination)

The first phase of context acquisition has the following list of context providers:

- Radar Camera: Provides the average speed and average acceleration of the vehicles in the corresponding lane.
- Automatic Incident Detection (AID): Provides the input if there is an accident in the lane or not.
- Timer: Provides the value of the traffic light timer for the corresponding lane.

These context events obtained are processed by the model and then finally consumed by the signal light, i.e. the context consumer.

The context input obtained from these context providers has then to be derived as per the following procedure:

- Traffic Light:
  - L1 → Red
  - L2 → Yellow
  - L3 → Green
- Average Speed:
  - avg_speed <= 20.0 → Low
  - 20.0 < avg_speed <= 50.0 → Medium
  - avg_speed > 50.0 → high

- Average acceleration:
  - avg_acc <= 10.0 → Low
  - 10.0 < avg_acc <= 35.0 → Medium

    - avg_acc <= 35.0 → High
- Automatic Incident Detection:
    - 0 → No accident
    - 1 → accident occurred

For the proposed work, the model uses fuzzy theory to classify the traffic of that lane into various categories (as mentioned in the later sections). This categorization is done on the basis of the average speed and average acceleration of the traffic in the corresponding lane. The context inputs obtained, make the system to be an event-based model which uses object-oriented context specification.

Entities and Attributes:

Signal Light:

- Light_color : range {“RED”, “YELLOW”, “GREEN”}
- Light_timer : range [0, 60]

Crossing:

- Crossing_ID : range {Ci; i = 1 to n, n = number of crossing}
- Lane_ID : range { Ri; i = 1 to 4}
- Avg_speed : range { 0, 70}
- Avg_acc : range { 0, 50}
- Time : range {0:0:0, 23:59:59}
- Current_Light_Status : range { Li; i = 1 to 4}

Class-Based Representation of the various entities and their attributes:

```
Class Light
{
	Light_Color string;
	Timer string
}

Class Crossing
{
	Crossing_Id string;
	Lane_Id string;
	Average_Speed float;
	Average_Acceleration float;
	Time string;
	Current_Light_Status string;
	Automatic_Incident_Detection boolean
}
```

The above-mentioned context input, consumers and the object-oriented specification work on the following context behaviours:

- At a particular crossing, if the traffic light status of one lane is green, then make the corresponding remaining traffic light status as red.
- When the traffic light timer expires, change the current traffic light status, i.e. change one colour to Green->Red and another to Red->Green.
- If traffic density in the lane is LOW and current light status is GREEN and the respective timer is not expired, then change the current light status to RED, and make the lane with HIGH traffic status as GREEN and reset the timer.

- If traffic density in all the lanes is approximately similar or in the moderate limit, then traffic lights status changes based on the traffic light timer.
- If an accident takes place on one particular road, then people are informed that an accident took place in that particular road by blinking the yellow traffic light until the current timer expires indicating people to go slow until the issue is resolved and inform nearby traffic control stations using the GPS module.

To make the model smarter to operate following time-constrained context behaviours have also been designed:

- Change the current traffic light status, i.e. change one colour to Green->Red and another to Red->Green, when the timer expires.

- If traffic density in the lane is LOW and current light status is GREEN for at least 10 seconds and the respective timer is not expired, while there is a lane with HIGH traffic density having current light status RED for at least 10 seconds and the respective timer is not expired; then change the light status with HIGH traffic density to GREEN and LOW traffic density to RED and reset the timer.

To make the real-time implementation of the smart model feasible, the probable uncertainty conditions, with appropriate context handling for the same has also been structured in the system:

- To check the validity of context input, in case of any such invalid context input, the system gives a prompt notification to the local traffic authority.

- To check if all the lights at a particular crossing are of different colours, in such impractical situations the system gives a prompt notification to the local traffic authority.
- To check if context providers are working properly or not (checking for continuous periods).
- To check signal timer operation i.e. if max 3 lanes at any particular crossing have the same timer value.

And as everyone knows the malpractice of citizens driving in the wrong lane. To handle such irresponsible actions, the following steps as been framed in the model:

- If a vehicle is travelling in the wrong direction i.e. opposite to the specified direction, it may affect the Average_Speed and Average_Acceleration data which will affect the traffic congestion level and our whole system. This conflicting situation is very hard to solve without a person physically present at the scene such as Traffic Police. Currently, we can alert the officials if a vehicle is driving on the wrong side of the road by capturing the license plate of the vehicle.

6. PROPOSED WORK

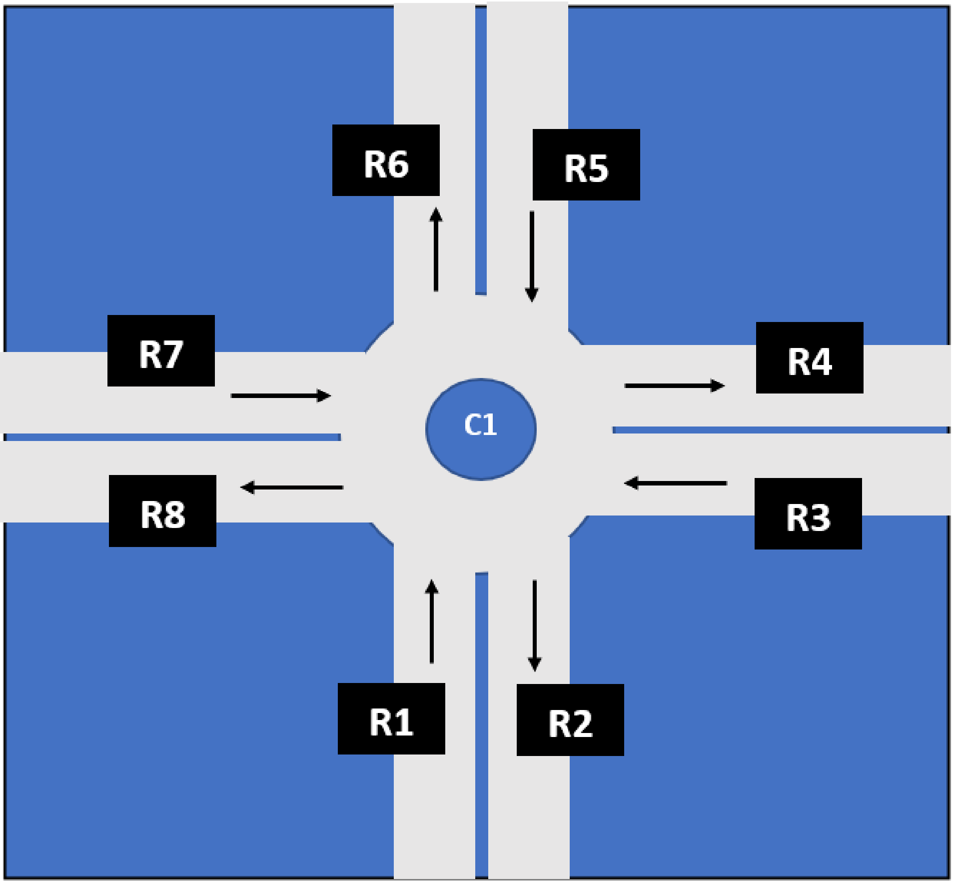
The context providers such as Radar Camera or CORDON multi-target Photo Radar System, Automatic Incident Detection (AID), Timer provides real-time data such as the average speed of the vehicles, average acceleration of the vehicles, if an accident took place, current light status and timer value, etc at every intersection. The data we obtained from these providers is primary data. We further classify this and refine this data into a proper dataset. We classify average speed into three types as “Slow”, “Medium” and “Fast”. Similarly, we classify average acceleration into three types as “Low”, “Medium”, and “High”.

Now based on the fuzzy rule, we further derive traffic congestion levels at each intersection. This fuzzy rule depends on average speed and average acceleration at the intersection.

Fuzzy Rule:

S No.	Speed	Acceleration	Traffic Congestion
1	Slow	Low	Medium
2	Slow	Medium	Medium
3	Slow	High	High
4	Medium	Low	Low
5	Medium	Medium	Low
6	Medium	High	Medium
7	Fast	Low	Free
8	Fast	Medium	Free
9	Fast	High	Low

Based on the above fuzzy rule, we will derive the traffic congestion level at each intersection in real-time. So now our approach is a hybrid approach that makes the traffic signal decision based on the timer and the local traffic density.



In this approach, as per the existing model, at a particular crossing, if the traffic light status of one lane is green, then the corresponding remaining traffic light status should be red. And when the traffic light timer expires, change the current traffic light status, i.e. change one light status to Green ⇒ Yellow ⇒ Red and another to Red ⇒ Yellow ⇒ Green anticlockwise. In this approach, if traffic density in the lane is LOW and current light status is GREEN for at least 10 seconds and the respective timer is not expired, while there is a lane with HIGH traffic density having current light status RED for at least 10 seconds and the respective timer is not expired; then change the light status with HIGH traffic density to GREEN and LOW traffic density to RED and reset the timer.

Also, if traffic density in all the lanes is approximately similar or in the moderate limit, then traffic lights status changes based on the traffic light timer, not on the congestion level. And if an accident takes place on one particular road, then people are informed that an accident took place in that particular road by blinking the yellow traffic light until the current timer expires indicating people to go slow until the issue is resolved and inform nearby traffic control stations.

We have also incorporated Uncertainty Handling and Conflicting situations and tried to resolve them. Here we are checking the validity of each context input, also checking if all the lights at a particular crossing are of different colours and if context providers are working properly or not (checking for the continuous period). We also check signal timer operation i.e. if max 3 lanes at any particular crossing have the same timer value and if there are any errors we inform nearby traffic control stations. We also have incorporated detection of malpractice of citizens driving in the wrong lane and then notifying the nearby authority.

7. CODE IMPLEMENTATION AND DATASET RESOURCE

The above-mentioned context-aware model has been implemented using the Python language at: Smart Traffic Management | Colab

For the code implementation the following synthetic dataset was built to verify the proposed model's performance for each of the context behaviours, uncertainty and time-constrained behaviours.

Link to dataset: Smart Traffic Management | Dataset

8. RESULT AND DISCUSSION

A smart traffic management system has been modelled and presented. The system is an event-based context-aware system that takes the context input from listed context providers, processes as per the context behaviours structured in the model and are finally consumed by the traffic light system as the context consumer. The model operates on the fuzzy theory to classify the traffic into certain criteria. The model basically focuses on improving the existing obsolete timer-based traffic light system by implementing smarter context-aware mechanisms into it.

To improve the system reliability, case-based and device failure based issues, conflicting situations and wrong-lane driving issues have also been addressed in the system. In such cases giving prompt notification to the local traffic, authorities are the primary action taken by the system. Along with this, in case the AID detects any accident on the lane, it signals a blinking yellow light across the lane and the crossing to indicate the rest of the traffic to go slow and also gives prompt alert to the local traffic authorities.

As a note for future work, improving the accuracy and reliability is a primary point. Along with that, the AID can only detect the occurrence of an accident, but the exact identification of involved vehicles is yet to be worked upon. The future work issue prevails with the identification of exact vehicles detected under wrong-lane driving issues. real-time implementation of the model is a good opportunity for UI/UX enthusiasts to work on this.

9. CONCLUSION

A smart traffic management system with dynamic operational features along with the traditional timer-based traffic light system has been modelled and presented. The system is smart enough to handle the case and device failure based uncertainties, any accident occurrence and also the issue of wrong-lane driving.

The real-time implementation of the system will for sure bring a better and smarter traffic management system to come into real-life action, and help to tackle the prevailing issues of the obsolete timer-based traffic light system.

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