Self-adaptive Traffic Signal Control System Using Machine Learning:A Review

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***Abstract*- Traffic signal control system was introduced in early of the twentieth century to manage the flow of traffic and to ensure that the vehicles and pedestrians move smoothly and safely on the roads.**

The traditional fixed time traffic signal control system is inefficient for metro cities in India has increased in the number of vehicles and randomness of traffic throughout a day, this results in traffic congestion problem. Such traffic congestion problem causes several issues like wastage of time, wastage of fuel, air pollution and noise pollution.

The self-adaptive traffic signal control system based on the traffic density on the road may overcome these issues. Several methods are proposed to make traffic signal control system intelligent by manipulating the signals according to the density of vehicles on the road. This paper summarizes a review of the proposed machine learning techniques to develop intelligent traffic signal control system

Keywords: Traffic Density, Self-adaptive, Machine Learning, Congestion.

I. INTRODUCTION

According to a survey by UN State of the World Population report in 2007, by 2030, 40.76% of India's population is expected to reside in urban areas [1]. Such urbanization results in the growth of the population which requires an increased number of transportation ways. Amongst the main transportation ways like Air, Rail and Road, almost 90% of transportation occurs by road [2]. Due to such high dependence of traffic on road, it causes severe traffic congestion problem.

Currently, Fixed Time Traffic signal control system widely used in India due to its simplicity and availability. But this system looks inadequate to control heavy traffic on the road because it does not respond to varying traffic flows and hence has the highest delay [4]. Such delay results in traffic congestion problem.

The traffic congestion problem leads to unnecessary delays and reduction in speed. Congestion in Delhi, Mumbai, Bengaluru and Kolkata costs the economy 1.47 lakh corer annually according to Global Consultancy Firm [4]. Traffic congestion problem also increases in the number of accidents on the roads, Fuel wastage, and pollution. These issues may be overcome by implementing a self-adaptive traffic signal control system based on the density of traffic on the road.

Machine learning is taking over the world. It helps to develop systems that can understand, learn, predict, adapt and operate on their own; there is no need of doing extensive programming [5]. By using machine learning techniques we could make traffic signal control system self-adaptive so that it learns the traffic density and based on the density it can make updates in the timing of RED, GREEN and YELLOW signals. This helps to reduce traffic congestion problems.

This paper provides a review of machine learning techniques used by different authors to make system self-adaptive and regulate the flow of traffic. Some of these methods use Reinforcement learning algorithm which is an area of machine learning where software agent learn how to behave in an environment by performing actions and Maximizing reward. In Reinforcement learning, the Q-learning helps to learn a policy, which tells an agent what action to take under what situation. It does not require a model of the environment and can handle problems with probabilistic transitions and rewards [5]. To dynamically adjust the timings for RED, GREEN and YELLOW signals depending on situation Reinforcement learning algorithm could be helpful.

Fuzzy Logic can be a considerably intelligent approach for handling traffic congestion. Fuzzy Logic is nothing but a method of reasoning that similar to human reasoning. The approach of Fuzzy Logic which follow the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO[6]. So ON and OFF timings for RED, GREEN and YELLOW signals are managed as per traffic density on the roads.

II. LITERATURE REVIEW

The main idea is to reduce the traffic congestion problem is by responding to the dynamic changes in traffic demand. In

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other words, adjust the timing cycles of signals by extending or reducing the time period of RED and GREEN signals.

With the help of Machine learning techniques such as Reinforcement Learning and Fuzzy Logic, the self-adaptive traffic signal control system could be developed.

A. Reinforcement Learning

Traffic signals are intended to control the traffic conditions. A Well- designed algorithm can reduce collision, waiting and traveling time, which will help to both vehicles and pedestrians. On the other hand inefficient algorithm will cause more chaos.

Reinforcement Learning is a type of Machine Learning which allows software agents to automatically determine the ideal behaviour within a specific context. Reinforcement Learning based on 5 key terms; ENVIRONMENT (The Physical world in which the agent operates), STATE (Current situation of the agent), REWARD (Feedback from the environment), ACTION/POLICY (Method), VALUE (The Future reward that an agent would receive).

The traffic light system proposed in [7] is based on distributed multi-agent Q-learning. In this system, the surveillance cameras are deployed to determine the queue length of both vehicles and pedestrians. A Q-learning agent collects the local traffic data and stored it in the database. The agent also collects the neighbourhood data by exchanging the information through an available network and stored it in the same database.

The proposed system use length of a waiting queue as the STATE of the Q-learning algorithm. In each time slot, only one ACTION can be executed, this action is calculated and selected from the action set by the Q-learning agent that maximizes REWARD.

The Deep Reinforcement learning model proposed in [8] traffic lights are used to manage the flow of traffic at the intersection of a road. The traffic information is gathered from the vehicular network which the Mobile Ad-hoc Network that creates a wireless network for Vehicle-to-vehicle (V2V) data exchange. In this model, the current state and tentative actions are fed to the primary convolutional neural network to choose the most rewarding actions. The current state and action along with next state and received reward are stored in the memory as a four-tuple <s, a, r, s'>. From the previous experience data in the memory are selected and used to update the primary neural networks parameters. Target neural network is different to increase stability during learning.

The model in [9] is composed of an online and offline part. In the online part, it uses the description of traffic condition as state s and uses reward r to describe improvement due to the action. In the offline stage, it collects data and set a timetable for the signals, after training with data samples the model will be put into the online part. In the online stage, at each time interval, the agent will take action *a* by observing state *s* and get the reward *r*. Then the tuple (*s*, *a*, *r*) will be stored in memory.

B. Fuzzy Control System

The traffic flow on the road has uncertainty and randomness. Fuzzy logic helps to deal with such uncertainty. Fuzzy logic is suited for modelling such a problem.

The proposed traffic control system in [10] has two main functions first is fuzzy phase selector and second is fuzzy green phase extender. The signal control system gets data from the detectors of a junction. Fuzzy phase selector specifies which of the current red phase should switch to green in next phases and green phase extender functions by specifying whether current green phase should extend or terminate.

In [11] the proposed intelligent traffic light control system data is collected by two electromagnetic sensors placed on the road for each lane. In the traffic light controller, two input fuzzy variables are considered, first is the density of the traffic on the arrival side and second is the density of traffic on queuing side. The output fuzzy variable would be the extension time needed for the green light on arrival side.

Two stages fuzzy logic control method of the traffic signal based on traffic urgency degree [12], includes two modules; first is an evaluation of traffic urgency degree for red light phase which computes traffic urgency degree and selects the red light phase with large traffic urgency to switch to next phase. Second is decision module which increments the green light time according to fuzzy reasoning based on a number of vehicles of the current green phase and the next green phase.

III. DISCUSSION

The era of machine learning leads to develop the smarter and self-adaptive systems, it makes machines to work more likely to the human being. In this paper, two machine learning techniques that are Reinforcement Learning and Fuzzy Control System are described for developing Self-adaptive Traffic Signal Control System.

As Reinforcement learning is a critic based approach which is based on key terms such as State, Action, and Reward. First of all the software agent considers the real-world situation which is STATE, the traffic light agent then observes the state and performs ACTION whether or not to change the signal timing based on traffic conditions. After that agent observes the environment and gets feedback from it. If the feedback is positive is called as a REWARD. At last, the State, Action, and Reward stored in memory for next Action.

The Fuzzy Logic used to develop adaptive systems because it allows qualitative modelling of complex systems and it is good for systems with uncertainties. Fuzzy logic makes Traffic Signal Control System self-adaptive by extending the timing of GREEN signal based on the density of traffic on the

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road. It first selects the phase which has switch from RED to GREEN and then it decides whether or not to extend the GREEN signal phase.

All the proposed systems in the paper follow the same methods;

1. Acquire traffic data: Choose input method to acquire real-time images video of traffic.
2. Extract the traffic parameters: Determine the number of vehicles, number of pedestrians on road from images or videos.
3. Determine the traffic density: Decide the level of traffic density based on the number of vehicles on road in different sides and identify which side signals should update.
4. Update the signal timing based on traffic density: Switch from RED to GREEN signal or extend the timing of the GREEN signal if the traffic density is heavy. On the other side if the density of traffic is low reduces the timing of GREEN signal.
5. Control traffic flow: Keep the persistent changes in signals according to traffic flow rate to control it.

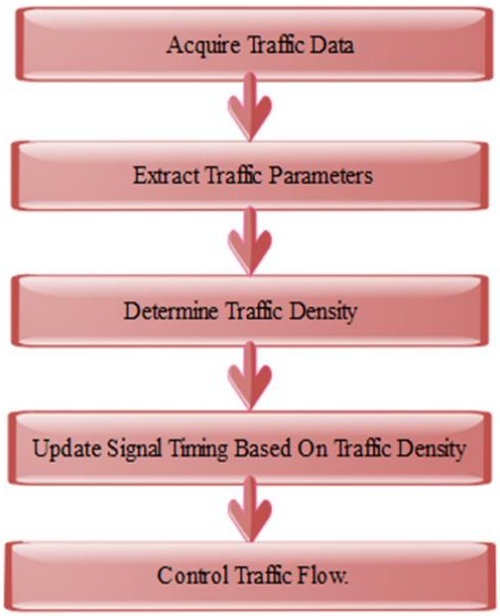

Fig.1.A Common architecture for self-adaptive traffic signal system

IV. CONCLUSION

This paper provides a review on Self-adaptive Traffic Signal Control System which controls the traffic on the basis of the density of vehicles. Nowadays mostly metro cities in India face traffic congestion problem which became a reason of wastage of time and fuel and many more issues. Current traffic signal control system is unable to handle heavy traffic and randomness of traffic. To manage traffic flow it is necessary that the Traffic Signal Control System must be Self-adaptive, so it can update signal timing according to conditions of traffic and this may be possible by using machine learning techniques. The paper summarizes the two machine learning techniques Reinforcement learning and Fuzzy Logic that will make traffic signal control system more efficient. In future, the further research in this area may lead the dynamic traffic signal control system.

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