Intelligent Traffic Signal Management using DRL for a Real-time Road Network in ITS

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The acceleration of urbanisation and the development of the pace of industrialisation help to grow the population of metropolitan areas, thus increasing the density of traffic flow. The sole way of managing traffic congestion is to mitigate it through optimising traffic signals at the intersections of a vast road network. The synchronization amongst the traffic signals at intersections is strongly needed in order to alleviate congestion and to allow vehicles to travel smoothly along intersections. Reinforcement Learning (RL) techniques in Intelligent transportation system (ITS) are not feasible for the management of traffic signals of large road networks due to enormous information of the state-action pairs. To overcome this problem, the emerging technology of Deep Learning allows RL to form Deep Reinforcement Learning (DRL) to measure up previously unwavering decision-making issues, for handling high-dimensional states and action spaces. DRL agents perform tasks through perception, monitoring the environment through action and learning as well as analysing the results of actions. In the present work, a single DRL agent is trained using the Policy Gradient algorithm in four different categories of Deep Neural Networks (DNN) to control the traffic signals dynamically. In case of a static road network, the functional implementation and efficacy of the Policy Gradient algorithm cannot be analysed accurately due to the less intricate details of static network. Hence, two different dynamic real time road networks have been considered here. Moreover, the real-time spatio-temporal information congregated from the dynamic real time map is provided as an input, so that the traffic signal duration can be adjusted adaptively in order to manage the traffic flow appropriately. The viability of the simulation experiment is investigated using three separate simulation metrics against the baseline, which is fixed signal duration frameworks and indeed the suggested method outperforms the baseline.

CCS Concepts: • **Computing methodologies → Reinforcement learning**; *Agent / discrete models.*

Additional Key Words and Phrases: Adaptive traffic signal Management, ITS, DRL, Policy gradient, Real time road network

1 INTRODUCTION

The vehicle industry has significantly developed due to flourishing technical progress and developments. Traffic uncertainty and unpredictability have surpassed the ability of traffic signal systems to work effectively on previously determined time schedules. As the traffic volume escalates, it also efficiently contributes to traffic congestion and road accidents. Highly dense traffic and slower speeds of vehicles characterise traffic congestion, which is a condition that exceeds the capacity of the lane in terms of traffic volume. It not only drains scarce public services, but also renders mobility resources unable to make the full collective usage that is incapable of allocating transport capital equitably. A number of traffic congestion problems occur, including unnecessary delays in travel, increased fuel wastage due to frequent frequencies of braking and intermediate gear [1]. However, there are common features and complex processes

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of managing traffic congestion in different metropolitan areas. To effectively monitor traffic flow, coordination between traffic signals at intersections must be improved; otherwise, congestion will continue to propagate across time to many other neighbouring intersections [2]. Interdependence among traffic signals at various intersections seems to be so significant for a metropolitan area that the variations in traffic signals can have repercussions on each other. Current traffic signal control methods also rely heavily on oversimplified knowledge and regulatory approaches, whereas recently there are enormous data, improved processing resources and sophisticated methods for driving smart transport. With an increase in population and modern innovations in transport systems, transport has developed into smart networks known as ITS [3]. Machine Learning (ML), on the other hand, seeks to control systems with minimal human intervention. Integration of ML and ITS provides adequate solutions for optimising traffic signal difficulties.

RL is a framework of ML, that is interactive with the environment and establishes the best policy for sequential decision-making in the various fields of sciences through trial and error method [4]. An RL agent verifies the status of the environment and therefore, carries out an operation. Any action performed earns a reward or penalty and this reward is determined by the environmental impact of the action. The goal of the agent is to learn the best selection technique to maximize the discounted cumulative reward by means of repeated ambient interactions. Generally, for a large scale road network, as state-action pairs extend exponentially, the difficulty of using RL in traffic signal management increases in an exponential manner. Deep Learning has been highly appreciated and combined efficiently with RL approaches to yield DRL [5] in order to solve this dilemma. DRL has been an effective solution for sequential decision-making control problems in recent years, and has shown an incredible success in complex, dynamic and high dimensional environments.

In the present work, efficiency of the Policy Gradient algorithm is tested in two real time dynamic road networks with multiple intersections in which traffic signal is connected to each intersection. The following are suggested contributions from the method proposed:

- An adaptive traffic signal management system based on DRL is proposed to monitor multi-intersection traffic signals as simultaneous control of all the traffic signals of the network permits more efficient traffic handling.
- The traffic flow is a sequential spatio-temporal data stream. The DRL agent uses this data stream of the traffic environment to coordinate the traffic signals on the intersections. In contrast, this understanding is indiscriminate in the sense in which the agent controls a single traffic signal.
- To precisely describe the temporal information of the traffic environment, a stack of five frames is used to define state representation. It encourages the agent to obtain more environmental knowledge, leading to a better choice of actions.
- The agent is trained using Policy Gradient algorithm in several Deep Neural Network (DNN) models such as Fully Connected Neural Network (FCNN), Convolutional Neural Network (CNN), Long Short Term Memory (LSTM), Gated Recurrent Unit (GRU) to estimate the best action selection policy to ensure effective traffic signal management.
- The productivity of Policy Gradient algorithm is already analyzed in a static network in [6]. However, dynamic real time networks help to portray actual scenarios with its associated complexities which is not possible to mention in static network. So, in this work, the entire simulation experiment is done in two different real time dynamic road networks, which is downloaded from OpenStreetMap (OSM).