AI Techniques for Urban Traffic Control and Mobility

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Abstract

The growing population has accelerated the process of urbanisation, and is putting under stress the urban transport infrastructure. This results in increased traffic congestion, with significant health, economy, and social issues. Artificial Intelligence techniques are increasingly demonstrating their capabilities in predicting and supporting urban traffic control, by extending the abilities of traffic authorities in planning and reacting to different traffic conditions. In this context, our main research topic fits in the autonomic traffic control theme, with the aim of supporting the design of autonomous traffic control systems.

1 Research Directions

According to a recent report from the United Nations, the proportion of world's population living in cities is expected to increase from the current 55% to 68% by 2045. This growth in urbanisation is going to exacerbate existing problems of traffic congestion in urban areas, that are already taking a significant toll in terms of economical and health costs. As the possibility to expand the physical infrastructure are limited, governments and traffic authorities are increasingly turning their attention towards the use of artificial intelligence techniques to maximise and optimise the use of the available infrastructure [Abduljabbar *et al.*, 2019].

The use of AI techniques is supported by the widespread availability of a variety of sensors, providing a wealth of spatio-temporal data that can help in gaining an overview of current and, potentially, future traffic conditions in a region of interest. It is also noteworthy that the advent of Connected Autonomous Vehicles (CAVs) can further extend the amount and timeliness of available data, as well as the range of operations that can be enacted by AI-based traffic control systems.

Traditionally, urban traffic control approaches have been designed to deal with changing traffic conditions to mitigate congestion and minimise delay for all network users. Leveraging on AI techniques and available data, there is now the potential for a game change in the field of traffic management and control; it is possible to predict in advance the likeliness of congestion or other issues in the network and proactively control traffic to avoid them. This can lead to fully autonomic traffic control systems, that can autonomously control traffic conditions, assess their likely evolution, and act if needed to ensure the best level of service of the network users.

Our main research topic fits in the autonomic traffic control theme, and the investigation we are performing is twofold. First, we investigate how model-based AI approaches can be used to support traffic engineers and to optimise traffic in urban regions, and second we explore how data generated from multiple sensors can be collated to support the design of accurate short- and medium-term traffic predictions.

2 Contribution

The specific contributions made on the research directions are summarised below, and focus on the use of knowledge models to support automated-planning-enabled traffic decisions and to support the day-to-day operations of traffic engineers. Further, we also considered the problem of demand forecasting for public transport systems.

2.1 AI-Enabled Urban Traffic Simulation

In [Bhatnagar *et al.*, 2022a] we demonstrated that specifically designed automated planning knowledge models, obtained by extending the work by Vallati *et al.* [2016], can lead to accurate simulations of traffic for the next 30-60 minutes in a region of interest. To verify the accuracy of the simulator, we compared simulated traffic to the snapshot estimated obtained from historical data collected by sensors in a region of the UK. Within the mentioned time limits, the measured average difference is of 10% in terms of expected vehicles. This result is of major importance for traffic authorities, that are generally not able to simulate large areas of the controlled regions due to cost of using commercial traffic simulators.

2.2 Urban Traffic Control via Automated Planning

In [Bhatnagar *et al.*, 2022b] we designed an architecture for the on-the-fly generation of planning knowledge models from existing sensors deployed in the area. We considered an area where SCOOT systems are in operation, and we demonstrated how to generate complete problem files that can be solved by state-of-the-art planning engines, as described in [Vallati *et al.*, 2016]. Further, we highlighted the challenges of validating and merging data collected from different types of source files, that are exacerbated in a real-time scenario.

On a related topic, in [Percassi *et al.*, 2023] we designed an efficient heuristic that can support planning engines in the task of traffic light optimisation to cope with planned events, such as sport events or concerts. The underlying idea is to identify the network bottleneck, i.e. the link or the junction that constrains the ability of a traffic corridor to move vehicles, and to optimise the corridor accordingly. The performed experimental analysis demonstrated that the heuristic can lead to the efficient generation of effective strategies for traffic lights.

2.3 Public Transport Optimisation

This line of work focused on the use of AI for supporting public transport systems, in particular the emerging customised bus system paradigm: this approach aims at proving on-demand transit services, where users can request in advance or when needed the use of a bus. In [Guo *et al.*, 2022] we investigated how to satisfy passengers' demand while minimising the operating costs of a customised bus system based on autonomous electric vehicles. The proposed approach, based on an adaptive large neighborhood search algorithm coupled with a greedy search technique, demonstrated to be able to generate high quality solution using historical data collected from the Beijing urban area.

3 Ongoing Work & Future Directions

Building on top of the contribution presented in the previous section, we are currently exploring three main research directions.

For the performed work, data has been mostly collected by a single data source, namely a SCOOT system in operation in the area of interest. While in many areas it is the case that no other data sources are available, it is becoming more and more frequent that a range of sensors are available, for instance CCTV cameras and Bluetooth sensors are now commonly deployed. We are investigating how to merge data from a range of data sources, with potentially different granularity and different levels of noise. This can pose serious challenges to the on-the-fly acquisition of knowledge, due to the need for identifying and correcting issues in data, but can also help to support short and long term predictions on traffic congestion [Ashwini and Sumathi, 2020].

Another area of investigation focuses on the identification of the most suitable models, between traditional time-series models [Barros *et al.*, 2015], graph based models, and sequential neural networks [Tedjopurnomo *et al.*, 2020] to exploit the potential of the huge amount of traffic data for traffic prediction. This analysis would also focus on approaches to support the work done on public transport.

Finally, we are interested in enhancing the scalability and flexibility of planning engines to control larger and more complex urban regions. In this regard, we are exploring the possibility to extend existing approaches to exploit parallel and cloud computing systems.

4 Conclusion

The growth in urban population is posing a serious challenge to urban traffic control. With an overall vision of creating an autonomic traffic control system, in this paper we presented the areas that have been investigated and where we plan to focus for future research. Of particular interest is the merging of data from a range of sources, that has the potential to support a more precise and comprehensive understanding of current and future traffic conditions.

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