بسم الله الرحمن الرحيم

شبكة المعلومات الجامعية

التوثيق الإلكتروني والميكروفيلم

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MONA MAGHRABY

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جامعة عين شمس

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قسم

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MONA MAGHRABY

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering Department

Traffic Control using Deep Reinforcement Learning

A Thesis submitted in partial fulfillment of the requirements of the degree of
Master of Science in Electrical Engineering
(Computer and Systems Engineering)

Submitted By

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Cairo, 2021

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Traffic congestion has a huge cost. Solving the traffic congestion problem has many benefits financially and environmentally. One of the methods of solving the traffic congestion problem is using a smart agent for traffic control rather than the currently deployed fixed-time traffic lights. The application of artificial intelligence to solving the traffic congestion problem has been going on for a while. However, most of the current research in this area depends on knowing lots of information about all vehicles in the network. While it produces promising results, applying these techniques in the current world is not easy.

In this research, reinforcement learning and deep reinforcement learning techniques are applied to the field of traffic control under the assumption that only minimal information is available. This approach produces results that are better than currently deployed fixed-time traffic lights without having heavy requirements. Two different models for solving the problem in a simple intersection are proposed. In the simple model test configuration, the agent's waiting time is 82.3% of the best fixed-time traffic lights' waiting time and the average CO_2 emissions produced by the agent is 97.5% of the emissions produced by the best fixed-time traffic lights. The advanced model test configuration reaches a policy which outperforms fixed-time traffic lights, and Longest Queue First (LQF) controllers. In constant probability, the best tested configuration waiting time is 85.76% of LQF controller and 75.15% of the fixed-time controller. In random probability, the best tested configuration waiting time is 96.43% of LQF controller and 87.18% of the fixed-time controller. The advanced model is applied to a complex intersection as well and outperforms a fixed-time traffic light after a few modifications.

Key words: Artificial Intelligence; Reinforcement Learning; Deep Reinforcement Learning; Traffic Control; Machine Learning

Thesis Summary

Traffic congestion is the condition that happens on traffic roads in which vehicles move at slower speeds than the normal road speed and the vehicle trips take longer time and queues of vehicles are formed. Traffic congestion has a massive cost. One cause of congestions is traffic intersections in which some of the vehicles have to wait for the others to pass to avoid accidents.

Traffic lights are used to control traffic inside an intersection by deciding which lane should be moving and which lane should be waiting to avoid accidents. The way traffic lights normally work is that they allow one lane to move while the conflicting lane is waiting for a fixed period of time and then switch to the opposite for another fixed period passing by an intermediate state in which it signals cars in the moving lane that this lane will be closed soon. These research experiments show the possibility of improving the currently widely used traffic lights controllers without needing huge investments.

Solving the traffic congestion problem has many benefits financially and environmentally. The application of artificial intelligence to solving the traffic congestion problem has been going on for a while. However, most of the current research in this area depends on knowing lots of information about all vehicles in the network. While it produces promising results, applying such techniques in the current world is not easy.

In this research, the thesis shows the potential of applying reinforcement learning and deep reinforcement learning in the field of traffic control without needing much information. Two models are proposed for controlling the traffic light. Both models show high potential as they beat the currently deployed fixed-time traffic lights in the problems under test. One model outperformed another controller based on longest queue first algorithm. That algorithm has access to more data than the suggested model, but its performance was worse.

Multiple configurations of the models were tested in a trial to understand the effect of different hyper parameters on the performance. These models can be deployed to the traffic lights without adding much cost like the approaches presented in most of the recent research in this field which depend on having lots of available data that are practically hard to acquire in today's world.

The thesis is divided into 7 Chapters as follows:

Chapter 1 is a quick introduction to the problem along with an explanation of the main contributions of this research.

Chapter 2 explains the theories upon which this research is based. It explains the concepts of reinforcement learning, and Q-Learning which is the base of the simple model and finally deep reinforcement learning which is the base of the advanced model.

Chapter 3 provides a formal description of the problem that is being researched. It explains the structure of the traffic intersection and the information that is available to the agent, the actions that are doable by the agent and the goal of the agent. It goes through some of the other work in the literature that is relevant to this research. The related work is divided into two categories:

- Single intersection which is divided into two approaches: Discrete state and continuous state approaches.
- Multiple intersections which is divided into two approaches: Coordinated and non-coordinated agents.

Chapter 4 explains the simple model which is based on tabular Q-Learning with details about the state, reward and action space. It also demonstrates the experiments that were done with the simple model. Two different model configurations are tested, one with a single sensor in each lane and the other with 2 sensors in each lane. It details the different traffic configurations tested in each case as well. It also shows the results that were produced in the experiments of the simple model along with a discussion of the results.

Chapter 5 explains the advanced model which is based on deep reinforcement learning and includes a neural network with details about the state, reward, action space and the structure of the model. It also demonstrates the experiments that were done with the advanced model. Two state configurations and two reward configurations were suggested and experimented. It also shows some experiments and results done to tune the hyper parameters of the model such as the number of sensors, the position of the second sensor, the dimensions of the neural network and the switch penalty factor. Finally, it explains the controllers that the agent is compared against and shows the results of the comparisons along with a discussion of the results.

Chapter 6 experiments with a complex intersection. It explains the intersection structure along with differences from simple intersection and possible new challenges due to the nature of the intersection. It explains how the advanced model was adapted to it then goes through some of the experiments that were carried out and their results along with a discussion of the results.

Chapter 7 concludes the work done in each of the models along with some suggested future work to continue this research.

Key words: Artificial Intelligence; Reinforcement Learning; Deep Reinforcement Learning; Traffic Control; Machine Learning