Solving The Urban Traffic Lights Scheduling Problem Using Mathematical Programming and a Firefly-Based Optimization Heuristics

by

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A Thesis Submitted to the

School of Innovative Design Engineering

Egypt-Japan University of Science and Technology

(E-JUST)

In Partial Fulfilment of the Requirements for the Degree of

Doctor of Philosophy

in

Industrial Engineering and Systems Management

2022

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SUMMARY

Traffic congestion is one of the challenges that face urban city planners, it affects the environment as it increases the emissions of CO_2 and the logistics systems as it increases the travel time of different vehicles, as well as the social and economic daily activities. There is no single approach that could tackle the traffic congestion problem. One possible way to decrease the impact of traffic congestion is to control the timings of traffic signals at the intersections to increase the flow passing through them via the scheduling of traffic light signals. In the urban traffic signals scheduling problem, it is desired to get the optimum schedule for each considered traffic signal to maximize or minimize a specific objective function(s); these schedules determine the active and inactive traffic phases during each cycle time.

Typically, there are two traffic signal control systems, the fixed-time control system and the adaptive traffic control system. In the fixed-time control system, the system parameters, such as the cycle length, the phase splits, and the phase sequence, are specified in advance based on historical data. This type of control system is suitable when the flow of an intersection shows no or low variability over time. On the other hand, in the traffic adaptive control system, The parameters are not fixed and are subject to changes according to flow rates and patterns. Hence, the adaptive control system can deal with the instantaneous flow of vehicles. The scope of this work is the adaptive control system as it is commonly used in the recent years and is considered the future of traffic control systems.

This thesis considers the traffic signal control problem through three phases: First, a mathematical programming model for solving the urban traffic signal scheduling problem is presented; the proposed mathematical model captures the physical constraints of the problem developing. The model is solved using Gurobi Optimizer as an optimization software to solve the proposed model which uses branch-and-bound algorithm in solving such types of models. The model is verified using randomly generated instances to ensure that all the constraints are necessary and sufficient to generate an optimum solution. The model could solve small instances however applying such a model to a real case study is impractical due to computational time limitations. Consequently, getting an optimum solution will consume a large amount of time. Hence, a Firefly-based heuristic is proposed to solve

the problem effectively and efficiently.The performance of both methods is simulated using the SUMO traffic simulator to verify the solutions. The performance of the solutions is measured using the average queue length of the vehicles for different roads, the average waiting time, and the average travel time.

Finally, to propose a model that could work adequately in smart cities where all the 4.0 revolution and IoT techniques could be applied, a Reinforcement Learning (RL) model with a new reward function is developed. The model controls the traffic flow dynamically with the change in traffic conditions. The RL agent is implemented using Python as a controller with many options. The Q-learning algorithm is used to learn how to take the right action that gives the best reward values. The new reward function outperforms the existing ones in minimizing waiting time and queue length, especially at low traffic flow. The results of the proposed methods are compared; although the mathematical model provides an optimum solution to the problem, the firefly-based heuristic provides an efficient solution to the problem (i.e. less computational time). Furthermore, the results of the RL model using the three different reward functions are investigated. The new proposed reward function outperforms the already existing reward functions in the reviewed literature.