OPTIMIZATION OF MULTI-AGENT TRAFFIC NETWORK SYSTEM WITH Q-LEARNING-TUNED FITNESS FUNCTION

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT

This study aims to explore the potential of implementing multi-agent-based Genetic Algorithm (GA) with interactive metamodel to acquire regular optimisation on dynamic characteristic of traffic flow. The idea is proposed in effort of accessing the functionality of the proposed algorithm to improve the smoothness of traffic flow in a network. As such, level-of-service of traffic network could be improved by optimising the utilisation of network capacity while minimising the travel delay and vehicles in queue. Traditionally, the common practice is to identify a fixed timing plan profile via offline and assumed it as a "nominal optimised" for the actual traffic flow. Whether the traffic signal is fully optimised under various traffic conditions, fluctuations in traffic demand and numerous uncertainties due to driver's driving behaviour remaining as a challenging topic. Scholars have proposed artificial intelligence (AI) to be integrated into the signal control system to improve the adaptiveness of the control system. However, the evaluation function used in the AI is developed based on historical traffic data. This offline predetermined evaluation function has limited the AI in exploring the stochastic and non-uniform traffic flow environment to search the optimum solution. Therefore, a notable fitness function with interactive metamodel for GA or known as improved GA is proposed. The dynamic environment causing the need of dynamic modelling for better dynamic optimisation will be catered via a specifically formulated interactive fitness function. The interactive metamodel is extracted using Q-Learning (QL) via online observing and learning of the outflow-inflow traffic characteristics. The improved GA is then embedded into the signal controller of every intersection or known as agent. Each agent has the autonomy in controlling their local intersection which are coordinated by a superior agent that has superiority in overwriting the local control decision if conflict occurs. The improved GA is tested using simulated grid traffic network model under various traffic scenarios. Results indicate the improved GA has improved 7.0 – 9.0 % in minimising the average delay as compared to the classical GA (without interactive metamodel).

ABSTRAK

OPTIMIZATION OF MULTI-AGENT TRAFFIC NETWORK SYSTEM WITH Q-LEARNING-TUNED FITNESS FUNCTION

Kajian ini bertujuan untuk menerokai potensi pelaksanakan sistem multiagen yang berasas Algoritma Genetik (GA) dengan iteraktif metamodel bagi mengoptimumkan aliran trafik yang dinamik. Idea ini dicadangkan sebagai satu usaha untuk mengakses kebolehguaan algoritma yang dicadang bagi meningkatkan kelancaran aliran lalulintas. Justeru, tahap perkhidmatan rangkaian trafik dapat ditingkatkan dengan mengoptimumkan penggunaan kapasiti rangkaian sambil meminimumkan kelewatan perjalanan dan bilangan kenderaan dalam barisan. Secara tradisional, profil pelan masa tetap akan dikenalpasti dan pelan ini akan dianggap sebagai "pengoptimuman nominal". Samaada isyarat lalulintas dioptimum sepenuhnya di bawah pelbagai keadaan trafik, variasi dalam aliran trafik dan beberapa faktor ketidakpastian yang disebabkan oleh tingkah laku pemandu adalah kekal sebagai topik yang mencabar. Oleh itu, para penyelidik mencadangkan penggunaan kecerdasan buatan (AI) untuk meningkatkan keberkesanan sistem kawalan lampu isyarat. Walau bagaimanapun, fungsi penilaian yang digunakan dalam AI adalah dibangunkan berdasar data-data aliran trafik masa lalu. Justeru, fungsi evaluasi tersebut mengehadkan AI dalam menerokai keadaan lingkungan aliran trafik yang stokastik dan tidak seragam untuk mencari penyelesaian optimum. Oleh itu, fungsi kecergasan yang ketara dengan iteraktif metamodel untuk GA dicadangkan. Keadaan dinamik menyebabkan keperluan iteraktif metamodel untuk pengoptimuman dinamik yang lebih baik dapat dipenuhi melalui fungsi kecergasan dinamik yang khusus dirumus. Model dinamik diekstrak dengan menggunakan Q-Learning (QL) melalui pemerhatian dan mempelajari ciri-ciri aliran trafik. Pendekatan yang dicadang itu kemudian dimasukkan ke dalam sistem kawalan bagi setiap persimpangan atau dikenali sebagai agen. Setiap agen mempunyai autonomi dalam pengawalan persimpangan masing-masing dan diselaraskan oleh satu agen penyelia yang mempunyai keunggulan dalam menggantikan keputusan kawalan jika konflik berlaku. Keputusan menunjukkan GA yang dicadangkan mampu meningkatkan prestasi 7.0 – 9.0 % berbanding dengan klasik GA (tanpa iteraktif metamodel).

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LIST OF ABBREVIATIONS

AF	–	Agent failure condition
AI	–	Artificial intelligence
ANFIS	–	Adaptive Neuro-Fuzzy Inference System
ANN	–	Artificial Neural Network
CBD	–	Central business district
CDF	–	Cumulative distribution function
CO_2	–	Carbon dioxide
DE	–	Differential Evolution
DE_{AW-AP}	–	DE_{AW-D} optimiser with adaptive population resizing
DE_{AW-AR}	–	DE_{AW-D} optimiser with adaptive reproduction mechanism
DE_{AW-D}	–	Decentralised Differential Evolution with average waiting
DE_{ED-AP}	–	DE_{ED-D} optimiser with adaptive population resizing
DE_{ED-AR}	–	DE_{ED-D} optimiser with adaptive reproduction mechanism
DE_{ED-D}	–	Decentralised Differential Evolution with estimated delay
DE_{IM-AP}	–	DE_{IM-D} optimiser with adaptive population resizing
DE_{IM-AR}	–	DE_{IM-D} optimiser with adaptive reproduction mechanism

DE_{IM-D}	–	Decentralised Differential Evolution with interactive metamodel
DMAS	–	Decentralised multi-agent system
FL	–	Fuzzy Logic
GA	–	Genetic Algorithm
GA_{AW-AP}	–	GA_{AW-D} optimiser with adaptive population resizing
GA_{AW-AR}	–	GA_{AW-D} optimiser with adaptive reproduction mechanism
GA_{AW-D}	–	Decentralised Genetic Algorithm with average waiting
GA_{ED-AP}	–	GA_{ED-D} optimiser with adaptive population resizing
GA_{ED-AR}	–	GA_{ED-D} optimiser with adaptive reproduction mechanism
GA_{ED-C}	–	Centralised Genetic Algorithm with estimated delay
GA_{ED-D}	–	Decentralised Genetic Algorithm with estimated delay
GA_{ED-H}	–	Hierarchical Genetic Algorithm with estimated delay
GA_{IM-AP}	–	GA_{IM-D} optimiser with adaptive population resizing
GA_{IM-AR}	–	GA_{IM-D} optimiser with adaptive reproduction mechanism
GA_{IM-C}	–	Centralised Genetic Algorithm with interactive metamodel
GA_{IM-D}	–	Decentralised Genetic Algorithm with interactive metamodel
GA_{IM-H}	–	Hierarchical Genetic Algorithm with interactive metamodel
GA_{PO}	–	Genetic Algorithm based programmable optimiser

GDP	–	Gross domestic product
GPS	–	Global positioning system
HMAS	–	Hierarchical multi-agent system
IoT	–	Internet of things
JKR	–	Public Works Department Malaysia
LAN	–	Local area network
LT	–	Left-turn
LWR	–	Lighthill-Whitham-Richards model
NC	–	Nominal condition
OC	–	Oversaturated condition
PDF	–	Probability density function
QL	–	Q-Learning
ROW	–	Right-of-way
RT	–	Right-turn
SC	–	Saturated condition
SCOOT	–	Split Cycle Offset Optimisation Technique
SCATS	–	Sydney Coordinated Adaptive Traffic System
SO	–	Swarm Optimisation