DRIVER BEHAVIOUR CLASSIFICATION FRAMEWORK IN THE CONTEXT OF CAR FOLLOWING FOR DRIVERS IN MALAYSIA BASED ON RANDOM FOREST ALGORITHM

MOHAMMED TALAL SALEEM

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Universiti Tun Hussein Onn Malaysia

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I dedicate this PhD thesis to my beloved family (my father, my mother and my sisters).

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ABSTRACT

Increasing road fatalities year after year is a significant challenge in many countries. However, real-time driver behaviour modelling in the car-following context for drivers in Malaysia has not been adequately studied due to issues with dataset, including availability, accuracy, completeness, diversity, data acquisition system availability, and techniques suitability. Hence, a five-phase methodology was designed to model driver behaviour in the car-following context for drivers in Malaysia. Review of previous work from literature, designing of a data collection system (DAS), profiling and analysing driver behaviour in the car-following context, classifying driver behaviour in the car-following context and solving issues related to missing LiDAR data represents the five phases of methodology, respectively. The real-time experiment on a federal highway road in Malaysia involved 30 participants. The results indicated that the proposed DAS design's efficiency, power, and capacity enabled it to collect driver behaviour data, pre-process it (on-board), and gather missing information due to road curvatures. Also, gender and age have statistically significant effects on drivers' behaviour during the car-following context for drivers in Malaysia. Female drivers are speedier (risky) and more cautious (keeping a long distance to the front car) than their male counterparts. Female drivers produced the optimum style and good stability behaviour in traffic flow and reported efficient driving style, while traffic status evaluation is difficult to be predicted when having male drivers on road. Senior drivers are regarded as safe drivers (less speedy) and are more prone to causing traffic disturbances than other groups of drivers. Middle-aged drivers reported efficient traffic flow characteristics. The classification framework showed that the Random Forest algorithm is the best technique, achieving 100% accuracy, 100% precision, and 100% recall, with speed and distance as the most effective classification features. The Random Forest algorithm can also impute the missing values of the LiDAR sensor. The result confirmed that the classification accuracy did not vary when using an imputed dataset (validation for the imputation process).

ABSTRAK

Peningkatan kematian jalan raya tahun demi tahun merupakan cabaran yang ketara di banyak negara. Walau bagaimanapun, pemodelan tingkah laku pemandu masa nyata dalam konteks mengikut kereta untuk pemandu di Malaysia belum dikaji dengan secukupnya disebabkan isu dengan set data, termasuk ketersediaan, ketepatan, kesempurnaan, kepelbagaian, ketersediaan sistem pemerolehan data dan kesesuaian teknik. Oleh itu, metodologi lima fasa telah direka untuk memodelkan tingkah laku pemandu dalam konteks mengikut kereta untuk pemandu di Malaysia. Kajian semula kerja terdahulu daripada literatur, mereka bentuk sistem pengumpulan data (DAS), memprofil dan menganalisis tingkah laku pemandu dalam konteks mengikut kereta, mengklasifikasikan tingkah laku pemandu dalam konteks mengikut kereta dan menyelesaikan isu berkaitan data LiDAR yang hilang masing-masing mewakili lima fasa metodologi. Eksperimen masa nyata di jalan raya persekutuan di Malaysia melibatkan 30 peserta. Keputusan menunjukkan bahawa kecekapan, kuasa dan kapasiti reka bentuk DAS yang dicadangkan membolehkannya mengumpul data tingkah laku pemandu, memprosesnya terlebih dahulu (pada papan) dan mengumpul maklumat yang hilang akibat lengkungan jalan. Selain itu, jantina dan umur mempunyai kesan ketara secara statistik ke atas tingkah laku pemandu semasa konteks mengikut kereta untuk pemandu di Malaysia. Pemandu wanita lebih laju (berisiko) dan lebih berhati-hati (menjaga jarak jauh ke kereta hadapan) daripada pemandu lelaki. Pemandu wanita menghasilkan gaya optimum dan tingkah laku kestabilan yang baik dalam aliran trafik dan melaporkan gaya pemanduan yang cekap, manakala penilaian status trafik sukar untuk diramal apabila mempunyai pemandu lelaki di jalan raya. Pemandu kanan dianggap sebagai pemandu yang selamat (kurang laju) dan lebih cenderung kepada penghasilan gangguan lalu lintas berbanding kumpulan pemandu lain. Pemandu pertengahan umur melaporkan ciri aliran trafik yang cekap. Rangka kerja pengelasan menunjukkan bahawa algoritma Hutan Rawak adalah teknik terbaik, mencapai ketepatan 100%, kepersisan 100%, dan ingatan semula 100%, dengan kelajuan dan jarak sebagai ciri pengelasan yang paling berkesan. Algoritma Random Forest juga boleh mengaitkan nilai penderia LiDAR yang hilang. Hasilnya

mengesahkan bahawa ketepatan klasifikasi tidak berbeza apabila menggunakan set data yang dikira (pengesahan untuk proses imputasi).

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LIST OF ABBREVIATIONS

ACC	Acceleration
ADAS	Advanced Driver Assistance System
ANOVA	Analysis of Variance
CAN bus	Control Area Network
DAS	Data Acquisition System
Dec	Deceleration
FC	Following Car
FIFO	First in First Out
FPGA	Field Programmable Gate Array
GPS	Geographical Positioning System
ITS	Intelligent Transportation System
LC	Leading Car
LiDAR	Light Detection and Ranging
MCU	Microcontroller Unit
NDS	Naturalistic Driving Study
OBD	On Board Diagnostic
OS	Operating System
TAIS	Time Acceleration Instability
TDIS	Time Deceleration Instability
TET	Time Exposed Time to Collision
TETH	Time Exposed Time Headway
THW	Time Headway
TIAI	Time Integrated Acceleration Instability
TIDI	Time Integrated Deceleration Instability
TIT	Time Integrated to Collision
TITH	Time Integrated Time Headway

TTC	Time to Collision
VANET	Vehicle Area Network

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This section and the ones that follow provide further information on the research's title and where it came from, addressing several study topics and elements. This section provides a brief description of the current state of the thesis problem and how it evolved and developed over time. It also includes the research objectives to help the reader understand the goals and aims of this thesis. The research questions and scope are detailed to describe the enquiries and the size and limits of the thesis contribution. Finally, the thesis layout provides a brief idea of the content of the subsequent chapters.

1.2 Car following context

Driver behaviour is accumulative learning built on human actions when driving a car. Like any other human behaviour, driver behaviour is generated from interactions with their surroundings, such as the environment, the car as a hardware machine, and cognitive factors (i.e., refers to the driver's cognitive abilities as a human). The abovementioned factors are made up of parameters shaping the driver's actions. As a result of the interactions, each group of people, specific community, or any defined type of population produce different driving behaviour/style due to driving conditions and environmental change according to traffic type and geographical location. In terms of traffic flow status, car-following behaviour is defined as the rear car being affected by the driving status of the front car when both cars are moving in the same lane.

The car-following model is one of the microcosmic driving behaviour models [1] [2]. Figure 1.1 shows the car-following scenario.

Many transportation applications depend on accurate driver behaviour modelling. ITS, microscopic modelling of traffic, and accident analysis and prevention are three key areas that could benefit from better understanding of driver behaviour [41] [3]. This section details organisations and other parties that stand to gain from advancements and improvements in this field of study.

The car-following model significantly assists in understanding factors/circumstances that influence driver behaviour and enhance traffic safety [4] [5], especially when nearing a car from behind in a variety of ecological surroundings [6], and in comprehending in what way motorists physically respond to various crucial circumstances and stream of traffic situations, such as a near-crash [7]. Understanding the causes of auto accidents and evaluating safety rules and regulations can be done by simulating driver performance, mainly mistakes, in the situation of a car-following situation in numerous simulated or actual experiments [7] [8], guaranteeing the configuration of reliable reactions to life-threatening cases [9]. Multiple metrics are represented by the characteristics that influence motorist performance in the context of car-following, such as road and real-time traffic flow situations. Models of car-following are changing over time and developing. Figure 1.1 presents a car-following scenario.

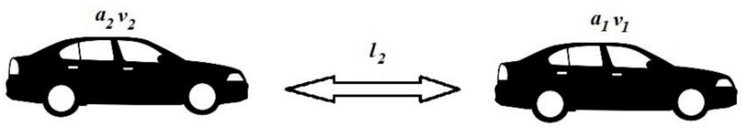

Figure 1. 1: Car-following Safe Distance Threshold [10]

Where, respectively, a1 and v1 represent the leading vehicle's acceleration and speed. L2 measures how close the leader and following are to one another. The accelerating speed and velocity of the car after it, respectively, are a2 and v2.

Complex traffic circumstances can be greatly influenced by different drivers with different driving styles. In the context of car-following, driver behaviour modelling can offer useful insights about traffic in terms of congestion, changing conditions, and continuous characteristics. Additionally, a car-following model can offer superior ways to end delays in busy places [4] [5] [6].

A good adaption approach for incorporating driver characteristics in ADAS can be built using elements of driver behaviour in the context of car-following. In order to maintain these technologies, satisfy people, and incorporate driving characteristics into intelligent system designs, ADAS adaption to driver behaviour is essential [11] [6] [12] [13] [14] [15] [16] [17] [18] [19]. Figure 1.2 shows how ADAS adapts to driver behaviour.

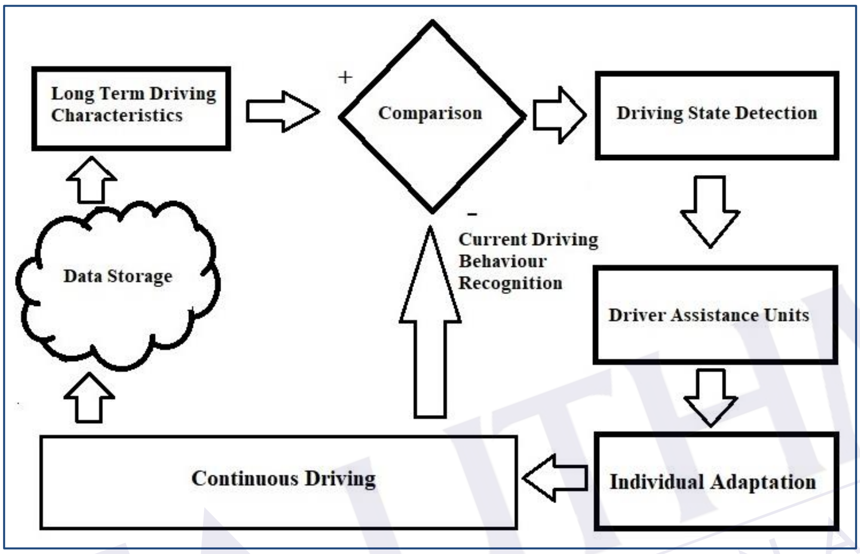

Figure 1. 2: ADAS Adaptation to Driver Behaviour [20]

Figure 1.2 presents the concept of the particular flexibility of the driver. The initial phase comprises deriving the characteristics of the driver, such as naturalistic headway distance, from the driving data of the driver, vehicle, and surroundings gathered using a continuous logging drive recorder. Identification of the deviating states, such as reduced attention and bad driving behaviour on the next driving task, is the next phase. By comparing the newly acquired driving data with a driver model that is based on extracted features and takes into account the longitudinal and lateral dynamics of the car, recognition is performed. According to how much the driving situation has changed, the system delivers driver support. Information on driver state can be utilised to choose the optimum assistance approach for the motorists, such as information assistance, driving advice, collision warning, or intervention operation, in order to promote driver acceptance of the system [20].

Advantages for ITS are mostly anticipated in the area of ADAS, in which some assistance/control logics or systems, like ACC, engage with motorists and where it is important to take into account both drivers' intentions and the effects of developments on their behaviour in order to increase (a) the efficiency of the innovations, (b) road (and traffic) safeness, and (c) acceptability of technology innovations [3] [21] [22].

Traffic focus and pace are greatly influenced by speed and the distance between two vehicles [23]. Moreover, a car-following model can recognise eco-habits and create automated processes that can be incorporated into the design of smart automotive products for autonomous vehicles [24] [25] [26] [27].

In the area of car-following, machine learning-based techniques are advised for modelling driver behaviour since they are faster, require less data handling, and avoid making long-term adjustments to metrics [28]. Additionally, machine learning techniques can reveal obscure characteristics that influence driving behaviour, providing a significant advantage in designing autonomous vehicles and comprehending traffic patterns [29] [30] [31]. Because they bring practicality, sufficiency, consistency, and further data inclusion to the modelling process, data-driven approaches can take the role of hypothesis-based approaches [28]. Online intelligent solutions that instantly recognise driving style can be implemented for the advantage of insurance companies and ITS development organisations [32] [33].

It is possible to use car following models to assess the loading conditions for bridges as well as to predict and test the traffic flow. The patterns of traffic loading have not received considerable attention [34]. When using precise information for specific populations, car-following models can produce useful results. Depending on their local environmental conditions, driving customs, automobile makes and models, traffic rules and policies, types of roads, and other variables, each group of people, country, or city displays a different driving behaviour. Examining driving practises in different nations' car-following contexts is crucial [35] [36].

During the car-following movement, the deceleration of the front car is shown in Figure 1.3. The four stages of the braking procedure include the response of the driver to the initiation of the braking light, the braking action, continuous braking, and the braking release. The following distance between the front and following cars in the free-running/flowing stage can be provided based on the examination of the braking technique in the car-following context when the driver of the following car observes the emergency braking of the front car [37]:

$$S_1 = V_0 . t_1 \tag{1.1}$$

The braking distance in braking action stage S_2 is as follows:

$$S_2 = V_0 . t_2 - \frac{1}{6} a_1 . (t_2)^2 \tag{1.2}$$

The braking distance in continuous braking stage S_3 is as follows:

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APPENDIX D

VITA

The author was born on May 9, 1987, in Baghdad, Iraq. He completed his secondary school at several schools at Baghdad, Iraq. He pursued his degree at Al-Nahrain University, Iraq, and graduated with the Bachelor Eng. in Electronics and Communication Engineering in 2009. Then, he was engaged in 2013 in the Master program at Communication Department, Engineering College, UNITEN university, Malaysia. The author was pursuing Ph.D. in the field of Electrical Engineering at Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia (formerly known as Institut Teknologi Tun Hussein Onn), 86400 Parit Raja, Batu Pahat, Johor, Malaysia. During this time, Mr. Mohammed Talal has the main author for many academic papers in areas of electronic and communication engineering.