ACCURACY AND QUICKNESS CRITERION-BASED DRIVING SKILL METRIC FOR HUMAN ADAPTIVE MECHATRONICS SYSTEM

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To my beloved mother and my family ☺

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ABSTRACT

Current research is focusing on understanding the driver in order to develop a car driving support system. The car driving support systems must rely on a reliable driving skill algorithm in order to provide optimal support. Previous studies on skill algorithm have combined tracking error and time related variable into algorithm formulation. This method however does not include a car orientation and lateral speed information as an integral part of the algorithm. Two new variables are introduced into the algorithm structure, namely, orientation angle and lateral speed. Nine participants were carefully recruited for a driving test to validate the algorithm. A simulated driving environment was specifically devised for this experiment. A driving track used in this experiment was segmented into five different severities for data analysis. Two fundamental goals have led to the collection of the data and the subsequent data analysis. The first is analysing the variables in relation to the driving task. The second involves data analysis being further extended into analysing the algorithm performance over estimating the driving skill index. The results reveal that the proposed variables are well correlated with the driving task, and improvement in algorithm performance is found to be almost double compared to previous algorithm.

ABSTRAK

Kajian penyelidikan terkini menumpukan perhatian kepada memahami pemandu bagi membina sistem sokongan pemanduan. Sistem sokongan pemanduan kereta perlu bergantung kepada algoritma kemahiran pemanduan yang boleh dipercayai bagi memastikan sokongan yang optimum. Kajian terdahulu telah menggabungkan ralat penjejakan dan pembolehubah yang berkaitan dengan masa ke dalam formulasi algoritma. Kaedah tersebut bagaimanapun tidak mengambil kira orientasi dan kelajuan sisi kereta sebagai sebahagian daripada formulasi algoritma tersebut. Dua pembolehubah baru diperkenalkan ke dalam struktur algoritma, iaitu sudut orientasi dan kelajuan sisi kereta. Sembilan peserta telah dipilih dengan teliti bagi menjalani ujian pemanduan untuk mengesahkan algoritma. Persekitaran simulasi pemanduan telah dibina secara khusus untuk eksperimen ini. Trek memandu yang digunakan dalam eksperimen ini telah dibahagikan kepada lima jenis kesukaran yang berbeza bagi tujuan penganalisisan data. Dua dasar telah membawa kepada pengumpulan dan penganalisisan data. Yang pertama adalah menganalisis pembolehubah berkaitan dengan tugas pemanduan. Yang kedua melibatkan analisis data yang diperluaskan dalam menganalisis prestasi algoritma dengan menganggarkan indeks kemahiran pemandu. Keputusan menunjukkan bahawa pembolehubah yang dicadangkan adalah sangat berhubung rapat dengan tugas pemanduan kereta, dan peningkatan dalam prestasi algoritma didapati hampir dua kali ganda berbanding algoritma sebelumnya.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

There is a growing number of disciplines for human-friendly mechatronics designs, such as human-factors engineering, ergonomics design and human centred design. No matter how well mehatronics are designed, however, there are always situations where the user has to adapt to a certain level of mechanical system handling. The reason is that, usually the machine itself is not designed to adapt to every human operator, although a human operator can adapt to every mechatronics system. A car is an example of the most unusual mechatronics system encountered by humans on a daily basis.

1.1.1 Human factor in road accident

It has been a challenge in driver behaviour since the the emergence of the automobile. With the rapid increase of vehicles on the road, safety has become a tremendous problem. Accidents can occur due to vehicle driving that could jeopardize not only the driver, but also passengers and the vehicle's surroundings. This requires measures that restrict the usage of vehicles and help the driver to drive in a safe and practically efficient manner.

Furthermore, because of the driving task is generic in nature this approach of evaluating driver skill can be generalized to other dynamic human-machine systems. This study is predicted to contribute, but not limited, to the following areas: skill quantification methods, intelligence driver support systems, HAM systems, human-machine collaboration systems, human-centered robotics, human-machine compliance systems, human-factors engineering, and ergonomics design.

1.3 Outline of the thesis

Chapter 2 presents an in-depth review of the literature on human skill evaluation, including several methods for characterizing human skills from the perspective of HAM systems, as well as knowledge on driver-car interaction. The purpose of this study is to understand human driver control action skills, and to describe the background and motivation behind this research. An analysis of the driving skill metric estimator algorithm development is given in Chapter 3. This chapter also describes the hypothesis suggested in this thesis, which is built upon previous algorithms proposed in the literature. Chapter 4 describes the methodology devised to test the validity of the proposed hypothesis, and the realibity of the algorithm in a controlled simulated driving environment. The method for data analysis used in this thesis is also discussed at the end of the chapter. In Chapter 5, all the data from the experimentation is presented. In this chapter, the important relationship between past research, the purpose of the current study, and the stated hypothesis is explore extensively. Lastly, the purpose and findings of this thesis are summed up Chapter 6, which also provides a conclusion and recommendations for future work.

driving task activities such as obstacle avoidance, or headway control are out of the scope of this work, and are not addressed.

The scope of this thesis is limited to path tracking driving skill of drivers holding a Malaysian driver’s license. In order to test behaviour that representing vehicle path tracking control, a scenarios of open car track similar to that of a normal roadway, with different conditions of curving severity have been chosen. This study was conducted in a limited experience of driving environment (i.e., the use of a simulated driving environment). There however still a need to study in practical life application although the experience of driving simulator is quite similar to drive in real environment. The objective measures taken are used for characterization and modelling typical behaviour of Malaysian road drivers.

1.2.5 Contribution of the thesis

This thesis proposed an improvement in current driving skill metrics. Four driving parameters related to the car handling task are selected from path tracking vehicle kinematics model. Those parameters which include $\theta_p, d, \dot{d},$ and $\dot{s}$ are then grouped into two distinct cumulative index namely accuracy, J_A and quickness, J_Q driving criterion. The component of J_A are θ_p and d while $\dot{d}$ and $\dot{s}$ are component for J_Q. The driving skill metric J is then a cumulative of those two driving criterion (i.e. J_A and J_Q are component for J).

Those selected driving parameter (i.e. $\theta_p, d, \dot{d},$ and $\dot{s}$) were shown to have a strong correlation against driving task after validated through a series of driving test experiment in a simulated driving environment which devised specifically for this research. Thus they are viable for the purpose of evaluating driving skill. Furthermore, the improvement of proposed driving skill metric is also validated. It is also proven that the proposed method is almost double in its performance as compare with previous metric.

1.2.2 Importance of work

Generally, skill quantification is very important in designing human machine collaboration. Thus, a driver support system needs first to understand and recognize the driver's competency level (i.e., driving skill) before it is able to provide the most suitable type of support to optimize overall system performance and better guide the driver in the learning process.

In addition, the driver support system needs a reliable skill estimation algorithm in order to provide suitable support and optimum enhancement. In conjunction with that, it requires a high integrity metrics to estimate the particular level of driver's skill. Thus, the research objectives are formulated as discussed in the next subsection.

1.2.3 Objectives

From the background discussed previously, the objectives for this research are formulated as follows:

(i) To define the car handling skill.
(ii) To find the parameters that related to car handling skill.
(iii) To develop the skill algorithm based on the selected parameters from objective (ii).
(iv) To analyze and verify the improvement of proposed algorithm against the previous studies.

1.2.4 Scope and limitations

It should be noted that, this thesis is hold on the assumption of a human remaining in control of a machine most of the time. To establish a more manageable scale of this study, this thesis only emphasis on the control aspect of the path tracking driving task. Many driving behavioral aspects that less related to common surroundings. Thus, this requires measures that can help the driver to drive in safe and practically efficient manner.

There are already many available method of driver support systems had being developed found in literature. They include total vehicle automation [19, 20] and system that work with driver either as advisory or emergency intervention to avoid collision system [21-23]. Because of driver is the greatest contributor in all road accident [2], method of driver support then must move beyond automated system by attempting to work in harmony with a human driver.

If driving parameters correlated to a particular car handling skill could be made available, this might be used for driver identification. Knowledge of driver-specific competency and preferences can be of great use in adaptive configuration of adjustable driver support systems [24, 25].

Driving skill, seen from controller's point of view, is defined as the ability of the driver to adjust the configuration of his/her control strategy according to response of vehicle system. It also suggested that the parameter of driver model is dependent on the vehicle parameter [26]. It can thus further be argued that any parameter from the car kinematics model can be used as driving parameter to determine driver characteristic.

Previous study on driving skill quantification method combine tracking error and time related driving criterion into driving skill metrics [10, 27]. This method however did not include car's orientation angle and lateral speed control information as an integral part of the driving skill metric. The aim of this study is to overcome such major drawbacks of current driving skill quantification methods. The new driving skill metric should incorporate parameter of car kinematic model for better driving skill estimation accuracy.

A driving test was conducted to investigate and validate the viability of the choosen parameter to represent driving skill as well as to validate the new metric performance inprovement.

proposed driving skill metric will be validated in a series of driving test in a simulated driving environment devised specifically for this research.

1.2 Research background

Current research has directed great focus on driver experience in operating a car to improve driving performance. Driver support systems need to first understand and recognize the driver's competency level of handling the car before they are able to provide the most appropriate type of support to optimize the overall system performance, as well as to help the driver better during the driving learning process to improve his/her driving skill.

This study investigates the method of quantifying driving skills for driver support systems involving validating the selected driving parameters as well as the driving skill metric performance against previous studies. Nine participants carefully recruited for the driving test. In order to test driving behavior that representing vehicle path tracking control, a scenarios of open car track similar to that of a normal roadway, with five different conditions of curving severity have been chosen.

It need to be reminded that the general topics of (1) driver's behavior understanding and (2) modeling the behavior; are quite broad in scope, when taken individually, or together. Thus, this study focuses only on car handling skill in path tracking driving task.

1.2.1 Research problem

As previously discussed, almost half a million of Malaysian citizens are at risk of road accident every day [3]. 46.9% of all accidents are caused by human factor [2]. Thus driving safety has become a tremendous problem since road accidents could jeopardize not only the driver, but also passenger and the vehicle's

In current vehicles safety systems, drivers do not have the possibility to receive detailed feedback about their individual driving competency. Moreover, drivers do not know whether the control parameters of the car are suitable for their individual skill level. In addition to challenging traffic, car handling skill is a vital factor. An intelligence system capable of providing personalized support for correct driving judgment, enhancing car handling skill and performing control support to maintain a reliable and accurate track of driving competency is the primary focus in driver support system design. It is however, a challenge to design a system that is adaptive to the driver rather than to the automotive characteristics. [15, 16].

A human Adaptive Mechatronics (HAM) system is the new paradigm of mechatronic system design. This system concept involves making mechanical systems more intelligent that have capability to adapt in various level of humans skills, as well as providing support that optimize control performance as well as improving the human operation skills [17, 18]. This new concept of system design is a useful framework in personalized car support system design.

1.1.3 Quantification of car handling skill

In driving, humans manipulate a series of complex car handling controls. Drivers have the capability of planning their next control strategy in case of track curving, obstacles and etc. For example, drivers control the car’s orientation in negotiating with circumstances, and utilize input information such as road severity and car state.

Driving skill index is one of the important parameters that must be made known by the car to understand the driver before its get into assisting the driver in a HAM system perspective. The index gives a measure of how well the driver is performing the driving task.

This study aims to investigate the driving parameter for the development of driving skill metric, which is the measure of the car handling quality index (i.e. driving skill index) of a driver. The chosen car handling parameter as well as

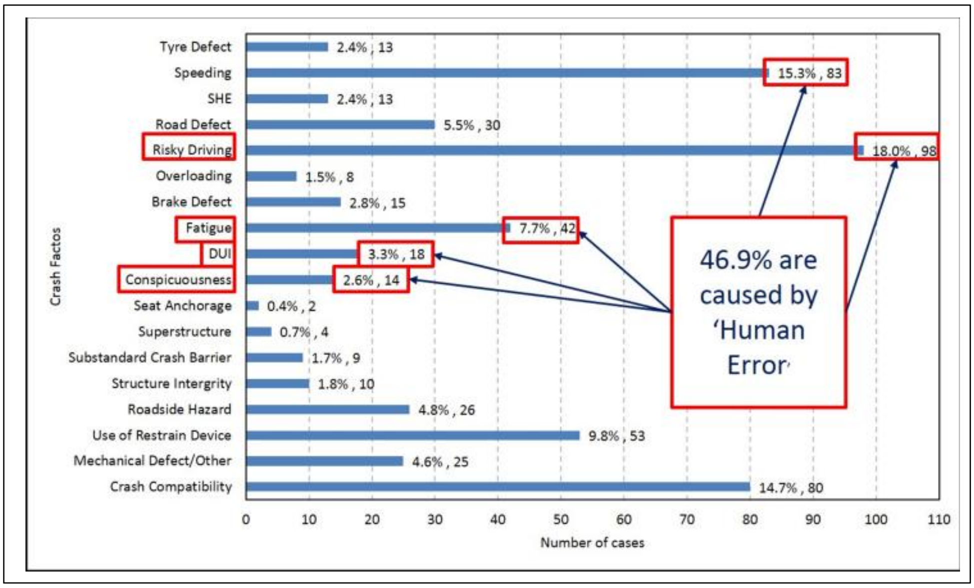

Figure 1.2: The factors that contribute to road accidents [2].

The contribution of the different factors that cause road accidents is found to be propotionated as depicted in Figure 1.2. The human factor is the greatest contributor, which is contributes to 46.9% of all accidents [2].

In summary, road accidents are problematic for intelligent car support and safety system design. Furthermore, it is suggested that the driver is the greatest factor that contributes to road accidents. This calls for a reconfiguration of active and preventive safety systems measures, preferably with settings that adapt to the characteristics of the individual driver, i.e., personalized car support systems.

1.1.2 Driver adaptive car support system

The prevention or reduction of traffic accidents requires countermeasures that have to be devised and introduced to prevent the behaviors that contribute to accidents. Current studies on vehicle-driver support systems that focus on car safety systems include collision warning, collision avoidance, as well as cooperative driving, and vehicle navigation and guidance systems. These systems are commonly referred to as Intelligent Transportation Systems [13, 14].

Accidents in Malaysia are reportedly increasing in number. The total number of casualties due to road accidents involving motor vehicles was 326,817 in 2004. According to the Ministry of Transport Malaysia, this number has increased to 477,204 accidents (146%) in 2013 [3] (Figure 1.1). Every day, almost two percent (or half a million) Malaysian citizens are at risk of road accidents.

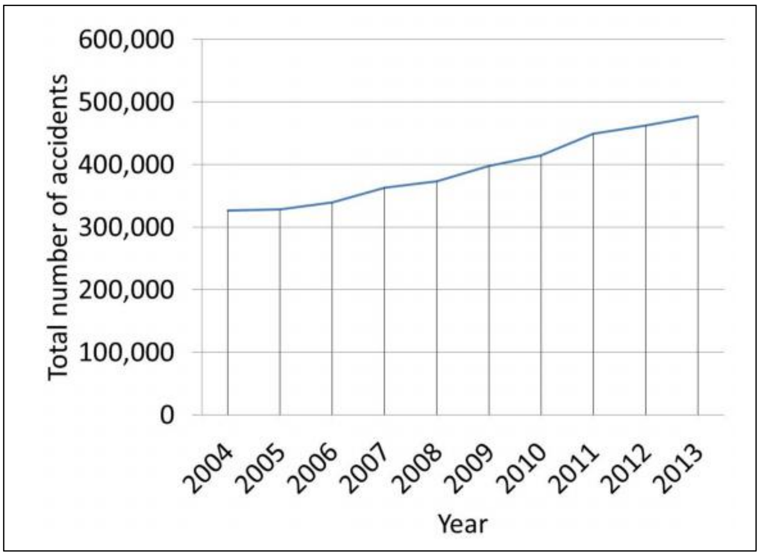

Figure 1.1: Total casualties caused by road accidents in Malaysia from 2004 to 2013 [3].

Factors that cause of car road accidents can be grouped based on several factors, namely, human, vehicle and road environment factors [12]. In general, the human factors are described as actions and behaviour of human driver throughout the time of the accident. Example of driver characteristic includes: speed is not appropriate for the situation, carelessness, driving skill, and driver impairment. Vehicle factors refer to mechanical faults or poor design of the vehicle also include lack of maintenance. Road emvironment factors include road design and road environment for example slippery road due to weather conditions.

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