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CAR POSITION AND ORIENTATION BASED DRIVING SKILL METRIC FOR ANALYTICAL DRIVING SKILL INDEX EVALUATOR

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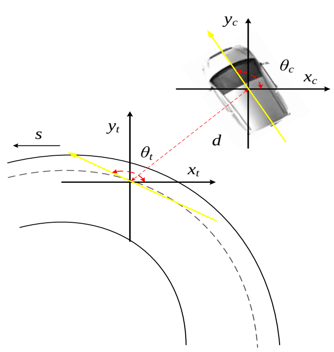
Graphical abstract



Abstract

This paper proposes an improved driving skill metric incorporating car-track deviation angle and car position off-set correction agility. The main advantage of the method is which it provides more accurate since this research is using more variables in the formulation for the skill metric compared to the old metric by using the same sample group of subjects. This paper reports nearly an average of 95% of improvement for the new skill metric estimation accuracy. The analysis further reveals the metric also has better driving skill index estimation consistency. The proposed method herein offers a means for characterizing driving skill in response to car-track input information and improving the intelligent behaviours of car support system.

Keywords: Human Adaptive Mechatronics, Skill Index, Human Machine System, Driving Application

1.0 INTRODUCTION

These days, our life is surrounded by machines. There are a lot of machines and gadgets that invented by human such washing machine, mobile phone and toaster. However, these gadgets or machines are operated dependently with human assistance. Therefore, human skill is the main subject since human comes with different skill and abilities.

Therefore, human factors become as one of the primary elements to be conceived to design the motion control system [1]. Unfortunately, the main curb of the human machine system (HMS), it is a one-way communication between human and machine whereby the machine is unable to adapt the human skill. It caused an unbalance condition of interaction between human and machine [1].

In order to solve this issue, human adaptive mechatronics (HAM) has been introduced. HAM is defined as an intelligent mechanical system that adapts themselves to the human skill under various environments, improves human skill, and assists the operation to achieve the best performance of the human-machine system [2]. This is leading to the development of new products, processes and systems that exhibit quality performance, such as reliability, precision, smartness, flexibility, adaptability, robustness and economical features [3].

It also allows to create, design and support the development of new concepts for realizing intelligent human oriented machines that can think, coordinate and featured by interactive cooperation with their human users [4].

2.0 RESEARCH PROBLEM

Based on an online newspaper article [5] which mentioned that Malaysia road is among the most dangerous place in the world due to high fatalities occurrences. Malaysia was ranked as the 17th unsafe place for driving. This is due to high percentage of fatalities for road accidents that occurred in Malaysia.

This fact is also supported by research done by The University of Michigan Transportation Research Institute [6]. From that research, Malaysia is listed as number 17 from the 193 countries for 'Fatality rate per 100,000 Population from Road Crashes', which means that 30 percent of fatal rate caused by road crashes besides the other three leading causes of death studied. The data used is applicable for the year of 2008, but it came from the World Health Organization (WHO) 2014.

Besides that, based on the investigated cases by vehicle type, passenger car take the highest percentage from 2008 to 2010 [7] compared to lorry, bus, motorcycle and other type of vehicles. There are numbers of injury and crash occurrence factors by horizontal and vertical profiles of the road. There are reasons of the crash occurrences which is conspicuousness, driving under influence (DUI)[8], fatigue, brake defect, overloading, risking driving, road defect, safety, health and environment (SHE) compliance, speeding and tire defect. The three highest factors that caused the crashes are risky driving which 93% while 69% is caused by the speeding driver and 44% for fatigue drivers.

Besides the reasons stated from the research done by researchers [7], there are other reasons that can caused the road accidents such as sleepy drivers [9, 10], over-confident drivers [11-13] and other reasons that come from drivers behavior [14-18]. Besides that, it also shows that passenger cars conquer the fatalities compared to the other type of vehicle. From this, it is determined that human error is the main reasons for the fatalities occurrences which involving passenger cars.

Based on the previous study [6, 7], the numbers of accidents or car crashes are increasing since 2008 until 2010. From the statistics it clearly shows that human error as the main factor of the car accidents. Basically, human requires time and high determination in order to operate a machine. The same thing applied for a car driver, human must get to know the car first before he can drive the car. Human should learn and know how to operate and manage the car in variety circumstances. Hence, human requires supervision and training to increase their knowledge and understand more about the car handling.

Driving a car is considered a manual control of complicated processes [19]. It involves dynamic interleaving and implementation of numerous critical subtasks [20]. From these situations, it is well explained that only human has the capacity to learn and understand the car, but unfortunately the car is unable to take part improve the skill and performance of the car driver. It shows that human (car driver) play an important role as a main controller and the machine (car) does not have the capability to identifies and adapt the changes of human features.

Based on the rising issue, this study is expected to assist human while driving a car. As for earlier stage, this research will come out with an algorithm that able to evaluate the human skill for driving applications. This paper will introduce an improved analytical driving skill metric, in which car-track deviation angle, θ_p and car position off-set correction agility, $\dot{d}$ is directly concerned in the model. The remainder of the paper is organized as follow: Section 3 will introduce to the existing formula. Then, the improved driving skill metric is discussed in Section 4, in Section 5 will discussed about experimental setup. The data process will be discussed further in Section 6 while the estimation accuracy of driving skill metric and result can be found in Section 7.

3.0 EXISTING FORMULA

In spite of various aforementioned method of characterizing human skill is empirical basis, there is a need to improve adequate performance criteria for evaluating human operating skill. However, in literature, there is a method of analytically quantification of human operating skill based on task accuracy and completion time criterion [21, 27]. This model is referred as criterion based skill metric. Based on this idea, for car driving application, a driving skill metric has been developed to measure and evaluate driver skill index as shown in (1). Figure 1 shows the preliminary test result of that model accuracy to estimate normal level driving skill index in simulated environment driving with estimation accuracy resulted at average 56.41% and with variability 29.58.

$$J = a - b(T_n + E_n) \quad (1)$$

The values of parameter a and b are 1 and 0.5, respectively. The detail of the metric development can be found in [22, 26]. Generally, this driving skill metric is inspired from linear model with shifting factor, a and scaling factor, b. From this model point of view, the driving task is reduced to just a line following task. T_n is time required by the driver to complete a driving task while E_n is driver road tracking error. In general, E_n and T_n can be appropriately see as speed and accuracy related

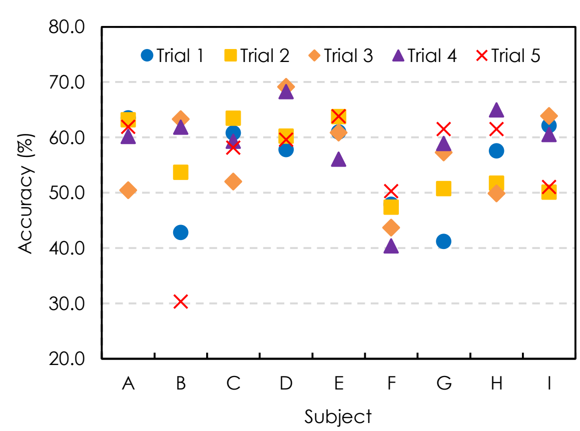


Figure 1 Results on previous driving skill index estimator accuracy

skill metric performance criterion respectively.

From Figure 1 it is shown that previous skill index metric does not show a quite low accuracy in determining a particular driver skill index which its capability can only provide an average of 56.41% of estimation accuracy. Furthermore, the consistency is very poor and it is clearly shown that throughout the course of the five trials of experiment by nine participants it is unable to maintain its integrity in estimation. The test shown a high variability in estimation which valued as 29.58 of accuracy estimation variance among participants. An ideal driving skill metric should be theoretically at 100 percent in estimation accuracy and valued as 0 (or no variability) for estimation variance.

4.0 SPEED AND ACCURACY BASED DRIVING SKILL METRIC

4.1 Framework for Driving Skill Metric Performance Criterion

In order to analyze the interactions between human subject computer Figure 2 shows the schematic diagram of car and road and its respective variables involve inspired from [23]. The car instantaneous position state variable is defined by x_c and y_c. θ_c and θ_t are car deviation angles and angle tangent to the road curve with respect to global coordinate respectively. The perpendicular distance between the car axles and the path is given by d. The distance travel along the road path at some arbitrary initial position is given by s, the arc length while $\vec{v}$ is the car linear velocity.

Based on aforementioned idea, the driving skill metric in (1) is improved in its T_n and E_n criterion specified as in (2).

Improved driving skill metric:

$$J = a - b(A + S) \quad (2)$$

where,

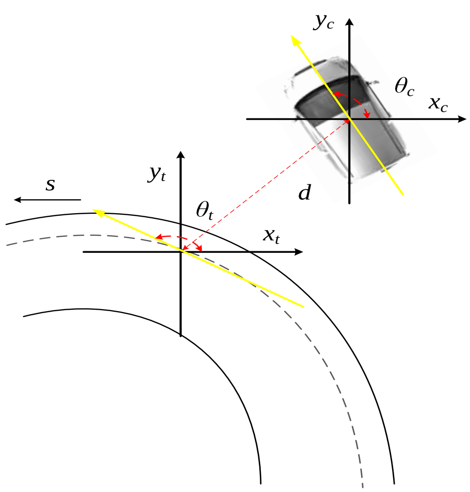


Figure 2 Setting of the variables for performance criterion of the driving skill metric

Accuracy performance criterion:

$$A = w_1\, d + w_2 \theta p \quad (3)$$

Speed performance criterion:

$$S = w_3 \dot{d} + w_4 \dot{s} \quad (4)$$

Car-path deviation angle:

$$\theta p = \theta c - \theta t \quad (5)$$

Velocity along the path:

$$\dot{s} = v \cos \theta p + \dot{\theta} t\, d \quad (6)$$

w_1,w_2, w_3 and w_4 are the theoretical parameter for the performance variable as shown in (3) and (4).

Theoretically speaking, the parameter could be an integer or a function of other independent variable. θp and d are variables for accuracy performance criterion. $\dot{d}$ and $\dot{s}$ are variables for speed performance criterion.

4.2 Variables processing – Normalization & Reflection

The variables mentioned above have to undergo theoretical normal driver normalization process using (7). In addition, for accuracy performance variables treatment, there will be an extra process called reflection as in equation (8) because of its strictly decreasing performance characteristic.

A theoretical normal driver normalization process is a process that transforms actual performance variables to actual-theoretical value ratio. Given x_1,x_2, … x_i, …, x_N a series of raw performance variables logged from a human operator. The normalization process is shown in equation below;

$$x_{norm} = \frac{\sum_i^N x_i}{x_{theo}} \quad (7)$$

The x_{theo} is variable value for a theoretical normal driving skill. In addition, all the performance variables i.e. θp, d, $\dot{d}$ and $\dot{s}$, for (3) and (4) must be processed by (7) before skill index is calculated. Monotonicity or magnitude interpretation of the performance variables become a great deal as accuracy and speed variables does not have a common monotonicity. The extra processing for the strictly decreasing performance variables is called reflection. A reflection is a process required for only a strictly decreasing performance variable by translating a point on one side to the opposite of a mirror (axis of reflection) while preserving its distance [24]. It can be proved that a reflected variable (x') can be calculated by using the normalize variable and theoretical variable (x_{theo}) as follows:

$$x' = -x + 2x_{theo} \quad (8)$$

5.0 EXPERIMENTAL SETUP

For the experimental operation, this research consists of two parts, which are hardware and software setup. The software setup covers the driving simulator arrangement while the hardware setup is for the steering wheel and pedals. According to Ertugrul

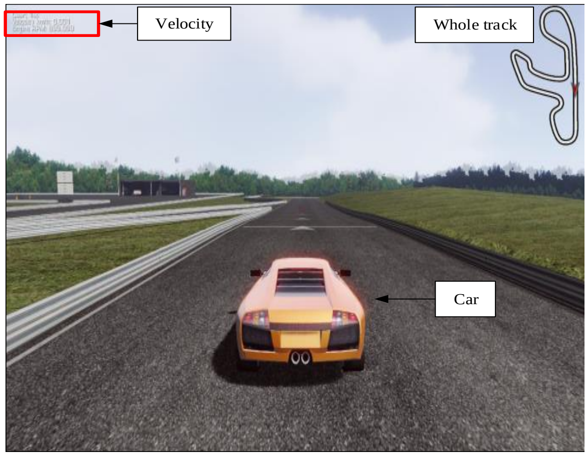


Figure 3 The driving simulator used for this experiment

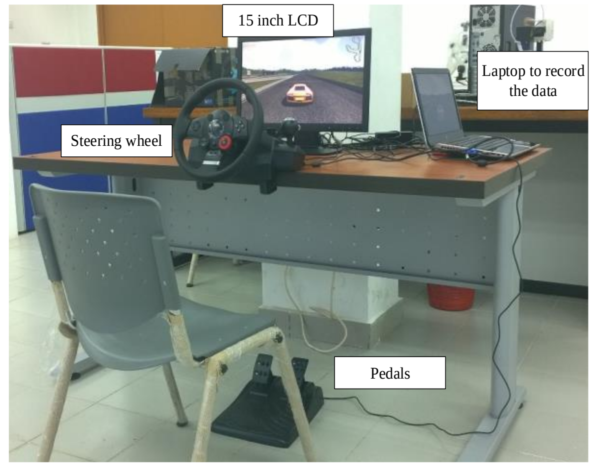


Figure 4 The hardware setup for this experiment

[25], driving is considered as one of the complex mechanical tasks that involved skill, human and machine.

5.1 Driving Simulator

Driving simulator used to analyze the interactions between human subject and computer simulation software. The experiment involves 9 human subjects with various driving (real-life and gaming) experiences. Subjects are instructed to follow predefined track as accurately as possible in the shortest as shown in Figure 3.

5.2 Hardware Setup

The experiments have been done by using a set of steering wheel and pedals manufactured by Logitech. The setup is shown in Figure 4. The steering wheel is attached to a desk to avoid rocking or slipping during the experiment. The gas pedal and brake are independent to each other.

5.3 Track

The driving simulation gives user an experience like driving in actual environment. The participants will drive in a track as depicted in Figure 5. Only a part of the track as segmented (red) will be used for data analysis. The segmented track characteristic will be discussed later in this paper.

In the driving simulator environmental setup, some parameters need to take into consideration. Table 1 shows the track and environment characteristic while Table 2 shows the car characteristics parameters for this experiment.

Track segment characteristic use for data analysis is depicted in Table 3. It is simplified and assumed, that the driver follows the center of track path. To test the skill index accuracy, this paper use method as shown in (9). The deviation between the actual values of driving skill index, J against theoretical

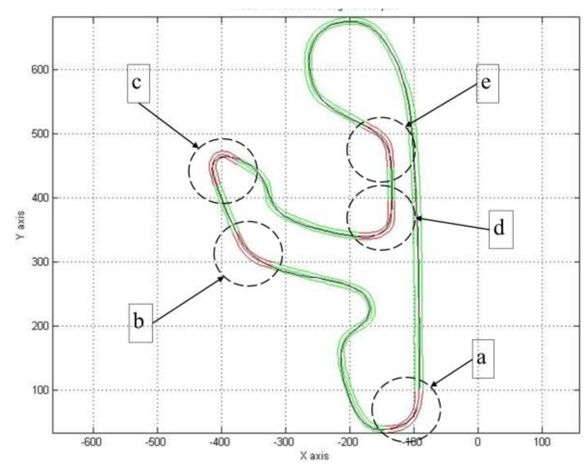


Figure 5 Track course (green) use in the study with segment (red) used for skill metric analysis

Table 1 Track and environment characteristic

Track length	2.5km
Day/Time	Daylight time i.e. 1100 hour
Environment	Clear; no fog and rain
Track surface	Asphalt and dry
Track width	10m

Table 2 Car characteristic

Horse power	580
Type of wheel drive	All-wheel-drive
Mass	1650kg
Top speed	329.93km/h
Other	0-0.97 km/h in 3.4 seconds

Table 3 Track segment characteristic used for skill metric estimation accuracy data

Segment	Start	End	Length
1	124	309	185
2	371	556	185
3	865	956	93
4	1025	1130	105
5	1254	1359	105

normal driving skill index, f will give information of how well the driving skill metric track the driver skill index. The percentage ration of that information over the f is the value of driving skill index accuracy, J_{acc}.

$$J_{acc} = |(f - J)|/f * 100 \tag{9}$$

5.4 Participants

Nine participants are carefully selected from both laboratory personnel as well as postgraduate student. All participants have knowledge of driving and held Malaysia's driving as well as ethical approvals were obtained before the experiment. In addition to that, all participants must have no history of neurological deficits. Participant that had exceptional skill in gaming and driving cannot be selected. Driver that had lack of driving knowledge also cannot participate in this experiment. In short, only driver that is categorized as normal skill driving are interested.

The participant will be given a five minutes' time to be familiar with the driving simulator before the test begin. Then, the participant is explicitly instructed to complete the driving through the track course for five laps with five minutes in between lap rest. In the course of diving, the participants must maintain car stability and she/he is not allowed to overshoot, over steer as well must maintain all four tires on the road or otherwise, the experiment is considering fail.

During the course of experimentation, it is assuming that there is no disturbance effect cause on the driving simulator hardware. In conjunction to that, it is also assumed there is no measurement noise recorded before the data is analysed.

6.0 DATA PROCESS

Based on the experiments done, the raw data will be collected. Then, the raw data will be processed before analyzes steps. This processing step is to extract the desired portions of the whole data. The desired portions of the collected data include, elapsed time, velocity, the coordinates of the car and the artificial intelligence best line for the track. Finally, the extracted data will be analyzed using MATLAB. Before proceed to the analyzing process, the collected data are required to undergo processing stage. Then the data extracted to Figure 6 shows the process done for the data before the researchers can used it for the analyzing purpose.

7.0 RESULT AND DISCUSSION

For both old and new driving skill metrics using same set of drivers. This research is limited to group based, which means, different group of subjects will provide with different skill metrics. By comparing the data in Figure 1 and Figure 7, it is clearly shows that the accuracy of driving skill index estimation is improved.

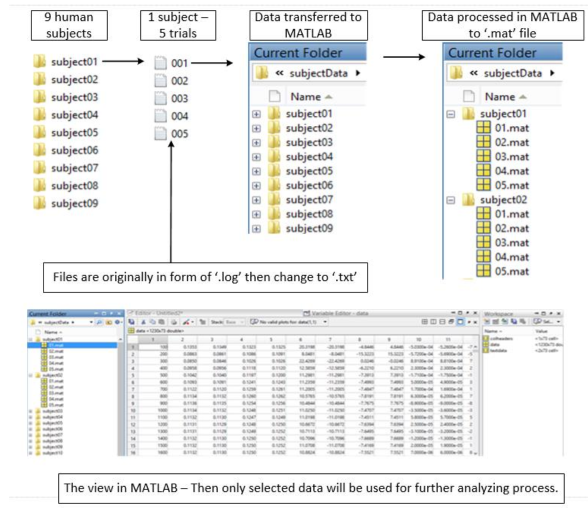


Figure 6 The data were undergone few steps before it is being used for the analyzing process

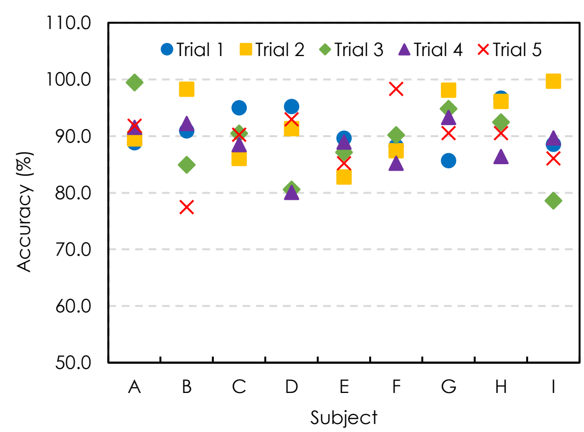


Figure 7 New driving skill index estimator accuracy

Table 4 Comparison between Both Skill Index Estimation Accuracy for Both Skill Metrics on Different Track Segment

		Segment				
		a	b	c	d	e
Accuracy (%)	J_{acc1}	56.42	49.22	46.89	44.39	48.51
	J_{acc2}	92.80	94.06	93.30	89.27	95.22
Improvement (%)		64.46	91.11	98.98	101.12	96.29

In addition, average estimation accuracy of improved skill metric is now increasing to 89.93% from 56.41%. The current estimation accuracy variability is now reducing drastically to 4.42 from 29.58. It thus proves that there is improvement in skill metric integrity as well as consistency in this new skill metric capability.

Further data analysis result shows in Table 4 on the driving skill index estimation accuracy for both skill index metrics test on different track segment. J_{acc1} and J_{acc2} are old and improved skill index metric respectively. From the Table 4, J_{acc2} shows an average of 93% estimation accuracy as compare to just 49% for J_{acc1}. It shows 95% of improvement in the new skill metric estimation accuracy.

In this study, the theoretical parameter for the performance variables w_1,w_2, w_3 and $w_4$are assume to be equal to one. It is not in this study interest to study the parameter values associates with the performance variables. Those parameters however, could contribute a significant information relating to those performance variables hence performance criterion. Thus it is open for a research opportunity in this area.

This paper however ignores performance variations due to the randomness of human motor-sensory process, emotions, fatigue and motivation in fact, the human operating skill does not relate to this attributes. Furthermore, this research also does not include the external circumstances and operating point which is important for the analysis of skill or performance evaluation. However, indeed a great significance to for those attributes to become an integral part of the driving skill metric.

8.0 CONCLUSION

Apparently, more driver attributes than simple time and error-ness factor can effectively estimate driving skill level. This paper concludes that the driving skill estimation accuracy can be quantified analytically using linear based driving skill metric by incorporating θp, d, $\dot{d}$ and $\dot{s}$ variables with better integrity and consistency. Furthermore, it can be further hypothesized that for more information on the car characteristic is included in the driving skill index formulation metric, the more accurate skill index will it be.

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