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Driver`s Steering Behaviour Identification and Modelling in Near Rear-End collision

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Abstract

This paper studies and identifies driver`s steering manoeuvre behaviour in near rear-end collision. Time-To-Collision (TTC) is utilized in defining driver's emergency threat assessment. The target scenario is set up under real experimental environment and the naturalistic data from the experiment are collected. Four normal drivers are employed for the experiment to perform the manoeuvre. Artificial Neural Network (ANN) is proposed to model the behaviour of the driver`s steering manoeuvre. The results show that all drivers manage to perform steering manoeuvre within the safe TTC region and the modelling results from ANN are reasonably positive. With further studies and improvements, this model would benefit to evaluate the driving reliability to enhance traffic safety and Intelligent Transportation System.

***Keywords**: driver behaviour modelling, driver steering manoeuvre, rear-end collision avoidance, artifitial neural network*

1. Introduction

Mobility is a part of the routine in human`s everyday basis and greatly contributes to the equality of life, as well as driving the economic growth and success. In conjunction with that, safe transportation system is vital for all parts of the society. However, the increasing numbers of the vehicle on the road gives negative impacts toward transportation system and and degrades the safety of the road users. Referring to the world Health Organization (WHO) reports, decades ago, road accident becomes one of the major contributors toward the world`s course of death [1]. From the global view, approximately 1.2 million people around the world die on roads and 20 to 30 million withstand non-fatal injuries yearly. It is predicted that, if current trend keeps on rising, road accident becomes the world`s third leading cause of death by 2020 [2].

Based on the reports provided by Malaysia Institute of Road Safety (MIROS) and Ministry of Transportation Malaysia, the figure of road accidents in Malaysia is increasing from year to year. Statistics show that in 2013 alone, the number of road accidents is increased by 3.1 percent compared to the year before and the figures remain increasing [3]. Rear-end collision is one of the contributor to accident causation in Malaysia [4]. According to the statistic and law, rear vehicle driver taking full or about 70% to 80% responsibility in rear-end collision if happened and it is widely accepted that driver error or unreliable behaviour of the drivers and unpredictable movement choices are key factors that contribute strongly to the crash [5]. Based on [6], cognitive error and inattentive or distracted driving are among major reasons of the road collision. Rear-end collision can be avoided or reduced if the driver can identify the potential risk earlier and take immediate corresponding measures. Thus, understanding how to mitigate or avoid danger associated with inattention and distraction is becoming increasingly important because of the emerging technology which has potential to increase the driver error [7].

Currently, driver behaviour identification and modelling received much attention from researchers and gives great impact in many, such as traffic flow microscopic simulation [8], Intelligent Transportation system for Advance Driving Assistance system (ADAS) [9] and vehicle dynamic [10]. Thus, the purpose of this work is to identify and model the driver`s steering

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manoeuvre behaviour in near collision particularly for rear-end collision situation with the presence of distraction whilst driving.

The neural network approach is proposed to establish the driver’s steering manoeuvre behaviour model. Based on real experiment set up, rear-end traffic environment is established and tests of driver`s steering manoeuvre behaviours in rear-end environment are done.

This paper is organized as follows. Section 2 presents the methodology in order to achieve the objective of this study, such as the configuration of research platform, experiment setup and data acquisition of target scenario, and modelling of driver steering manoeuvre behaviour. Result and discussion can be found in section 3 and conclusion in section 4.

2. Research Method

2.1. Configuration of Research Platform

This study uses real vehicle platform named i-Drive to perform data acquisition. This platform was designed to fit the intelligent vehicle system related activities and equipped by several systems and modules, which are 1) Embedded Computer for data processing and monitoring, 2) In-Vehicle Controller Unit, 3) Data acquisition module such as Vision Monitoring Unit, Inertial Measurement Unit (IMU), steering control module, perception processing Module (radar-related parameters, one front radar and two rear radars-left and right). User Datagram Protocol (UDP) and Controller Area Network (CAN) are utilized for the mean of the communication system such as data exchange between in-vehicle modules and remote monitoring for data collection. Specification of the i-Drive system and radars are depicted in Table 1 and 2 respectively.

Table 1. Specification of i-Drive

Vehicle Model	Proton Exora 1.6 CPS
Engine Type	1.6 CamPro CPS DOHC
Maximum Output[hp(kW)/rpm]	125(93)/6500
Maximum speed (km/h)	170
Maximum Torque(Nm/rpm)	150/450
Transmission	4-speed automatic
Dimensions(mm)	(L)4592 x (w)1809 x (H)1480
Kerb Weight (kg)	1400 to 1486

Table 2. Specification of radars

Parameter	Front Radar	Rear radar
Distance Range (m)	1 to 90	1 to 50
Azimuth Angle (degree)	$\pm 50^0$	$\pm 75^0$
Elevation Angle (Degree)	$\pm 8^0$	$\pm 6^0$
Cycle Time (ms)	50	38
Radar Frequency Band (GHz)	24.0 – 24.25	24.05 – 24.25

2.2. Data Acquisition and Target Scenario

The experiment adopted in this paper was focused on driver`s steering manoeuvre behaviour in near collision with preceding vehicle which suddenly decelerate at the maximum speed and stop in the middle of the road [11]. Since, the experiments were conducted in real situation, safety precautions were the priority, and the substitution of static obstacle was used to replace the sudden stop of the preceding vehicle.

The configuration and scope of the collision avoidance experiment is shown in Figure 1 and the derivations of the experiment are as follows:

1) The road is two-sided straight road with width of 3.5 meter each as shown in figure 1a).
2) Static obstacle was located in the middle of the left lane and the i-Drive vehicle moves at a given constant speed (between 50km/ to 60 km/h) towards it.
3) Road condition during the experiment was normal and dry.

4) Drivers were requested to emphasize steering intervention rather than the braking action during performing avoidance manoeuvre.
5) Two cones were used in this experiment to indicate the important points. Cone B was set where the driver receives the distraction from distracter, which positioned at the right side of the road and finishes the distraction at cone A. The distance between cone B and cone A is 20 meters.
6) The introduction of the distracter in this experiment was intentionally to disturb the driving activity of the driver. He/she was required to put her/his hand up and begin to make some gesture until i-Drive vehicle reached cone A. During the distraction time, drivers were approximately can be said lose ability to focus and control the vehicle.
7) Avoiding manoeuvre only happens on the rightward due to enough space for the i-Drive vehicle to pass through.
8) Cone A is the point where drivers begin their steering manoeuvre to avoid collision from happens. The location of cone A is 30 meters away from the obstacle. Quantitatively speaking, this range was decided by considering an important parameter called Time-To-Collision (TTC), [12] noted that TTC plays an imperative role in threat assessment for collision avoidance. TTC is defined by:

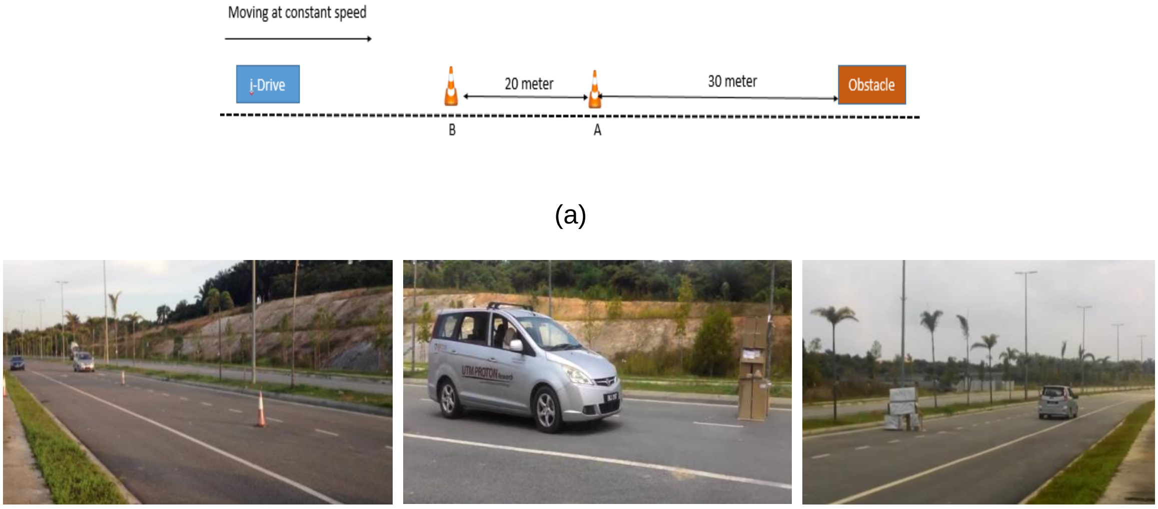
$$TTC = \frac{Relative\ Distance\ Between\ cars}{\text{Relative Velocity Between cars}}$$

In this study, the elected TTC is 2s, and this value is generally recognized as a sufficient range and time to evade the critical situation [13].

In order to model the driver`s steering behaviour during the avoidance manoeuvre, the following sensory information were taken as the inputs to the driver.

1) The distance between the i-Drive vehicle and the obstacle (from front radar).
2) The relative velocity between the i-Drive vehicle and the obstacle (from front radar).
3) The speed of the i-Drive vehicle (from In-Vehicle control unit).
4) Yaw rate of the i-Drive vehicle (from Inertial Measurement Unit).

The outputs from the drivers are stated as follows: steering angle of the i-Drive vehicle (Encoder from steering Control Module).



(a)

(b)

Figure 1. a) and b) The configuration of collision avoidance experiment

2.3. Procedure of Experiment

In this study, four drivers have carried out the manoeuvre assignment under real environmental experiment set up. The details of the drivers are tabulated in Table 3. Each of them needs to perform 10 times of collision avoidance manoeuvre by steering alternately between each other to keep the driver`s risk perception towards the obstacle persist. The drivers were asked to drive the i-Drive vehicle at a given constant speed and by the time the i-Drive vehicle reaches cone B, drivers were supposed to have a look at the right side of the road to see the distracter hand`s gesture until the distracter pull down his/her hand (i-Drive vehicle already reached cone A). At this moment, drivers need to look up straight again and perform the steering manoeuvre to avoid the obstacle. The manoeuvre behaviours were measured from cone B until drivers finished the collision avoidance trajectory. Before the real experiment, drivers were given, 5-time trial session to practice and to get use to the i-Drive system.

Table 3. Individual information of the driver

Driver	Age (Year old)	Driving experience (year)
A	26	7
B	28	8
C	33	13
D	33	10

2.4. Steering Modelling using Neural Network

Driving activities and driver behaviours are nonlinear in nature and have no particular form. Artificial Neural Network (ANN), can be considered one of the effective candidates to model such system since it is suitable for problems which have difficulties to establish the clear link between cause and effect [14, 15]. Modelling and system identification in ANN can be established by using teaching signal and input data. Thus, this study used ANN in modelling the driver`s steering manoeuvre behaviour. Figure 2 shows the structure of ANN that is employed in this study and it comprises input layer, one hidden layer with 10 hidden neurons, and output layer in the frame. The network will be trained by using Levenberg-Marquardt back propagation algorithm since this algoritm requires less tranning time and the transfer function used between inputs to hidden layer and hidden to output layer are sigmoid hidden neurons and linear output neurons respectively. All the related parameters that were collected from the experiment are used as input data, training data and target to ANN. The input and target data literally consisted of four parameters and one parameter respectively as depicted in Figure 2. Before proceed to the training stage in ANN, data processing procedure was performed in order to increase the reliability of the collected data. The most optimal trajectories (minimum tracking error) data are selected as an input to ANN. As a result, 30 data out of 40 steering manoeuvre in total are used as inputs to ANN. From these data, 20 of it are used for training and learning for the means of model development and 10 are classified as unlearning data, which are utilized for observing the efficacy of the developed model.

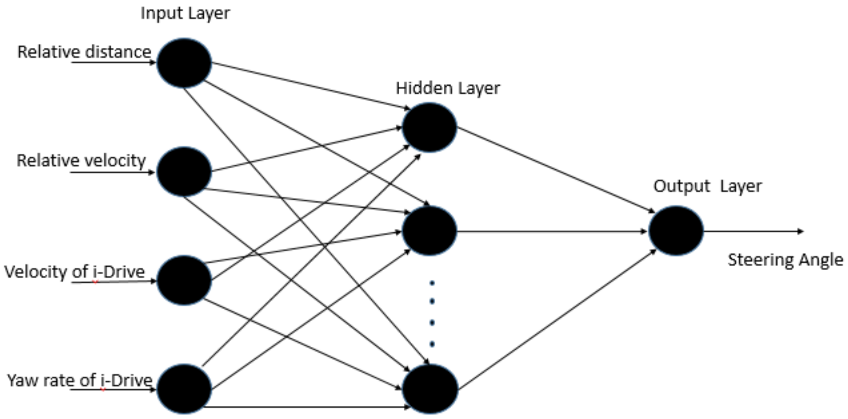


Figure 2. Neural Network configuration

3. Results and Analysis

In this section, results and discussions that related to this study are presented.

3.1. Experimental Results

Based on the experiment set up in the earlier section, all data from examining drivers were collected and four profiles of driving data (a trial of each driver) are shown in Figure 3-5. The distance that measures in meter (x-axis) for all data was attained from front radar and 0(zero) meter showed where the obstacle was located. In all figures, a) and b) illustrate yaw rate and steering angle of i-Drive vehicle respectively, from those figures, it can be observed that, even though distraction was given during driving, all drivers managed to perform steering manoeuvre within the safe TTC region (approximately 30 meters from the obstacle) with the average steering angle between 60^0 to 90^0. This finding indicates that proper selection of Time-To-Collision (TTC) could contribute to the success in avoiding the collision from happen. In figure C) from all figures, shows the speed of the i-Drive vehicle when approaching the obstacle, and the results indicated that there are slight decrease in speed during avoidance manoeuvre, because of drivers tend to release the throttle pedal to reduce the speed rather than use the brake to secure the manoeuvre. From that observation, braking action can be considered just to assist the driver “if needed” (in this study breaking action is considered null) during avoiding task with steering. Therefore, it can be supposed that the steering action seems to include high-level decision making than the braking action. In the following analysis, focus is given to the relationship between the sensor information and the steering operation.

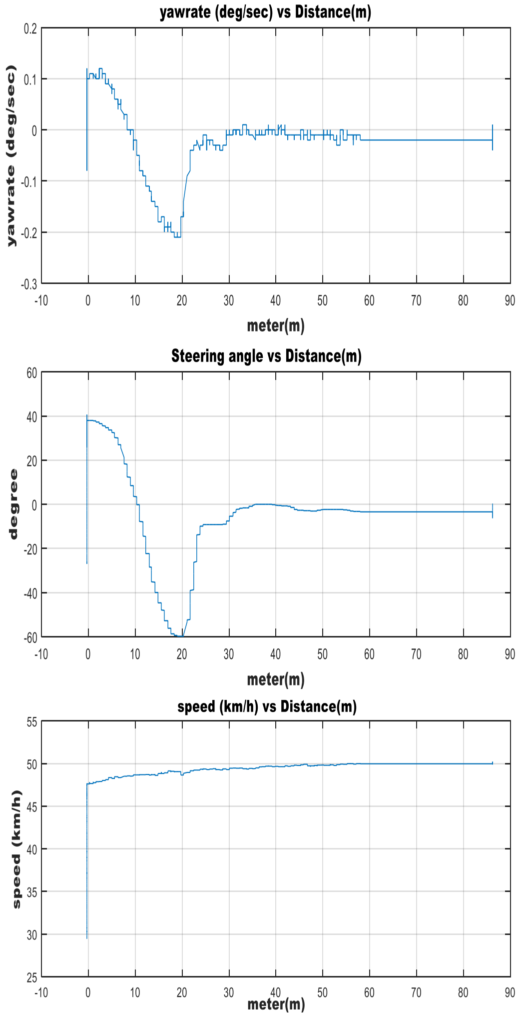


Figure 3. Driving Profile of Driver A

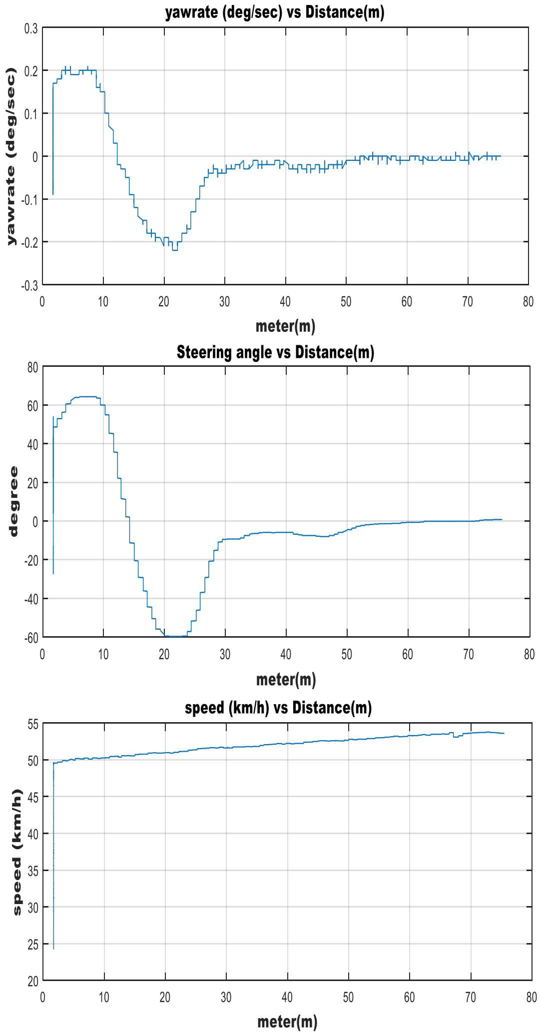


Figure 4. Driving Profile of Driver B

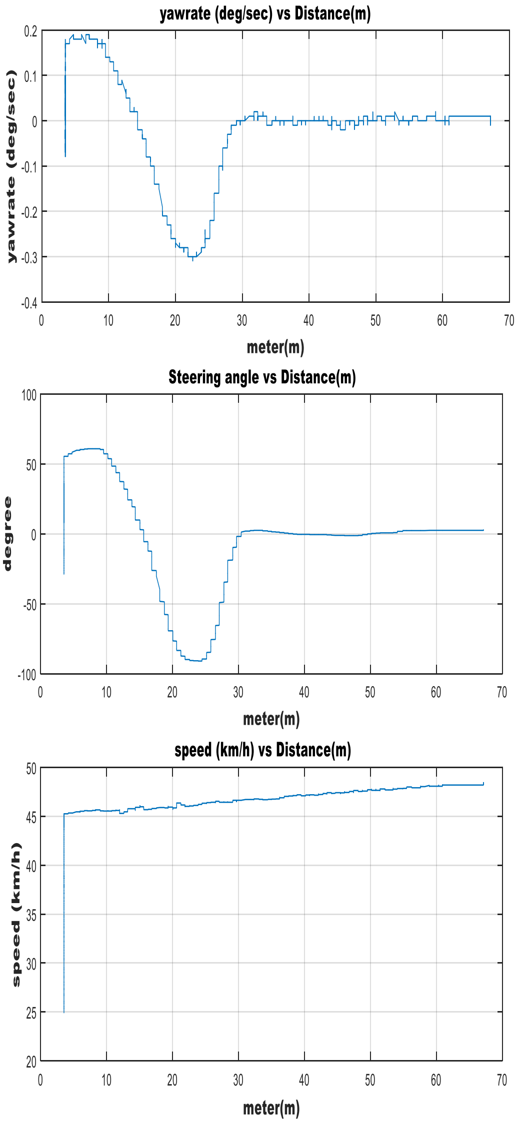


Figure 5. Driving Profile of Driver C

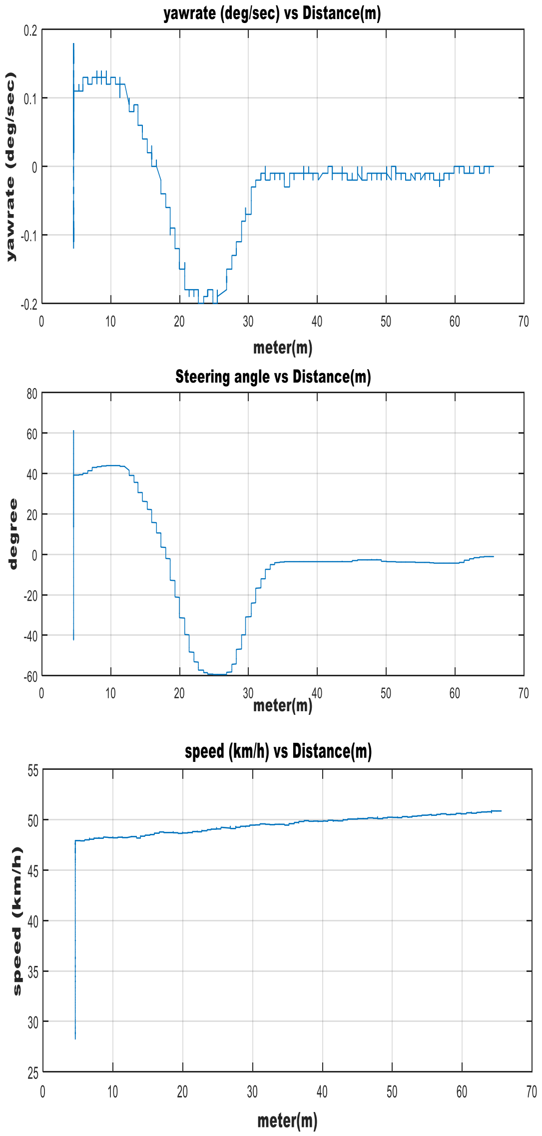


Figure 6. Driving Profile of Driver D

3.2. Steering Behaviour Modelling Result

With 20 times of manoeuvre and 160000 of training data at sampling time of 1 millisecond (ms), it took 10 minutes to complete the training. This is actually to develop and to create a nominal model with regard to the loaded data. Data that being use in this phase can be divided into three parts which are 70% for training the network, 15% for validating the developed network and another 15% for testing the developed network. Figure 6 and Figure 7 show the performance results of the developed model and estimated steering angle from NN model respectively. It can be seen that the value of Means Square Errors (MSE) are relatively high but is reasonable for some explanations: 1) the model could be said reliable as long as the test set error and validation set error have similar characteristics, 2) naturalistic data from driving are considered as nonlinear, not uniform, fluctuate and differ from each other. Therefore, it is very difficult to get a cluster of exact manoeuvre behaviour to develop the model. The validations and overall performances of training and learning data are charted in Table 4 and it was found that for this study the fit is reasonably good for all data set (training/learning data set and unlearning data set), with Regression value for each case is above 0.96.

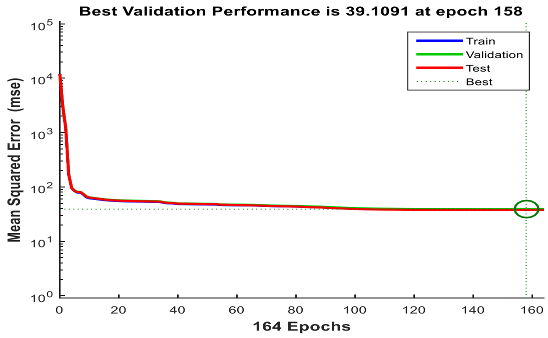


Figure 6. Model performance based on MSE

Table 4. Regression results for network performance

Regression Type	Regression Value (learning data set)	Regression Value (unlearning data set)
Training	0.97434	-
Validation	0.9737	-
Test	0.97464	-
Overall	0.97429	0.9673

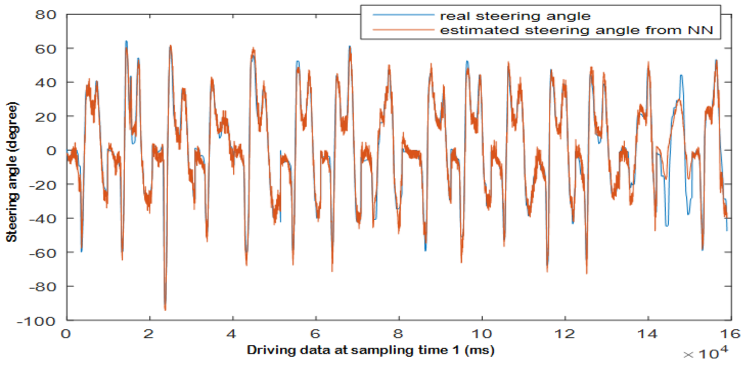


Figure 7. Simulation result for estimated steering angle from ANN

4. Conclusion

The steering manoeuvres of normal drives in near rear- end collision with the presence of distraction while driving has been analyzed using TTC that reflects driver`s risk perception and steering manoeuvre profile of the driver are modelled using ANN. Although the modelling results of the steering manoeuvre show reasonably positive result. Further studies therefore, necessary to really understand the correlation between parameters before implement it at any future vehicle safety-related application such as Advance Driver Assisting System (ADAS).

References

[1] A Kareem. Review of global menace of road accidents with special reference to Malaysia-a social perspective. *Malaysian Journal of Medical Sciences.* 2003; 10 (2): 31–39.

[2] Global Status report on road safety 2015. World Health Organization (WHO). 2015

[3] S Media. Statistik Pengangkutan Malaysia 2013. Kementerian Pengangkutan Malaysia. 2013.

[4] ANS Zainal Abidin, SA Mohd Faudzi, F Lamin, AR Abdul Manap. MIROS Crash Investigation and Reconstruction Annual Statistical Report 2007–2010. 2012.

[5] LB Nabatilan, F Aghazadeh, AD Nimbarte, CC Harvey, SK Chowdhury. Effect of driving experience on visual behavior and driving performance under different driving conditions. *Cognition, Technology &Work.* 2012; 14(4): 355–363.

[6] M Chan, A Singhal. The emotional side of cognitive distraction: Implications for road safety. *Accident Analysis & Prevention.* 2013; 50: 147–154.

[7] TC Lansdown, AN Stephens, GH Walker. Multiple driver distractions: A systemic transport problem. *Accident Analysis & Prevention.* 2015; 74: 360–367.

[8] HH Yang, H Peng. Development of an errorable car-following driver model. *Vehicle System Dynamic*. 2010; 48(6): 751–773, 2010.

[9] M Bueno, C Fabrigoule, D Ndiaye, A Fort. Behavioural adaptation and effectiveness of a Forward Collision Warning System depending on a secondary cognitive task. *Transportation Researh Part F:Traffic Psychology and Behaviour.* 2014*;* 24: 158–168.

[10] M Plöchl, J Edelmann. *Driver models in automobile dynamics application*. *Vehicle System Dynamic.* 2007; 45: 7–8.

[11] JHK JH Kim, S Hayakawa, T Suzuki, K Hayashi, S Okuma, N Tsuchida, M Shimizu, S Kido. Modeling of driver’s collision avoidance behavior based on piecewise linear model. *2004 43rd IEEE Conference on Decision and Control. Bahamas.* 2004; 3: 2310–2315,

[12] R Van Der Horst, J Hogema. *Time-to-collision and collision avoidance systems.* Proc. 6th Work. I*nt.* 1993: 1–12.

[13] S Sekizawa, S Inagaki, T Suzuki, S Hayakawa, N Tsuchida, T Tsuda, H Fujinami. Modeling and recognition of driving behavior based on stochastic switched ARX model. *IEEE Transections on Intelligent Transportation System.* 2007; 8(4): 593–606.

[14] Y Lin, P Tang, WJ Zhang, Q Yu. Artificial neural network modelling of driver handling behaviour in a driver-vehicle-environment system. *International Journal of Vehicle Design.* 2005; 37(1): 24–45.

[15] J Zheng, K Suzuki, M Fujita. Car-following behavior with instantaneous driver-vehicle reaction delay: A neural-network-based methodology. *Transportation Research Part C: Emerging Technoogy.* 2013; 36: 339–351.