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Identification of Driver's Fitness using Video Images and Steering Based Features

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ABSTRACT

Driver's Fitness is defined as a measure of a person's physical strength, flexibility, and endurance to drive. Two main factors that lead to unfit driver are drowsiness and fatigue. This paper discusses features extracted from live video of drivers and steering wheel displacement to identify the relative state of driver's fitness. A software based system, Driver's Fitness Monitoring and Training System (DFMTS) was developed for to acquire the required data, extract the selected features and identify driver's fitness. Fifteen participants were tested in an automotive simulator. Results obtained showed that there are identical patterns of the selected features found among the unfit driver's.

Keywords: Driver's Fitness, steering wheel displacement, Driver's Fitness Monitoring and Training System (DFMTS), automotive simulator.

ABSTRAK

Kecergasan pemandu didefinisikan sebagai ukuran kekuatan fizikal, kefleksibelan dan daya tahan seseorang untuk memandu. Dua faktor yang menyebabkan pemandu tidak sesuai untuk memandu adalah keletihan dan mengantuk. Kertas ini akan membincangkan pencirian yang diekstrak dari video nyata pemandu dan anjakan roda stereng untuk mengenalpasti paras relatif kecergasan pemandu. Sistem berdasarkan perisian, Sistem Pemantauan Kecergasan Pemandu dan Latihan (DFMTS) dibangunkan untuk mendapatkan data, mengekstrak pencirian yang dipilih dan mengenalpasti kecergasan pemandu. Lima belas penyertaan telah dipilih secara rawak untuk pengujian dalam penyelaku automotif. Keputusan awal yang diperolehi menunjukkan terdapat corak yang hampir sama bagi ciri yang dipilih di antara pemandu yang tidak sesuai.

Kata kunci: Kecergasan pemandu, anjakan roda stereng, Sistem Pemantauan Kecergasan Pemandu dan Latihan (DFMTS), penyelaku automotif.

INTRODUCTION

A fit driver is defined as a driver who is alert and able to react to any given situation. The fitness level is inversely related to driver's drowsiness and fatigue. Accidents due to drowsiness or fatigue can cause unnecessary loss of money and lives. Such situation increases the interest to offer in-vehicle technique that makes driving safer, hence the need for a reliable in-vehicle drowsiness detection system. An online driver's fitness identification system should preferably be able to warn driver before the drivers becomes unfit to drive. Reliable detection should not only depend to sophisticated sensor that may disturb driver. One feature that makes such system applicable to real world situation is that the sensing mechanism must be unobtrusive in driving scenario, such that it would not disturb the driver or cause unnecessary discomfort.

Multi features detection methods allows the detection process to become more accurate and reliable as compared to single feature drowsiness detection. In this research, the features used were reviewed from other researches by researchers and organization such as NTHSA (National Traffic Highway and Safety Administration), (VTI) Swedish National Road and Transport Research Institute, National Road Transport Commission (NRTC) and several car manufacturer researches such as by Toyota and Nissan (NHTSA 2003, Kircher et al. 2002).

Based on their findings, 3 drivers performance data (Steering Reversal Rate, PERCLOS and head movement along y-axis) and two exogenous variable (time of driving and period of driving) for fused together for the detection purposes. These features were selected partly because their acquisition is non-obtrusive and the respective computational cost is minimal.

OBJECTIVE

The objective of this research is to determine whether there are relationships between driver's fitness and image and steering based features. Ultimately, these features will be used in the Driver's Fitness Monitoring System (DFMS), an invehicle, online drivers' fitness monitoring system (Jailani et al. 2004). The working framework of DFMS is shown in Figure 1.

SYSTEM DESIGN

Steering Wheel Based Features

There are few types of features which can be obtained from steering wheel movement and these features were shown by their respective researchers to have a certain degree of relationship to driver's drowsiness and fatigue. The features are: Steering reversal rate (Belz, S.M. 2000) Steering wheel movement, Steering velocity (Sherman et al.. 1996), Standard deviation of steering wheel movement (Bittner et al.. 2000) and Steering adjustment method (Fukuda et al.. 1995).

Bittner et al. (2000) uses VHAL index (a ratio of fast movement steering and slow movement steering) to detect drowsiness. They assumed that drowsy driver select easy driving strategy and compensate large deviations which can be detected from steering wheel movement. The VHAL index value decreased with increasing fatigue (Bittner et al. 2000). Steering wheel adjustment interval was used by Fukuda et al. to detect drowsiness. They estimated drowsiness according to the change of steering interval by extracting data from steering angle. Fukuda et al. also implement individual difference as a coefficient of drowsiness judgment in his system. Brown mentioned that the deterioration of steering skills is the most valid and accessible measure of drowsiness which accompanies driver's fatigue. Thiffault et al. (2000) states that the effect of fatigue can be observed by changes of steering wheel movement amplitude. Overall, it can be concluded that steering wheel is a suitable data source for drowsiness and fatigue detection system.

STEERING REVERSAL RATE

Belz (2000) hypothesized that steering wheel reversal rate decreases as a function of time on the road or driver's fatigue. Steering wheel reversal generally increased over time thus suggesting fatigue induced reduction in vigilance and decreased driver performance. The trend was frequently observed. High individual variability, however, was thought by the researchers to be the factor that limited the utility of this measure.

Wierwille and Muto (1981) found that during a long-duration simulator-based driving task, the number of steering reversals greater than two

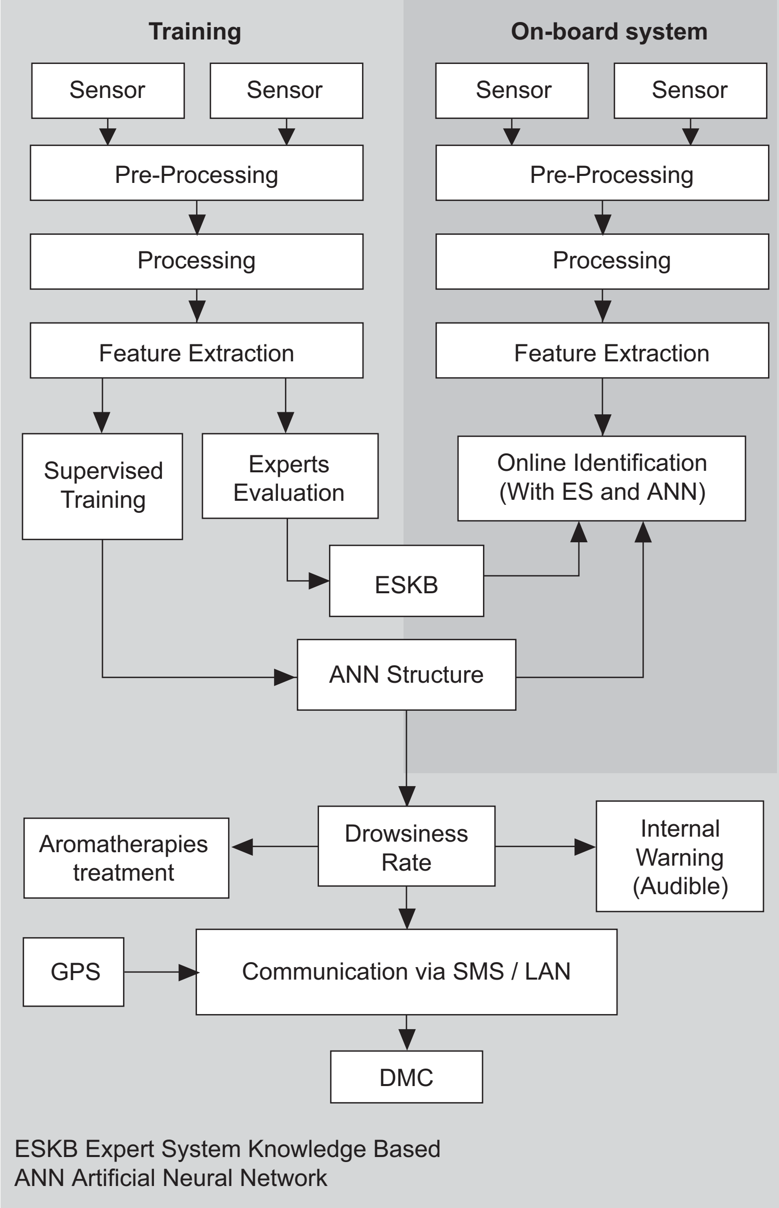


FIGURE 1. Modules in driver's fitness monitoring system

degrees increased while the numbers of small steering reversals (one-half to two degrees) were found to decrease. Average steering reversal amplitude and standard deviation also increased over time. Belz indicated that the implication of this trend is non-fatigued drivers detect and respond to environmental changes quickly with tight, precise corrections whereas fatigued drivers appear to have an increased detection threshold for what may constitute a necessary change and are not likely to respond as quickly as non-fatigued drivers. Fatigued drivers, therefore, are more likely to make fewer, more coarse corrections. In this study, the steering reversal rate was chosen as the main features extracted from the steering wheel for classification of drowsy driver.

To capture steering wheel position, a quadrature optical incremental encoder is attached to steering wheel in the car simulator. The arrangement allows the transitions counting and state viewing of the opposite channel during this transition. With this information, it can be determined if A leads B and subsequently the direction. The reversal rate is then calculated from the position of the steering wheel using the relationship below:

$$SRR_k = \frac{S_k - S_{k-1}}{\Delta t} \qquad (1)$$

with

$$S_k = \frac{\left|E_k - E_{k-1}\right|}{E_{\max}} \times 360^\circ \qquad (2)$$

where

SRR_k Steering Reversal Rate at time $t = k\Delta t$
S_k Steering position at time $t = k\Delta t$
S_{k-1} Steering position at time $t = (k-1)\Delta t$
Δt sampling time interval

VIDEO IMAGE BASED FEATURES

Video image based features was used extensively by researchers the world over in determining suitable parameters for drowsiness and fatigue detection. Examples of features extracted from live video images of drivers are such as head movement, head nodding and eye closure.

A survey done by NTHSA (2002) shows that 37% of the driving population have nodded off for at least a moment or fallen asleep while driving at some time in life. 92% of driver admit have nodded off while driving that they startled awake. The percentage show that head movement data or head nodding is a valid indicator of drowsiness.

Head movement is a time sensitive indicator. It can be interpreted as a drowsiness indicator (Popieul *et al.* 2003). In fact, the increase of the variability of the head position is logical and can be explained by the conjunction of two main factors. First, lots of researches in the field of psychophysiology of vigilance and tiredness have shown that as a subject becomes drowsy, there is a reduced muscle tone throughout his body (Lal *et al.* 2001). In car driving, global relaxation of the body leads the driver to "shrivel" in his seat. This global trend of the posture has an influence on the bead position: mean head position tends to lower with time. Furthermore, feeling more and more uncomfortable with time, the driver tries regularly to restore a good driving position, which leads to an increase in the variability of positions and speeds of the head (Popieul *et al.* 2003). Head movement can also be interpreted as an increase in the subsidiary or collateral activities as indications of the individual level of arousal (Lal *et al.* 2001). Behavioral variations (rubbing, yawning, nodding, singing) induce head movements variations, and could be among the causes of the increase of the variability in head movements. Experiments made on long time periods revealed that evolutions of head movement's indicators were consistent with those of drivers performance indicators. (Popieul *et al.* 2003).

IMAGE PROCESSING

Figure 2 shows the flow of image processing steps in DFMTS. All image acquisition and processing tasks were developed as software objects (classes) using C++ through the used of object oriented programming approach. An ActiveX™ control for face identification was developed utilizing the above classes. This ActiveX™ control was used in DFMS to provide DFMS with online image based features.

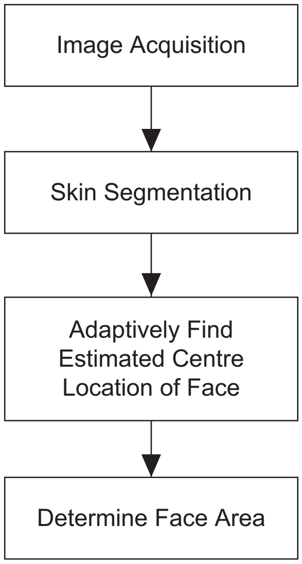


FIGURE 2. Estimating the head location

Head Movement Detection

Head movement in the x and y-axis (HMX and HMY respectively) were calculated from the estimated center of the face position. The center position was estimated using statistical methods applied on the segmented area of the skin. Each area with high probability of being a skin is marked as 1, and area with low probability of being a skin is marked as 0. A center position of dominant face from an input video image is then estimated using the following relationship:

$$\begin{bmatrix}\bar{x}_k\\ \bar{y}_k\end{bmatrix} = \left(\sum_{x=\bar{x}_{k-1}-\frac{\Delta w_x}{2}}^{\bar{x}_{k-1}+\frac{\Delta w_x}{2}} \; \sum_{y=\bar{y}_{k-1}-\frac{\Delta w_y}{2}}^{\bar{y}_{k-1}+\frac{\Delta w_y}{2}} \begin{bmatrix}x\\ y\end{bmatrix} h(x,y)\right) \times \left(\sum_{x=\bar{x}_{k-1}-\frac{\Delta w_x}{2}}^{\bar{x}_{k-1}+\frac{\Delta w_x}{2}} \; \sum_{y=\bar{y}_{k-1}-\frac{\Delta w_y}{2}}^{\bar{y}_{k-1}+\frac{\Delta w_y}{2}} h(x,y)\right)^{-1}$$

where,

$$h(x,y) = \begin{cases} 1; & RGB(x,y) > 0 \\ 0; & RGB(x,y) = 0 \end{cases}$$

and

SRR_k Steering Reversal Rate at time $t = k\Delta t$
S_k Steering position at time $t = k\Delta$
S_{k-1} Steering position at time $t = (k-1)\Delta t$
Δt sampling time interval

RGB(x,y) is the Red, Green and Blue component of a pixel at location (*x,y*).

In the presence of multiple faces within one scene, only the dominant face which is centered and is significantly larger than the rest will be identified as the face. Figure 2 shows the example of the head detection process. Movements in the x and y axis are defined as the different between the current absolute position of the center location($\bar{x}_k, \bar{y}_k$) and the previous absolute position of the center location($\bar{x}_{k-1}, \bar{y}_{k-1}$).

$$\begin{pmatrix} HMX_k \\ HMY_k \end{pmatrix} = \begin{pmatrix} \bar{x}_k \\ \bar{y}_k \end{pmatrix} - \begin{pmatrix} \bar{x}_{k-1} \\ \bar{y}_k - 1 \end{pmatrix}$$

Reaction Time (T_R)

Reaction Time was used in the experiments as a numerical value of driver's fitness. Theoretically, an alert and fit driver will response faster to a stimulus (e.g.: sudden existence of obstacle on the road) as compared to a less alert and fit driver. The Reaction Time, T_R was therefore defined as the time difference between a stimulus was given to a test driver and the time taken by the tested driver to response to the stimulus. It is inversely proportional to the drivers' alertness and fitness. In the experiments that were carried out, the stimulus was given in the form of a red light and the driver is required to push a button on the steering to indicate that he is alert and fit.

METHOD

Experiment Setup

The experiment took place in a fixed based simulator, the Automotive Simulator for Driver's Behavioral Anthropotechnic Study (ASIS). A Sony PS2 based racing game was used to provide in-city driving scenario. Each subject is allowed to drive until they feel tired. There is no fix distance and time limit. The experiment was carried out at around 2.00 p.m. The drowsiness level estimated is a little bit higher during that period due to body circadian cycle and after-meal factor.

The variables measured from the experiments and discussed in this paper were:

1. Head movement in x and y axis, (*HMX* and *HMY)*
2. Steering Reversal Rate(SRR)
3. Reaction Time Data (T_R)

Driver's Fitness Monitoring and Training System (DFMTS), a locally developed system for data acquisition, feature extraction and identification of driver's fitness was used extensively through out the experiments. The Graphical User Interface(GUI) of DFMTS is shown in Figure 3 below.

RESULT

Online Head Detection and Isolation

100% online head detection and isolation from the live video stream obtained from the camera was achieved throughout the experiment. Figure 4 below shows two examples of successful head detection and isolation.

OVERALL RESULTS

The results obtained from the experiments were shown in Table 1. Pearson correlation coefficient, ρ, was used to calculate the strength of relationship between σSRR , HMX and HMY

Current Value 61813
Previous Value 61843
Delta -30

c:\Data\ZAhd.txt

Parameters
PERCLOS 0.7682877
HMY 0
HMX 0
SRR 1.7903636
TOD 931
POD 2
EL 0.2872363

0.7682877
0.52
64
250

Current Time is: 15:31:08
Period of Driving: 2 minute

FIGURE 3. GUI of DFMTS

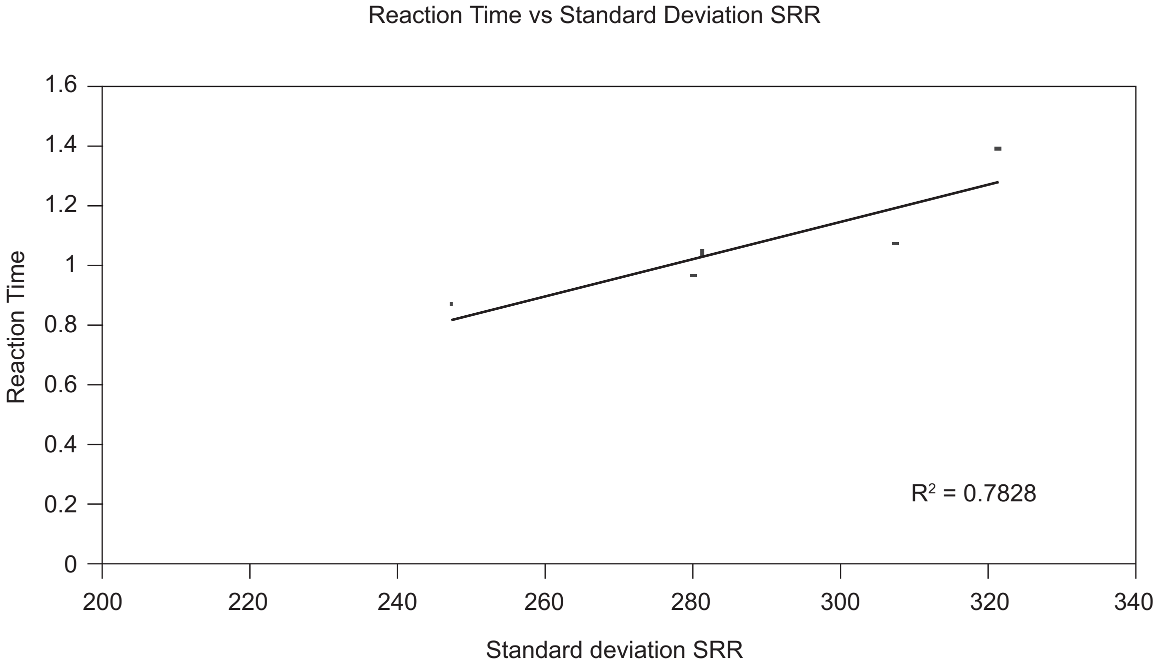
	Original Frame	**Processed Frame**
Sample 1		
Sample 2		

FIGURE 4. Sample Of areas from live video frame identified as face area

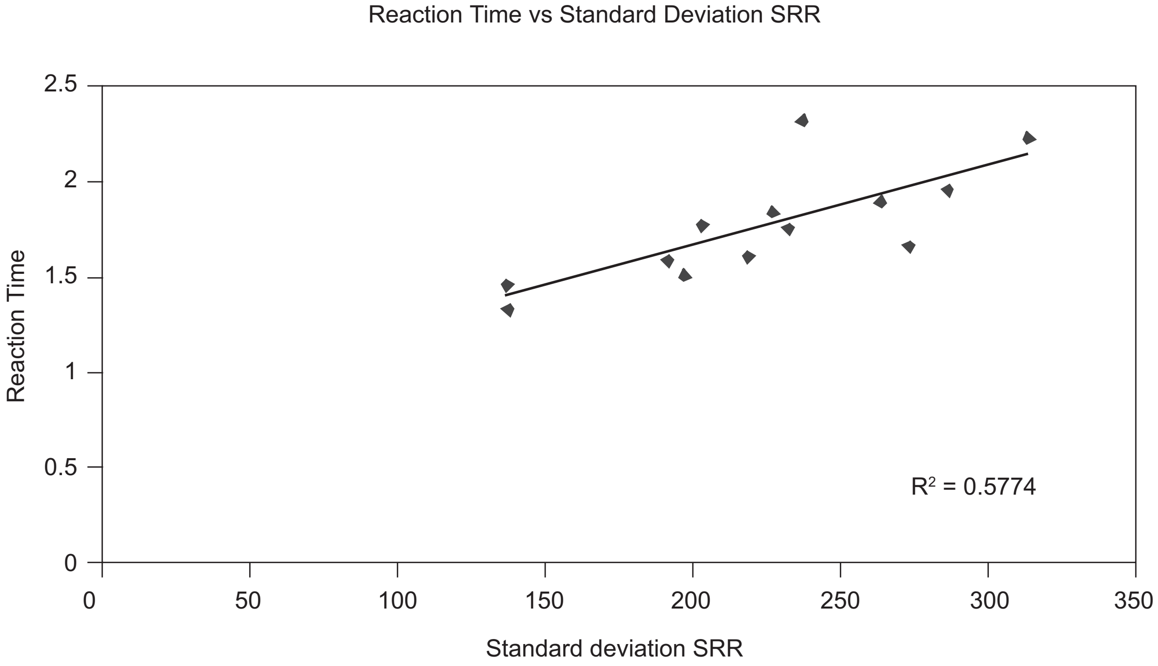
TABLE 1. Summary of ρ values

Sample #	$\rho_{TR\ vs\ \sigma_{SRR}}$	$\left\lvert\rho_{TR\ vs\ \sigma_{SRR}}\right\rvert$	$\rho_{TR\ vs\ HMX}$	$\left\lvert\rho_{TR\ vs\ HMX}\right\rvert$	$\rho_{TR\ vs\ HMY}$	$\left\lvert\rho_{TR\ vs\ HMY}\right\rvert$	$\rho_{\max}$	$\bar{\rho}$
1	-0.2253	0.2253	0.5913	0.5913	0.2963	0.2963	0.5913	0.37097
2	0.6566	0.6566	-0.1657	0.1657	-0.0605	0.0605	0.6566	0.29427
3	-0.2442	0.2442	0.6896	0.6896	0.1822	0.1822	0.6896	0.372
4	0.9218	0.9218	-0.3261	0.3261	0.8546	0.8546	0.9218	0.700833
5	0.0634	0.0634	0.8833	0.8833	0.9017	0.9017	0.9017	0.616133
6	0.4755	0.4755	-0.0629	0.0629	0.4436	0.4436	0.4755	0.327333
7	0.3482	0.3482	-0.5663	0.5663	0.1838	0.1838	0.5663	0.3661
8	0.6163	0.6163	0.4679	0.4679	0.6194	0.6194	0.6194	0.567867
9	0.7599	0.7599	0.6512	0.6512	0.3107	0.3107	0.7599	0.573933
10	0.3361	0.3361	0.5501	0.5501	0.188	0.188	0.5501	0.358067
11	0.1896	0.1896	0.7116	0.7116	0.4399	0.4399	0.7116	0.447033
12	-0.093	0.093	0.2929	0.2929	0.508	0.508	0.508	0.297967
13	0.3988	0.3988	-0.3808	0.3808	-0.8013	0.8013	0.8013	0.526967
14	0.4702	0.4702	-0.1615	0.1615	0.3978	0.3978	0.4702	0.3432
15	0.8848	0.8848	0.6086	0.6086	-0.1164	0.1164	0.8848	0.5366
Avg.		0.44558		0.473987		0.42028	0.6739	

with TR. The averages of the absolute value of the correlation coefficient for each relationship were between 0.446, 0.474 and 0.420. These values indicates that there are relationship between the investigated variables, though the relationship was not very strong on the average. However, at individual sample level, there are samples that indicates that while the relationship might not be strong between TR and σSRR, the relationship between TR and HMX and between TR and HMY is quite strong (sample 5 and sample 11) and vice versa (sample 9). In short, there are cases in which the relationship between TR and an independent variable is weak but the relationship between TR and other independent variables are strong. This behaviour can be attributed as the individual trait of each sample. ρmax shows the largest value of ρ for every sample and the average value of



(a)



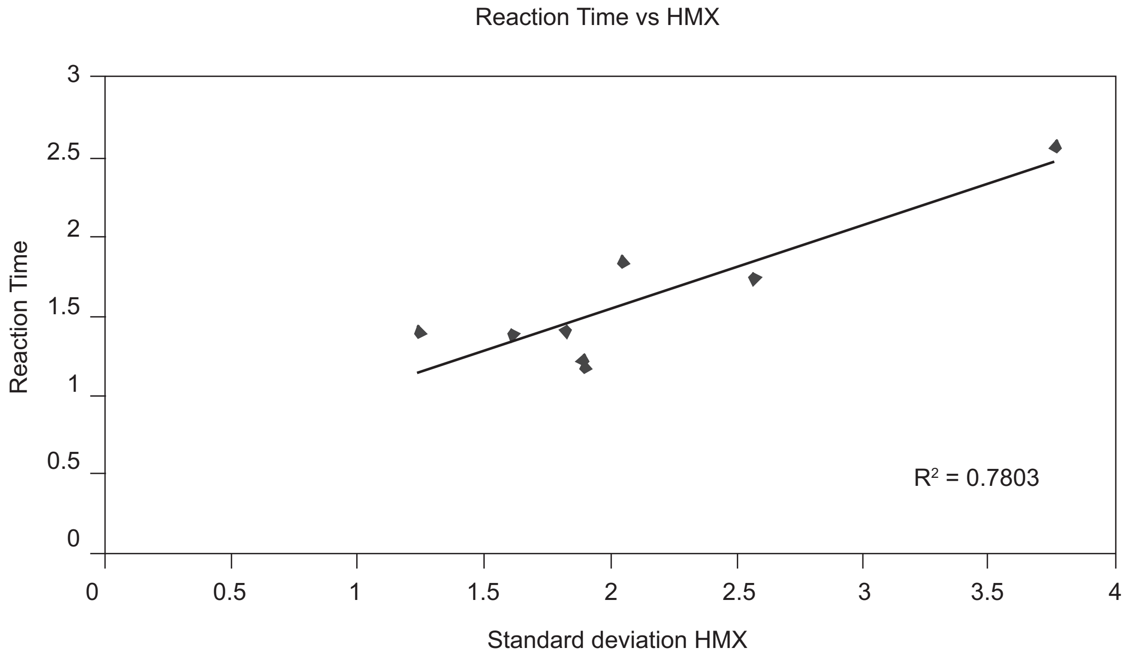
(b)

FIGURE 5. Relationship between T_R with standard deviation of SRR for (b) subject #18 and (a) subject #9

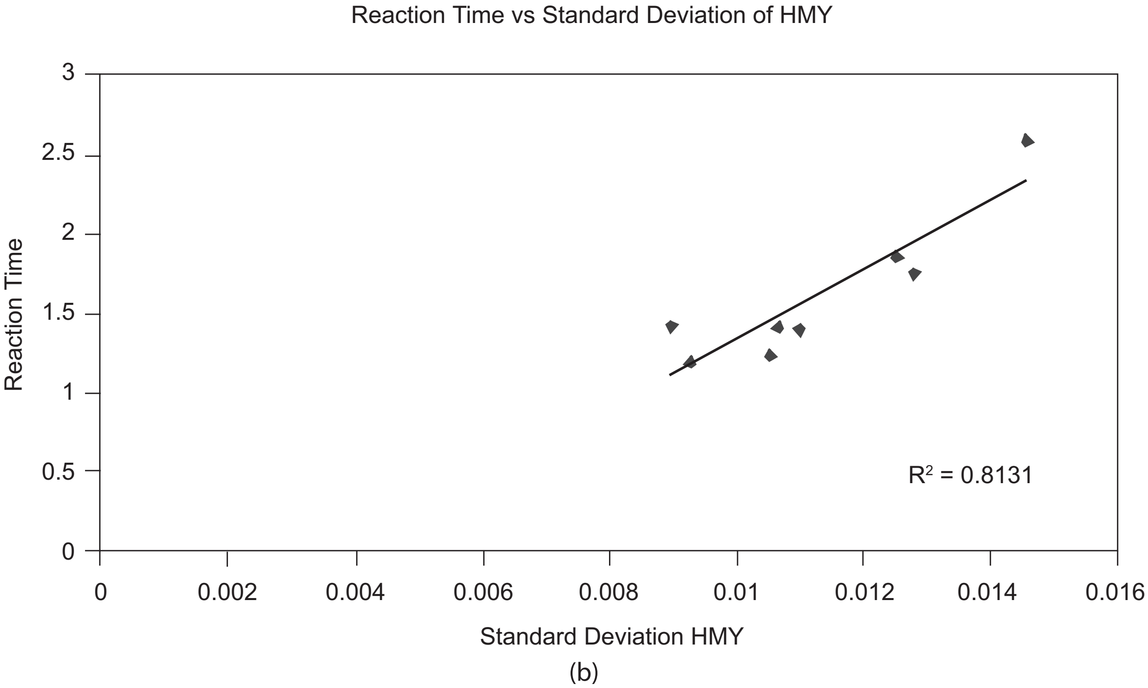
ρmax ($\overline{\rho}_{\max} = 0.674$) is relatively higher than the average correlation coefficient values. The absolute value of ρ was used in the calculation since the interest was on the strength of the relationship rather that the way the relationship goes.

Relationship between T_R and σ_{SRR}

70% of the analyzed data shows positive correlation between Reaction Time and Standard Deviation of SRR. The best linear relationship fit shows a strong positive correlation between the investigated variables with a Pearson correlation coefficient value of ρ = 0.9218. Figure 5(a) and (b) show example of the relationship between for TR and σSRR two random, subject #15 and subject #9. Both give positive relation that shows as reaction time slower, the driver tend to make



(a)



(b)

FIGURE 6. Analysis of head movement for subject #5.

larger steering deviation, as sign of tiredness or early drowsiness.

Relationship Between *HMX* and *HMY* with T_R

The best linear relationship between T_R and *HMX* has a Pearson correlation coefficient of $\rho = 0.8833$. Figure 6 shows the plot of T_R vs. *HMX* and *HMY* for Subject #5. It can seen that head movements show good correlation to reaction time which is indicator of drowsiness.

CONCLUSION

The experimental results proved that there is existence of a significant relationship between the selected parameters and drivers fitness. However, individual variability was also significant and it was observed that it is not possible to derive a single mathematical relationship that can generalized the relationship between the selected parameters and driver's fitness as the correlation between investigated variables varies. In other words, the exact nature of the relationship varies between individual and therefore, a model which is personalized towards an individual would be able to better describe the relationship. Furthermore, in this paper, only linear relationship was assumed and investigated between the selected parameters and drivers fitness. It is highly likely that the relationship that occur is non-linear in nature. In the future, non-linear relationship between the selected features and driver's fitness will be investigated using Artificial Neural Network and Expert System. Nevertheless, the main objective of determining the existence of relationship between the selected parameters and driver's fitness was fulfilled and showed.

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