Faculty of Electronic and Computer Engineering

ELECTROPHYSIOLOGICAL DEGRADING CORRELATES FOR DRIVING ATTENTION LOSS THRESHOLD DETERMINATION

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A thesis submitted
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DECLARATION

I declare that this thesis entitled “Electrophysiological Degrading Correlates for Driving Attention Loss Threshold Determination” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature :.....

Supervisor Name :.....

Date :.....

DEDICATION

To my beloved father and mother,

my husband and children

whose steadfast love and prayers

that always been my source of strength

ABSTRACT

Statistics by Malaysian Institute of Road Safety Research (MIROS) showed that attention loss significantly lead to road accidents. Hence, the area of research on attention detection for driver safety is becoming more important. There have been a number of studies that displayed the possibility of identifying drivers' attention using electroencephalography (EEG) signal. The studies obtained the Event Related Potential (ERP) waveform from a small pool of samples. However, the data obtained were insufficient to significantly characterize attentiveness and inattentiveness due to the unique characteristic of each individual. Therefore, the aim of this research is to define the attentiveness state of each subject from large number of samples in controlled parameters to minimize the variability gap of the ERP peak between each individual. The experiment has been conducted using driving simulator to obtain the EEG data from two groups of subjects which were categorized as attentive and inattentive state by using two distinct stimulations i.e., listening to radio and no stimulation. The obtained results show significant boundary and similarity patterns for the level of attentiveness in both groups. Due to these patterns, a hybrid mean-fuzzy (HMF) technique was proposed to analyze the peak of N170 ERP decrement value versus the accident score based on the driving performance and attention threshold was determined accordingly. Three levels of attention namely 'attentive', 'the beginning of inattentiveness' and 'inattentive' state were presented within a new framework scale in the form of a fish bone diagram known as Attention Degradation Scale (ADS). In order to validate the feasibility of the proposed ADS for both groups, the analysis of the data has been done with and without ADS. Based on the outcome, 52% of the subjects were detected as attentive whilst 56% were in inattentive state which is significant as the percentage obtained with ADS was more than without it. Finally, a prototype application has been implemented to prove the theoretical data of attention level prediction. The prototype has successfully warned the subjects of potential accidents whenever the attention level was below the threshold value. Therefore, the findings of this research can be a promising foundation for alarm system which based on attention recognition technique that potentially would be able to reduce road accidents specifically with the proposed ADS.

ABSTRAK

Statistik oleh Institut Penyelidikan Keselamatan Jalan Raya Malaysia (MIROS) menunjukkan bahawa kehilangan tumpuan boleh membawa kepada kemalangan jalanraya. Oleh itu, bidang penyelidikan mengenai pengesanan tumpuan bagi keselamatan pemandu menjadi semakin penting. Terdapat sejumlah kajian menunjukkan terdapat kemungkinan mengenali tumpuan pemandu dengan isyarat elektroensefalografi (EEG. Kajian memperolehi bentuk Potensi Berkaitan Peristiwa (ERP) dari satu sampel yang kecil. Walau bagaimanapun, data yang diperoleh tidak mencukupi untuk mengenalpasti tumpuan dan kurang tumpuan disebabkan oleh keunikan EEG bagi setiap individu. Oleh itu, tujuan penyelidikan ini adalah untuk menentukan keadaan tumpuan setiap subjek daripada jumlah sampel yang banyak dalam parameter terkawal untuk meminimumkan jurang keberubahan puncak ERP antara setiap individu. Ujikaji telah dijalankan menggunakan simulator pemanduan untuk mendapatkan data EEG dari dua kumpulan subjek yang dikategorikan sebagai keadaan tumpuan penuh dan kurang tumpuan dengan menggunakan dua stimulasi yang berbeza iaitu, mendengar radio dan tiada rangsangan. Hasil yang diperoleh menunjukkan corak sempadan dan kesamaan yang signifikan tahap tumpuan kedua-dua kumpulan. Disebabkan corak ini, teknik hibrid pemurataan-fuzzy (HMF) dicadangkan untuk menganalisis puncak nilai penurunan N170 ERP berbanding skor kemalangan berdasarkan prestasi memandu dan ambang tumpuan ditentukan dengan sewajarnya. Tiga tahap tumpuan iaitu keadaan 'penuh tumpuan', 'permulaan anjakan tumpuan' dan 'anjakan tumpuan' telah dibentangkan dalam kerangka skala baru dalam bentuk gambarajah tulang ikan yang dikenali sebagai Skala Anjakan Tumpuan (ADS). Untuk mengesahkan penggunaan ADS yang dicadangkan untuk kedua-dua kumpulan, analisis data telah dilakukan dengan dan tanpa ADS. Berdasarkan hasilnya, 52% subjek dikesan sebagai memberi tumpuan manakala 56% berada dalam keadaan kurang tumpuan yang signifikan kerana peratusan yang diperoleh dengan ADS adalah lebih daripada tanpanya. Akhirnya, aplikasi prototaip telah dilaksanakan untuk membuktikan data teori mengenai ramalan tahap tumpuan. Prototaip telah berjaya memberi amaran kepada subjek kemalangan yang berpotensi apabila tahap tumpuan berada di bawah nilai ambang. Oleh itu, penemuan kajian ini boleh dijadikan landasan yang menggalakkan sistem penggera yang berasaskan teknik mengesan tumpuan yang berpotensi untuk mengurangkan kemalangan jalanraya secara khusus dengan ADS yang dicadangkan.

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LIST OF ABBREVIATIONS

ADAS	-	Advanced Driver Assistance Systems
ADS		Attention Degradation Scale
Ag/Ag-Cl	-	silver-silver chloride
ANFIS	-	Adaptive Neuro Fuzzy Inference System
ANN	-	Artificial Neural Network
BCI	-	brain-computer interface
CRF	-	Conditional Random Field
DMS	-	Driver Monitoring System
DWT	-	Discrete Wavelet Transform
ECG	-	Electrocardiography
EEG	-	Electroencephalography
EMG	-	Electromyography
EOG	-	Electrooculography
ERP	-	Event Related Potential
F-VAS	-	Fatigue Visual Analog Scale
FFT	-	Fast Fourier Transform
FL-RSEFNN	-	Functional - link recurrent self-evolving fuzzy neural network
GD	-	gradient descent
GPS	-	Global Positioning System

HMM	-	Hidden Markov Model
ICA	-	Independent Component Analysis
KNN	-	K-Nearest Neighbors
KSS	-	Karolinska Sleepiness Scale
LDA	-	Linear discriminant analysis
LM	-	linked mastoids
MEMS	-	microelectromechanical systems
MIROS	-	Malaysian Institute of Road Safety Research
NHTSA	-	National Highway Traffic Safety Administration
NMRR	-	National Medical Research Register
PSD	-	Power Spectral Density
REM	-	Rapid eye movement
SNR	-	signal to noise ratio
SVM	-	Support Vector Machine
SVR	-	Support Vector Machine Regression
SWS	-	Slow Wave Sleep

LIST OF SYMBOLS

Cz	-	Vertex lobe
Fpz	-	Forehead lobe
Oz	-	Occipital lobe
α	-	Alpha frequency band
β	-	Beta frequency band
δ	-	Delta frequency band
θ	-	Theta frequency band
γ	-	Gamma frequency band

LIST OF PUBLICATIONS

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CHAPTER 1

INTRODUCTION

1.1 Research background

Driving is a complex task that requires sensory, motor and higher-level cognitive components which will analyze decision to prioritize the information, predict the scenarios and coordinate movement responses (Uc and Rizzo, 2008). While attention is a shifting process within the central nervous system that can be detected focally in certain regions of the brain through electrical activity using electroencephalography (EEG).

Loss of attention during driving may lead to serious injuries and fatalities. With the increase of road accidents due to the lack of alertness during driving, this research is crucial, especially in Malaysia. Transport Minister of Malaysia reported that a total of 521,466 accidents were recorded in 2016. This is an increment from 489,606 in 2015, 80.6% of the fatal accidents were due to human error including speeding, drowsiness, driving distraction and loss of attention (Babulal, 2017). Table 1.1 shows the statistical report of road accidents in Malaysia, based on the latest report by Malaysian Institute of Road Safety Research (MIROS) (Malaysian Institute of Road Safety Research (MIROS), 2017). The numbers revealed are quite worrying as road accidents are gradually increasing every year. This situation is not only a problem in Malaysia, but it is a worldwide issue. The fatal crash statistic in the United States which was reported by the National Highway Traffic Safety Administration (NHTSA) shows that an increment of 1900 accidents from 2015 to 2016 (National Highway Traffic Safety Administration, 2018).