Faculty of Industrial and Manufacturing Technology and Engineering

A NEW COMPUTERIZED DRIVING SYSTEM USING COGNITIVE SKILLS APPROACH IN MINIMIZING DRIVING FATIGUE AMONG YOUNG DRIVERS

Muhammad Shafiq Bin Ibrahim

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MUHAMMAD SHAFIQ BIN IBRAHIM

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DEDICATION

To my beloved wive, Amirah Najat Binti Moktar, my adorable children, Muhammad Soleh Bin Muhammad Shafiq and Azra Nayla Binti Muhammad Shafiq, my loved parents, Ibrahim Bin Ahmad and Siti Suhaida Binti Mohd Sarip and my dear in laws Moktar Bin Siron and Norasiken Binti Abu Bakar.

ABSTRACT

Driving fatigue is a leading factor in traffic accidents among young drivers in many countries, including Malaysia. Despite the availability of many fatigue detection technologies and the development of decision support systems to meet transportation industry concerns, the number of traffic accidents in Malaysia is increasing. Hence, the current research aimed to develop a computerized system for driving fatigue that employed cognitive skill analysis to predict the level of fatigue experienced by young drivers. This system would warn about the driver's current situation and propose a solution to determine if it is safe to continue driving. Five major phases involved as the pillar in the development of the system: phase 1 (knowledge acquisition), phase 2 (experimental design), phase 3 (perform real world driving experiment), phase 4 (perform regression analysis) and phase 5 (develop decision support system for driving fatigue). The system assessed driving fatigue through the relationship between factors, namely driving duration, body mass index (BMI), types of roads and gender, and cognitive skills, such as working memory capacity, attention level and decision-making skills. These cognitive skills were assessed using an electroencephalogram (EEG) through the analysis of theta (θ), alpha (α) and beta (β)-waves. A total of 52 real-road experimental runs were conducted by 52 subjects. The DSSfDF's functional framework was divided into three parts. First, the system predicted the user's power spectral density (PSD) data during driving for θ-waves (working memory capacity), α-waves (attention level) and β-waves (decision-making skills) utilising the 12 equations by entering information, including BMI, gender and types of roads in the system using the Graphical User Interface (GUI). A timer button (which represents driving duration) was then clicked, and the driving began. The system then started to calculate the user's PSD data, starting at 00.00.01 seconds and onwards. Second, at minute 30 of the drive, the first alarm, accompanied by the warning 'Stay Alert', was activated for all users. Third, the final alarm accompanied by the warning 'Stop Driving and Have a Rest' was activated based on the user's current PSD data and the PSD values as a person fatigued obtained by a previous study. The Prob>F values for factors A (driving duration), B (BMI), C (types of roads), and D (gender) for all three cognitive skills were all less than 0.05, indicating that these factors had a significant influence on cognitive skills. The diagnostic plots showed that all 12 equations accurately predicted the experimental data compared to the actual data. The DSSfDF validation experiments revealed that all drivers self-reported experiencing severed fatigue when the final warning was triggered. This study suggested that driving fatigue was present at the end of the driving session and that the final warning triggered by the DSSfDF was compatible with drivers' current fatigue level while driving. Therefore, the current study has accomplished its goal of addressing the problem of driving fatigue among young drivers. The findings of the current study could provide valuable insights for researchers and decision-makers involved in road safety to mitigate the occurrences of traffic accidents caused by driver fatigue.

SISTEM PEMANDUAN BERKOMPUTER BAHARU MENGGUNAKAN PENDEKATAN KEMAHIRAN KOGNITIF DALAM MEMINIMUMKAN KELESUAN MEMANDU DI KALANGAN PEMANDU MUDA

ABSTRAK

Kelesuan ketika memandu adalah faktor utama kemalangan jalan raya dalam kalangan pemandu muda di banyak negara, termasuk Malaysia. Walaupun terdapat banyak teknologi pengesanan kelesuan dan pembangunan sistem sokongan keputusan untuk mengatasi masalah dalam industri pengangkutan, bilangan kemalangan jalan raya di Malaysia semakin meningkat. Oleh itu, penyelidikan semasa bertujuan membangunkan sistem berkomputer menggunakan analisis kemahiran kognitif untuk meramal tahap kelesuan ketika pemanduan. Sistem ini memberi amaran tentang situasi semasa pemandu dan mencadangkan sama ada pemandu selamat untuk meneruskan pemanduan. Lima fasa utama terlibat dalam pembangunan sistem: fasa 1 (pemerolehan pengetahuan), fasa 2 (reka bentuk eksperimen), fasa 3 (melakukan eksperimen pemanduan dunia sebenar), fasa 4 (melakukan analisis regresi) dan fasa 5 (membangunkan sistem sokongan keputusan untuk kelesuan memandu). Sistem ini menilai kelesuan pemandu melalui hubungan antara faktor, iaitu tempoh pemanduan, indeks jisim badan (BMI), jenis jalan raya dan jantina, dan kemahiran kognitif, seperti kapasiti ingatan bekerja, tahap perhatian dan kemahiran membuat keputusan. Kemahiran kognitif ini dinilai menggunakan electroencephalogram (EEG) melalui analisis gelombang theta (θ), alpha (α) dan beta (β). 52 eksperimen jalan raya telah dijalankan oleh 52 subjek. Rangka kerja DSSfDF dibahagikan kepada tiga bahagian. Pertama, sistem meramalkan data ketumpatan spektrum kuasa (PSD) pengguna semasa memandu untuk gelombang θ (kapasiti memori berfungsi), gelombang α (tahap perhatian) dan gelombang β (kemahiran membuat keputusan) menggunakan 12 persamaan dengan memasukkan maklumat , termasuk BMI, jantina dan jenis jalan dalam sistem menggunakan Antara Muka Pengguna Grafik (GUI). Butang pemasa (yang mewakili tempoh pemanduan) kemudiannya diklik, dan pemanduan bermula. Sistem kemudiannya mula mengira data PSD pengguna, bermula pada 00.00.01 saat dan seterusnya. Pada minit 30 pemanduan, penggera pertama diaktifkan, disertai amaran 'Stay Alert'. Penggera terakhir yang disertai dengan amaran 'Stop Driving And Have A Rest' diaktifkan berdasarkan data ramalan PSD semasa pengguna dan nilai PSD sebagai orang lesu yang diperolehi oleh kajian sebelumnya. Nilai Prob>F untuk faktor A (durasi memandu), B (BMI), C (jenis jalan), dan D (gender) untuk ketiga-tiga kemahiran kognitif semuanya kurang daripada 0,05, menunjukkan bahawa faktor-faktor ini mempunyai pengaruh yang signifikan pada kemahiran kognitif. Plot diagnostik menunjukkan bahawa semua 12 persamaan secara tepat meramalkan data eksperimen berbanding dengan data sebenar. Eksperimen pengesahan DSSfDF mendedahkan bahawa semua pemandu melaporkan mengalami kelesuan apabila amaran akhir diaktifkan. Kajian ini mencadangkan bahawa kelelahan memandu dikesan pada akhir sesi memandu dan amaran akhir yang ditimbulkan oleh DSSfDF bersesuaian dengan tahap kelesuan pemandu semasa pemanduan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AF	-	Atrial Fibrillation
APMs	-	Accident Prediction Models
ADHD	-	Attention Deficit Hyperactivity Disorder
ANOVA	-	Analysis of Variance
Adj R^2	-	Adjusted R squared
BMI	-	Body Mass Index
COVID-19	-	Coronavirus disease 2019
CCD	-	Charge-Coupled Device
C	-	Central
CMFs	-	Crash Modification Factors
DSS	-	Decision Support System
DAC	-	Driver Alert Control
DAS	-	Driver Alert System
DSSfDF	-	Decision Support System for Driving Fatigue
DAC	-	Driver Alert Control
ECG	-	Electrocardiogram
EMG	-	Electromyography
EOG	-	Electrooculogram
EEG	-	Electroencephalogram
F	-	Frontal
FFT	-	Fast Fourier Transform

GTKP	-	Global Transport Knowledge Partnership
GUI	-	Graphical User Interface
HTS	-	Heat Transportation System
IRAP	-	International Road Assessment Programme
JDS	-	Johns Drowsiness Scale
KSS	-	Karolinska Sleepiness Scale
LDW	-	Lane Departure Warning
MIROS	-	Malaysia Institute of Road Safety Research
MCO	-	Movement Control Order
MFIS	-	Modified Fatigue Impact Scale Survey
NSF	-	National Sleep Foundation
O	-	Occipital
P	-	Parietal
PCS	-	Pre-Collision System
PRACT	-	Predicting Road Accidents
PSD	-	Power Spectral Data
SSS	-	Stanford Sleepiness Scale
SPSS	-	Statistical Package for the Social Sciences
SSE	-	Sum of Squares
SMSS	-	Sequential Model Sum of Squares
T	-	Temporal
USA	-	United States of America's
UK	-	United Kingdom
VGA	-	Video Graphics Array
WHO	-	World Health Organization

LIST OF SYMBOLS

%	-	Percentage
α	-	Alpha
β	-	Beta
δ	-	Delta
θ	-	Theta
γ	-	Gamma
Hz	-	Hertz
Cm	-	Centimetre
C.V.	-	Coefficient of Variation
dB	-	Decibel
°	-	Degree
µV	-	Micro Volt
Min	-	Minute
Prob	-	Probability
Kg	-	Kilogram
Kg/m^2	-	Kilogram per meter square
df	-	Degrees of freedom
σ	-	Standard Deviation

LIST OF APPENDICES

LIST OF PUBLICATIONS

The followings are the list of publications related to the work on this thesis:

Ibrahim, M.S., Kamat, S.R. and Fukumi, M., 2024. Regression analysis of heart rate for driving fatigue using Box-Behnken design. *Journal of Mechanical Engineering (JMechE)*, 21(1), pp. 165-176. (SCOPUS: Q4)

Ibrahim, M. S., Kamat, S. R., Shamsuddin, S., Isa, M. H. M., & Fukumi, M, 2023. Regression Analysis of Oxygen Saturation Level for Critical Driving Fatigue Factors using Box-Behnken Design. *Journal of Advanced Manufacturing Technology (JAMT)*, 17(3), pp. 70-81. (SCOPUS Q4)

Ibrahim, M.S., Kamat, S.R., Shamsuddin, S., Isa, M.H.M. and Ito, M., 2022. Electroencephalogram (EEG)-based Systems to Monitor Driver Fatigue: A Review. *International Journal of Nanoelectronics & Materials*, 15, pp. 365-380. (SCOPUS, Q4)

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Ibrahim, M.S., Kamat, S.R. and Shamsuddin, S., 2023. The role of brain wave activity by electroencephalogram (EEG) in assessing cognitive skills as an indicator for driving fatigue: A review. *Malaysian Journal on Composites Science and Manufacturing*, 11(1), pp. 19-31.

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is now one of the most urbanized countries in the Southeast Asia, an intergovernmental organization that also include Brunei, Indonesia, Myanmar, Cambodia, Thailand, Philippines, Vietnam and Singapore. The urban population in Malaysia has significantly escalated from 70% in 2010 to 78.21% in 2022. The trend is predicted to reach larger than 80% in year 2030 (Economics, 2023). As a result of urban sprawl, the human population has become more dependent on the transportation system. This is compatible with a skyrocketed number of registered vehicles in Malaysia from 3,447,712 units in 1996 to 33,300,000 units in 2021 (CEIC, 2021). The improvement in transportation system is indeed, a major contributor to economic expansion, however, the rapid growth of mobility in urban regions cause massive economic losses in road safety. A recent statistic released by Malaysia Institute of Road Safety Research (MIROS), reveals that the number of road crashes in Malaysia has alarmingly increased with a record from 462,426 cases in 2012 to 567,516 cases in 2019. However, the rate was drastically declined to 418,245 cases in 2020 due to the implementation of movement control order (MCO) during Covid-19 pandemic before rapidly rising to 915,874 cases from 2021 to 2022 (MIROS, 2021).

In most countries around the world, young drivers have higher accident rates than older and more experienced drivers. Harith (2022) used the phrase "young drivers" to refer to those aged 18 to 24. A study looked into the ratio and distribution pattern of vehicular incidents by age in Klang Valley, Malaysia, and discovered that drivers aged 15 to 25 are