Development and Implementation of a Driver Hypovigilance Detection System Based on EEG using DWT

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By

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LIST OF ABBREVIATIONS

A/D	Analogue to Digital Convertor
ADDI	Alpha Dependent Distraction Index
ADSI	Alpha Dependent Sleepy Index
ANN	Artificial Neural Network
ANOVA	Analysis of Variance
AR	Average Rejection
BCI	Brain Computer Interface
BP	Back Propagation
BVP	Blood Volume Pressure
CA	Approximation Coefficients
CAR	Common Average Reference
CCD	Charge Coupled Device
CD	Details Coefficients
CHCLK	Channel Clock
CHNU	Channel Number
CMRR	Common Mode Rejection Ratio
CNS	Central nervous system
CPT	Continuous Performance Test
CPU	Central Processing Unit
CSD	Cross Spectral Density
CSP	Common Spatial Pattern
CWT	Continuous Wavelet Transform
DAQ	Data Quasition
DCLK	Data Clock

DFT	Discrete Fourier Transform
DR	Detection Rate
DSTRT	Data Start
DWPT	Discrete Wavelet Packet Transform
DWT	Discrete Wavelet Transform
ECD	Eye Closure Duration
ECG	Electrocardiography
EEG	Electroencephalogram
EMG	Electromyography
EoG	Electrooculography
ERP	Event Related Potential
FB	Filter Bank
FIR	Finite Impulse Response
FLD	Fisher Linear Discriminator
FN	False Negative
FNR	False Negative Rate
FP	False Positive
FPGA	Field Programmable Gate Array
FS	Fuzzy System
GPS	Global Position System
GSR	Galvanic Skin Response
GUI	Graphical User Interface
HRV	Heart Rate Variability
ICA	Independent Component Analysis
IO	Input / Output

IWPT	Inverse Wavelet Packet Transform
JTV	Johns Test of Vigilance
KNN	K Nearest Neighbour
KSS	Karolinska Score Scale
LACLK	Load Clock
LCD	Liquid Crystal Display
LDA	Linear Discriminate Analysis
MIROS	Malaysian Institute of Road Safety Research
MRA	Multi Resolution Analysis
MSB	Most Significant Bit
MSE	Multi Scale Entropy
MUX	Multiplexer
NSF	National Sleep Foundation
PCA	Principle Component Analysis
PCI	Peripheral Component Interconnect
PERCLOS	Percentage Eye Rate Closure
PIB	Patient Interface Box
PNN	Probabilistic Neural Network
PSD	Power Spectral Density
PWD	Pseudo Wigner Distribution
RBF	Radial Basis Function
RD	Random Diagonal
RF	Radio Frequency
RMSE	Root Mean Square Error
SBC	Single board computer

SC	Spectral Centroid
SCR	Surface Laplician
SD	Standard Deviation
SDLP	Standard deviation of lane position
TORCS	The Open Racing Car Simulator
SDLP	Standard Deviation of Lane Position
SDRAM	Skin Conductive Resistance
SL	Storage Dynamic RAM
SMS	Short Message Service
SOM	Self Organizing Map
STFT	Short Time Fourier Transform
STRT	Start
SVM	Support Vector Machine
SWM	Steering Wheel Movement
TN	True Negative
TP	True Positive
TPR	True Positive Rate
TSK	Takagi-Sugeno-Kang
USD	Universal Serial Bus
VLD	Variation of Lane Deviation
WPT	Wavelet Packet Transform
WVD	Wigner Ville Distribution

LIST OF SYMBOLS

δ	Delta Band
θ	Theta Band
α	Alpha Band
β	Beta Band
γ	Gamma Band
σ	Adjustable Smoothing Parameter in PNN
£	Width of the Gaussian Function
ψ	Wavelet
ω	Angular Frequency
Ω	Ohm
K Ω	Kilo Ohm
μV	Micro volts
μS	Micro Second
S	Signal
S_{EXT}	External Signal
A	Mean Amplitude of the Aamplitude Spectrum

Pembangunan dan Pelaksanaan Pemandu Hypovigilance Sistem Pengesanan Berdasarkan EEG menggunakan DWT

Abstrak

Dalam tesis ini, analisis isyarat "electroencephalogram" (EEG) dalam bidang masa-frekuensi dengan aplikasi untuk pengenalan pengawasan-hiper pemandu telah dimajukan. Sebanyak lima stimuli telah dipertimbangkan dalam memajukan sistem pintar pengawasan-hiper ini. Dengan menggunakan sistem antarabangsa 10-20, 14 multi-saluran EEG tanpa-wayar telah ditempatkan di permukaan kulit kepala. Pengkalan data EEG telah disediakan menggunakan 50 subjek (43 lelaki dan 7 perempuan) dan pelbagai keadaan pengawasan-hiper (neutral, alih perhatian rendah, alih perhatian sederhana, alih perhatian tinggi, berjaga, mengantuk, mengantuk kuat, peringkat tidur) telah dirangsang menggunakan stimuli audio dan visual (pemain media, GPS, fikir mental, SMS, dan memandu untuk 1 jam). Indeks pengalihan perhatian, mengantuk dan pengawasan-hiper diperoleh dari jalur-jalur frekuensi EEG; delta (0-4Hz), theta (4-8Hz), alpha (8-12Hz), dan beta (14-32Hz) menggunakan "Discrete Wavelet Transform" (DWT) dan "FFT" hibrid. Ciri-ciri statistik ("Spectral centroid" (SC), "Power Spectral Density" (PSD)) yang diperoleh dari jalur-jalur frekuensi EEG dengan menggunakan pelbagai ombak kecil (db4, db8, sym8, and coif5) telah digunakan untuk mengelaskan tahap pengawasan-hiper menggunakan tiga pengelasan "Probabilistic Neural Network" (PNN), "K Nearest Neighbour" (KNN) dan "subtractive fuzzy classifier". Sebagai hasil kajian ini, kadar pengesanan indeks purata pengalihan perhatian dan indeks mengantuk adalah 88.75% dan 85%, kedua-duanya berasaskan db4. Selain itu, klasifikasi mengantuk dan peralihan perhatian yang berasaskan "subtractive fuzzy classifier" mencapai kadar pengelasan maksimum 79.21% dengan menggunakan sym8 dan 84.41% menggunakan db4. Implementasi matematik penapisan pra-pemprosesan Butterworth, DWT dan FFT berasaskan kod bahasa C telah dilaksanakan melalui system terbenam masa sebenar (TS7800) menggunakan indeks pengawasan-hiper untuk pengesanan kerana kaedah indeks memerlukan masa pengiraan dan penggunaan memori yang rendah berbanding kaedah pengelasan. Kaedah bank penapisan konvensional telah disiasat dan dibandingkan dengan kaedah hibrid dalam istilah kepelbagaian indeks dan pengelasan. Kesimpulannya, sistem pengesanan pengawasan-hiper berasaskan db4 memberi kadar purata pengesanan yang terbaik menggunakan kaedah indeks. Hasil tesis ini adalah antaramuka grafik pengguna (GUI) yang dibanggunkan dalam platform Visual Basic dengan DWT sebagai aplikasi pemprosesan isyarat, sebagai tambahan kepada peranti keras sistem pengesanan masa sebenar.

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ABSTRACT

In most real-time scenarios, it is highly essential to evaluate the level of hypovigilance in drivers, pilots, security guards and sportsmen to ensure efficient performance in their work. Driver hypovigilance is one of the major causes for road accidents. Drowsiness and distraction are two major components of hypovigilance. Most real time detection systems use the conventional classifier based approach to distinguish different levels and proposed the measurement index to differentiate lower numbers of hypovigilance levels (such as drowsy versus awake, distraction versus neutral, etc.). Furthermore, existing detection systems are bulky and costly. In this thesis electroencephalogram (EEG) signal analysis in the time-frequency domain with application to driver hypovigilance recognition is developed. Five stimuli are considered for devolving an intelligent hypovigilance detection system. 14 wireless multi channel EEG are placed over the entire scalp through international 10-20 system. The EEG dataset is developed with 50 subjects (43 males and 7 females) and the discrete hypovigilance states (neutral, low distraction, medium distraction, high distraction, awake, drowsy, high drowsy, sleep stage 1) are evoked by using audio and visual stimuli (media player, GPS, mental think, SMS, and driving for 1hour). Distraction, sleepy, and hypovigilance indices were derived from EEG frequency bands; delta (0-4Hz), theta (4-8Hz), alpha (8-12Hz), and beta (14-32Hz) using hybridization of Discrete Wavelet Transform (DWT) and FFT. Two statistical features (Spectral centroid (SC), Power Spectral Density (PSD)) derived from EEG frequency bands using different wavelets (db4, db8, sym8, and coif5) are used to classify the hypovigilance levels using three classifiers namely; Probabilistic Neural Network (PNN), K Nearest Neighbour (KNN) and subtractive fuzzy classifier. As a result of this study, the average of distraction and sleepy index detection rate were 88.75% and 85% respectively, both based on db4. On the other hand, subtractive fuzzy classifier based distraction and drowsiness achieves maximum classification rate of 79.21% based on sym8, and 84.41% based on db4, respectively. The embedded system (TS7800) has been used in this research as real time hypovigilance detection system based on hybridization of discrete wavelet transform and fast Fourier transform. The conventional filter bank method had been investigated and compared with hybrid method. The Results of this research indicated that db4 based hypovigilance detection system gave best average detection rate using index method. While classification method showed that sym8 and db4 gave high accuracy results when they were applied for features extraction of distraction and drowsiness states, respectively. The output of this thesis is the newly distraction, drowsiness, and hypovigilance indices obtained by hybridization of DWT and FFT, in addition to hardware real time detection system based on embedded system.

CHAPTER 1

INTRODUCTION

1.1 Background

Driver hypovigilance is one of the major causes for road accidents. Drowsiness and distraction are two major components of hypovigilance. The Development of an efficient detection system is highly essential to reduce the number of road accidents in day-to-day life. Researchers have already developed many research tools to efficiently monitor the above factors using different modalities. Although researchers have been working in this area for the past several decades, many detection systems do not work efficiently in real-time scenarios. This is due to inefficient methodology on appropriately detecting the driver's hypovigilance levels. Hence, the development of an effective level measurement index is truly essential for reducing fatalities and economic losses due to vehicle accidents. Based on statistics from the Malaysian Institute of Road Safety Research (MIROS), the number of road accidents increased to 397,194 in 2009 compared to 250,429 in 2000. Moreover, MIROS statistics revealed that 414,421 road accidents were reported in 2010 (Carskadon and Dement, 2011).

The U.S.A National Highway Traffic Safety Administration concluded that drivers have a higher level of distraction by 30% during driving and about 100,000 accidents cases are registered every year by the police due to severe driver fatigue (Stutts *et al.*, 2003). Thereby, an estimated 550 deaths, 71,000 injuries and $12.5 billions in economic losses occur each year.