Developing Vehicle-Based Advanced Warning System for Driver Drowsiness Based on a Hybrid Algorithm

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Certificate of authorship

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of requirements for a degree.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Preface

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Refereed conference Proceedings

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ZILBERG, E., BURTON, D., ZHENG MING, X., **KARRAR, M**. & LAL, S. (2007) Methodology and initial analysis results for development of non-invasive and hybrid driver drowsiness detection systems. *The 2nd International Conference on. Wireless Broadband and Ultra Wideband Communications, 2007. AusWireless 2007.*

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Glossary

Acronyms	**Detailed**
802.11	a set of standards for wireless networks
ABM	Advanced Brain Monitoring
ACARP	Australian Coal Association Research Programme
AFM	Advanced Fatigue Management
AMP	Alertness and Memory Profiler
ANOVA	analysis of variance
APSR	averaged power spectrum ratio
ARL	Atlas Researchers Ltd
ARRB	Australian Road Research Board
ASL	Applied Science Laboratories
AUC	area under the curve
B&W	Black & White
BFM	Basic Fatigue Management
BMI	body mass index
BP	Blood Pressure
C4	Central EEG measurements
CAM	Video camera
CRF	Fiat Research Centre
DARPA	Defense Advanced Research Projects Agency
DC	direct current
DFFT	discrete fast Fourier transform
DSP	Digital Signal Processing
ECG	electrocardiogram
ECU	Engine Control Unit
EDA	electrodermal activity
EDR	electrodermal response
EDVTCS	Engine Driver Vigilance Telemetric Control System
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
ESS	Epworth Sleepiness Scale
ETS	Eye tracking system
FFT	Fast Fourier Transform

Acronyms	**Detailed**
Fp1, Fp2	Frontal Polar EEG measurements
g	Grams
GB	Gigabyte
GEE	generalised estimating equations
GHz	Giga Hertz
HFLC	high-fat/low carbohydrates
HREC	Human Research Ethics Committee
Hz	Hertz
IrDA	Infrared Data Association
kg	Kilogram
LAN	local area network
LCB	Locus-of-control
LED	light emitting diodes
LFHC	low-fat/high carbohydrates
LOC	left outer canthus
MB	Megabyte
MBDAR	The maximum of the MBIARs of the 10 values
MBIAR	Maximum Body movement Increase Amplitude Ratio
MFMC	medium-fat/medium carbohydrates
mg	milligram
MINDS	MicroNod Detection system
ml	millilitre
MMBDAR	Maximum Body movement Decrease Amplitude Ratio
MMBIAR	The maximum of the MBIARs of the 10 values
MPEG4	Moving Picture Experts Group-4
MPSR	maximum power spectrum ratio
msec	milliseconds
MSLT	Multiple Sleep Latency Test
MUARC	Monash University Accident Research Centre
NCSDR	National Center on Sleep Disorders Research (USA)
NHTSA	National Highway Traffic Safety Administration (USA)
NREM	non rapid eye movement
NSW	New South Wales
NTC	National Transport Commission (Australia)
O2	Occipital EEG measurements

Acronyms	Detailed
PAL	Phase Alternating Line
PC	Personal Computer
PERCLOS	percentage of eyelid closure
POMS	Profile of Mood States
PS	Power Spectral
PSG	Polysomnography
RAM	Random-access memory
REM	Rapid Eye Movement
RF	radio frequency
RLL	Residual log-likelihood
ROC	right outer canthus
ROC	Relative Operating Characteristic
RPSR	relative frequency band power spectrum ratios
RTA	Road and Traffic Authority, NSW (Australia)
SAS	statistical analysis software
SD	Standard Deviation
SE	Standard Error
sec	Seconds
SEM	Slow Eye Movement
Sen	Sensitivity
Spec	Specificity
SSS	Stanford Sleepiness Scale
TAC	Transport Accident Commission, Victoria (Australia)
TBIAR	Test Body movement Increase Amplitude Ratio
UK	United Kingdom
US	United States
USA	United States of America
USB	Universal Serial Bus
USD	United States Dollar
UTS	University of Technology, Sydney
VAS	Visual Analogue Scale
VRTC	Vehicle Research & Test Center (USA)
Wi-Fi	Wireless LAN (Local Area Network)

Abstract

Fatigue is a major public health issue causing substantial emotional and financial burden on society. Driver fatigue is identified in nearly 20-30% of road fatalities, and can cost around AUD 3 billion per year. Providing drivers with early warning systems for fatigue could minimise fatigue-related road accidents. A car driving simulator study was conducted and physiological data such as electroencephalography (EEG), eye activity, movement sensor data, video and questionnaire information were obtained for the purposes of developing a drowsiness detection algorithm. The study was conducted at the Monash University Accident Research Centre (MUARC) where sixty non-professional drivers aged between 20-60 years were recruited. The study was conducted in the afternoon and the driving sessions lasted up to 3 hours of monotonous day and night driving scenarios with realistic scenery.

The preliminary analysis identified sections of data where clear episodes of drowsiness were evident. The analysis revealed that it was possible to detect drowsiness from a combination of physiological signals consisting of EEG, car seat movements and eye activity. Once the association between episodes of drowsiness and various signals were established, statistical analysis was performed on the entire data set. Two types of EEG processing were employed at this stage based on EEG alpha power and alpha burst analysis. A significant association was established between the probability of drowsiness and EEG alpha activity, with alpha burst duration resulting in a better association. Drowsiness detection algorithms based on these two methods were then developed.

The association established between drowsiness and the seat movement signals was far less than that between drowsiness and the alpha signals. The seat movement signals were then combined with both methods of alpha analysis. Adding seat movement signal to either of the two EEG methods resulted in improved associations with drowsiness with alpha burst association still being superior. The algorithm based on the combinations of alpha burst and seat movements formed the basis for the new hybrid algorithm.

Subjective measures of drowsiness, lifestyle and behaviour were also examined in this research and validated against video ratings of fatigue. It was shown that increased anxiety, anger and an unhealthy diet were associated with an increased probability of drowsiness.

The findings of this research can serve as a foundation for designing future vehicle-based fatigue countermeasure devices as well as highlight potential difficulties and limitations. Such driver fatigue studies will also benefit from further investigations of driver lifestyle and behavioural factors.