UNIVERSITI PUTRA MALAYSIA

EMOTION RECOGNITION FOR AUTOMOTIVE DRIVERS USING SIMULATED DRIVING APPROACH

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By

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In last decade, wide range of active safety system had been installed in modern vehicles. Traction control system, auto-braking system, auto wipers and auto lighting are great inventions designed to reduce road accidents. Still, statistics indicates that accident rate in Malaysia had not been compromise despite inclusion of these features. In year 2013, approximately 777,000 registered vehicles were involved in road traffic crashes, with damage cost of more than 9.3 billion Ringgit Malaysia. Automobile network encompasses network between road, vehicles and drivers. Road and vehicles had made great progress, whereas part concerning drivers had left to be the most delicate of this network.

This study encapsulates stress and anger as prime emotion encouraging road accident. Electrodermal Activity (EDA) and Electromyography (EMG) of corrugator supercilli had been contemplated for neutral, stress and anger emotion recognition. Simulated driving task with preset scenario had been developed for emotion stimulation. Experimental data were recorded from 20 healthy subjects. Acquired EDA signals were filtered, Short-Time-Fourier-Transformed and had mean, median and variance features extracted, on the contrary, EMG signals were rectified, filtered and had mean, standard deviation and root mean square computed. Recorded EDA and EMG data manifested significant difference ($p < 0.05$) only between neutral-stress and neutral-anger emotion groups. Regardless, no significant difference ($p > 0.05$) was perceived between stress-anger groups.

Additionally, two-class and multi-class Support Vector Machine (SVM) classification accompanied by cross-validation method had been dispatched to differentiate subjects' emotion when performing simulated driving task. Dataset from 10 subjects were used for training and another 10 were for testing purpose only. Classification accuracy exceeding 80% had been achieved between

neutral-stress and neutral-anger groups when incorporating EDA, less than 70% accuracy was achieved for separation between stress-anger groups. EMG features failed to perform in view of corrugator supercilli may not be compelling measure.

This study had incorporated new techniques (Short-Time-Fourier-Transform) for EDA analysis, apart, it is the one of the pioneer study that utilizes EDA for anger emotion recognition, still, classification result acquired is more preferred than past literatures. The research can still be extended by refining signal processing techniques for better classification accuracy and conducting real-world driving experiment for more persuasive result.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGENALAN EMOSI UNTUK PEMANDU AUTOMOTIF MENGGUNAKAN KAEDAH PEMANDUAN BERSIMULASI

Oleh

JONATHAN OOI SHI KHAI

Januari 2017

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Selama ini, pelbagai kawalan keselamatan telah dipasang dalam kenderaan. Beberapa ciptaan seperti Sistem Kawalan Cengkaman (Traction Control System), automatik brek sistem, automatik pengelap kenderaan, dan automatik lampu kereta adalah fungsi yang dicipta untuk membantu mengurangkan kes kemalangan. Namun begitu, kadar kemalangan di Malaysia masih dalam statistik yang tidak memuaskan . Di tahun 2013, sebanyak 777,000 kenderaan berdaftar terlibat dalam kemalangan terbabas dengan mencatatkan nilai sebanyak 9.3 billion ringgit malaysia. Automobil telah meluaskan rangkaian keselamatan di antara jalanraya, kenderaan dan pemandu. Tetapi tingkah laku masih di kategorikan dalam tahap yang merisaukan.

Dengan ini, tujuan kajian ini ialah untuk mengesan emosi pemandu dengan mengunnakan "Electrodermal Activity (EDA)", dan "Electromyography (EMG)" di salah satu bahagian mata iaitu "corrugator supercili" untuk keadaan neutral, tekanan atau marah . Kajian ini menggunakan simulasi pemanduan untuk tujuan merekodkan emosi 20 pemandu. Semua subjek yang digunakan adalah dalam keadaan yang sihat. Data yang diperolehi akan ditapis oleh EDA untuk signal, "Short -Time -Fourier Transformed (STFT)" dengan min, median dan variance akan dikira, dan EMG signal akan diperbetulkan, ditapis, untuk mencapai min, sisihan piawai dan min punca kuasa dua akan dikira. Rekod menunjukkan EDA dan EMG memberikan hasil ($p<0.05$) ialah antara neutral-tekanan dan neutral-kemarahan. Tiada bacaan ketara untuk ($p>0.05$) dalam kategori tekanan-kemarahan.

Sebagai sokongan, dua kelas dan mutli kelas Mesin Sokongan Vektor (SVM) telah digunakan dalam silangan pengesahan untuk mengesan emosi pemandu dalam simulasi pemanduan. 10 subjek di kaji dalam latihan dan 10 subjek hanya dalam tujuan kajian sahaja. Klasifikasi ketepatan direkod setinggi 80% untuk

kategori neutral-tekanan dan neutral-kemarahan dalam kombinasi EDA , 70% ke bawah dalam kategori tekanan-kemarahan. EMG manakala tidak mempunyai prestasi yang mengkagumkan dalam kajian ini.

Kajian ini telah membuktikan teknik baru iaitu STFT dalam EDA analisis, dan meneruskan kegunaan EDA untuk mengesan emosi pemandu dengan pengiraan teknik yang lebih tepat dalam pemprosesan signal dan klasifikasi di samping melancarkan kajian dalam sistem pemanduan nyata untuk ketepatan maklumat.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013)are adhered to.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
EDA	Electrodermal Activity
EMG	Electromyography
EEG	Electroencephalography
ECG	Electrocardiography
MIROS	Malaysian Institute of Road Safety Research
MOSTI	Ministry of Science, Technology and Innovation, Malaysia
PSD	Power spectrum density
SC	Skin conductance
SD	Standard deviation
SCR	Skin conductance response
SCL	Skin conductance level
ST	Skin temperature
SVM	Support vector machine

CHAPTER 1

INTRODUCTION

This chapter describes importance of emotion study on automotive drivers. Despite availability of wide ranges of active safety system, road crash had still been a severe issue had to be resolve in any manner, whereby monitoring of drivers emotion is suggested in this study. Existing problem for designing a reliable in-lab driving simulator and selection of emotion recognition approach had been addressed. Aim and scope of work had also been clearly stated.

1.1 Background

Motor vehicles are a crucial commodity in modern civilization. However, the high number of traffic accidents demonstrates grievous social problem. Road crash are the eighth leading cause of death globally, and leading cause of death for youngsters aged 15 – 29 (World Health Organization, 2013). The cause encompasses inferior road condition, lack of adequate law that address accident risk factors (speed, drink-driving, seat-belts and child restraints) and limitation of active safety systems (World Health Organization, 2013)(Hachisuka, 2013).

Active safety system ranges from active accident avoidance framework, which overrides drivers' control when road crash is likely to occur, for example, traction control system - a secondary function of anti-lock breaking system, that anticipate loss of grasping force when throttle input and engine torque mismatched due to road surface condition, auto-breaking mechanism that stops vehicle immediately before front or rear end collision, to passive assisting system that assist drivers' in tasks other than driving, for instance, voice command that aids control of in-vehicle information system. These systems are sensational creations designed with vase chronicles of algorithmic acknowledgement, which are superior to human reaction, presumed to provide better driver experience and improve driver-passenger-pedestrian safety (Patterson and Adams, 2014)(Oldham, 2014)(Traffic Technology Today, 2014)(Edgerton, 2013)

Still, insights demonstrated that road mishap rate had not been a bargain. World Health Organization (WHO) reported there has been no overall reduction of fatal road crash comparing year 2009 and 2013, considering increase of number of registered vehicles by 15%. Approximately 20-50 million non-fatal injuries and 1.24 million fatal accidents occurred on the world's road annually (World Health Organization, 2013)(World Health Organization, 2009). As for Malaysia, 777,817 out of 22,702,211 enlisted vehicles were involved in road crashes with harm expense of more than 9.3 billion Ringgit Malaysia, which losses emerges from treatment expenditure, decreased productivity of victims (MIROS, 2014)(Nurulhuda.J, Ho.J.S, & Jamilah.M.M, 2013). This pricey figure ranked Malaysia 46th out of 172 worldwide and 2nd out of 10 Southeast Asia countries for fatal accidents (World Health Organization, 2013). Presumed fatalities for 2015 and 2020 are 8,060 and 10,716 (Rohayu, Sharifah Allyana, Jamilah, & Wong, 2012). Wherefore, it is imperative to re-examine the wellspring of mischance and methodology of aversion.

Road traffic crashes, which comprise a public health concern is influenced by environmental (road and vehicle) and human (drivers) factors (Moriyama, 2012). On that record, current research focus shall consider monitoring of drivers' emotion, which impacts their driving conduct (Hachisuka, 2013).

Emotion is a broad phenomenon and difficult to define, also because there are different views of it. Emotion consists of physical and mental sensations coupled with thoughts, causing thoughts or themselves can be caused by thoughts. This can result in avoidance behavior or approach behavior. Avoidance behavior mainly occurs with negative emotions (angry) and approach behavior mainly with positive emotions (happy). Emotion is believed to coupled with feelings, which explains a person's internal feelings and thoughts, besides, other internal processes or true feelings the person might not aware of (C D Katsis, Katertsidis, Ganiatras, & Fotiadis, 2008)(Busso et al., 2004). Aristotle, the Greek philosopher thought emotion as a stimulus that evaluates experience based in potential gain or pleasure, Descartes consider emotion mediate between stimulus and response (D. Singh, 2012) while physiologist concludes that emotion influences judgment directly by serving as experiential and bodily information regarding how one's feel about the object or of judgment (Kamaruddin & Wahab, 2010).

Emotion of drivers directly influences their driving behavior, whence, possesses close relationship with road safety. Ability to understand and monitor drivers' emotion aids promoting better driving ethics and development of emotion-based accident prevention system. Past research manifested fatigue / drowsiness, anger and stress driving possesses high correlation with road crash (Danaf, Abou-Zeid, & Kaysi, 2014)(Yamaguchi, Wakasugi, & Sakakima, 2006)(G. Yang, Lin, & Bhattacharya, 2005). This research only focuses on only stress and anger emotion as drowsy recognition device had been introduced (Coxworth, 2011).

1.2 Problem statement

Monitoring drivers' emotion during real world driving task requires abundant cost, preparation, and approval; therefore, in-lab driving simulator would be an effective and efficient manner for this research. There are three essential factors while setting up a driving simulator, which are the element, scenario and environment for emotional data monitoring.

Element, which composed of driving unit, visual and audio systems, shall be sufficient to simulate real-world driving condition. This is to ensure that it successfully stimulate the favored emotions for this study. An ideal set of driving unit shall encompass force feedback steering wheel, sensitive break and gas pedals, drivers' seat and high definition visual-audio system. Yet, it is a challenge to get synchronizing these elements; besides, enormous amount of fund is required (Hachisuka, 2013).

Scenario comprise of driving simulator software. The software shall be user friendly and allows detailed configuration. Track layout, road width, slippery level, weather condition, time of driving, visibility and all details related to emotion stimulation shall be interchangeable. This is to ensure accurate stimulation of studied emotion. For instance, smooth driving scenario promotes neutral emotion while heavy driving aids stimulating stress emotion (R. R. Singh, Conjeti, & Banerjee, 2013).

Determining environment of simulator is another noteworthy task. Temperature, airflow, camera location and noise level of the driving simulator needs detailed study and monitoring to preserve emotion's authenticity (Sebe et al., 2007). On the contrary, due to variation in driver's background, such as nationality, gender, driving experience and safety levels, drivers may experience different emotion at similar scenario (Jeon, Walker, & Yim, 2014). Accordingly, all subjects shall best be from the same or similar ethnicity.

Automated visual expression algorithm for emotion recognition had been heavily research for past few decades due to advancement of computing field. Humans recognize facial expressions virtually without effort or delay; however, key challenge in this approach is imaging conditioning. View, position and numbers of camera needs to be regulated to acquire optimum scale of image (Chibelushi & Bourel, 2003). Environment pattern and illumination such as background pattern, occlusion, uncontrolled lighting cause difficulty in face tracking and features extraction (Gross, Shi, & Cohn, 2001). Besides, artifacts like, glasses, shades and cap may directly affect its performance (C.D. Katsis, Goletsis, Rigas, & Fotiadis, 2011). Moreover, it is highly dependent on spatial position of face (Busso et al., 2004), people with different cultural and economic background tend to have variations in their expression (Bettadapura, 2012)(Harrigan, Rosenthal, & Scherer, 2008). Consequently, facial expression recognition system presence today is still inconsistent, thus, they are still unsuitable to be introduced in the motor vehicle (G. Lee, Kwon, Kavuri Sri, & Lee, 2014)(Haidet, Tate, Divirgilio-Thomas, Kolanowski, & Happ, 2009).

Speech signal recognition approaches detects user emotion using short-spoken sentences. Most researchers have used global prosodic features as acoustic cues for emotion and, in which utterance-level statistics are calculated. Pitch contour and energy in the utterances are features that normally analyzed (Busso et al., 2004). Major drawback of this approach is unavailability of global-level acoustic feature to describe the dynamic variation along an utterance (Busso et al., 2004). This spells out speech recognition framework is insufficient to work independently on motor vehicles.

Biosignal recognition approach uses physiological signals of users as input. Researchers that engineered this approach believes that this is a more natural means of affective state recognition, in that the influence of emotion and mood on facial expression and speech can be suppressed while these status is inherently reflected in the activity of nervous system (D. Singh, 2012). For instance, during frightened or stress, we would experience rapid breathing, heart races, muscle tenses and palm sweat, while these are bodily changes are monitored by central and peripheral nervous system, this may be analyzed by psychophysiological measures. (Vehkaoja et al., 2005)(Christos D Katsis, Katertsidis, Ganiatsas, Fotiadis, & Member, 2008)(R. R. Singh et al., 2013).

The vital challenge of biosignal recognition approach is necessity of electrode (Saper, Chou, & Scammell, 2001). EEG required placement of electrodes on the scalp to detect brain signal, EMG places electrode on the skin to detect muscle activity, ECG places electrode on the chest to detect heart activity while EDA places electrode on the palm or other regions of the body to measure the skin conductance. Presence of these electrodes limits the inclusion of biosignal recognition approach in a motor vehicle. A favorable emotion recognition framework shall only assist driving task by preventing road crash while not interfere and influence the driver. Hence, electrodes shall be repositioned form conventional location (direct placement on driver's body) to existing parts of vehicles, for instance, arm rest, steering wheel and gear shifting stick (Jeong, Lee, Park, Ko, & Yoon, 2007)(T. Takahashi et al., 2005).

Therefore, electrode location and accident-induced emotion recognizing performance of potential biosignal approaches shall be thoroughly reviewed. The most convenient and consistent method shall be employed for this research. Moreover, biosignal with least channels, yet possesses comparable performance shall be maneuver to reduce processing power and time (Tsihrintzis, Virvou, Stathopoulou, & Alepis, 2008).

1.3 Objectives

1. To develop an in-lab driving simulator that assists neutral, stress and anger emotion stimulation.
2. To establish statistical significant difference for biosignal measures between neutral-stress and neutral-anger emotion groups.
3. To achieve favorable classification accuracy for differentiating neutral from stress and anger emotion during simulated driving task with Electrodermal activity (EDA) and Electromyography (EMG) approach.

1.4 Scopes of work

This study aimed to recognize neutral, stress and anger emotion of driver when performing simulated driving task. An in-lab driving simulator developed with Speed Dreams and Logitech G25 racing wheel was incorporated with predesigned scenario and experimental procedure intended for stimulating the described emotions. EDA and EMG biosignal measures are presumed to differentiated stress and anger from neutral emotion of drivers. The recorded biosignal were processed offline for artifact removal and feature extraction. Statistical analysis was performed using extracted features and presumably significant difference ($P < 0.05$) was achieved between neutral-stress and neutral-anger groups. Lastly, a classifier was introduced for emotion classification, whereby classification accuracy was expected to exceed 80% between neutral-stress and neutral-anger emotion groups.

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