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Attention Level Determination by Using Fuzzy

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Abstract: For safe driving, it is always crucial to keep 100% attention on driving without distraction. The road accident may happen with just a blink of eyes. Previous studies have shown that peak decrement of N170 wave is related to degrading of attention. However, to determine the level of attention is challenging due to inter-variability of decrement range between subjects. Hence, in this study, the attention level is investigated by analyzing the peak of N170 decrement versus accident score using fuzzy rule-based to minimize the grey area. Accordingly, three levels of attention are found, i.e., attentive, begin of inattentive and inattentive. 23.3%% or less decrements of N170 peak is associate to significant attentive. When the decrements reach the 34.3% of N170 peak, the subjects showed the inattentive behavior and most of the subjects have shown that, 41.03% of N170 peak decrements is significant inattentive. This finding gives a promising foundation in developing a hardware for attention alarm system.

Keywords: safe driving, N170 wave, level of attention, fuzzy rule-based, attention alarm system

1. Introduction

An electroencephalogram (EEG) is a test that detects the electrical activity occurring at the surface of the brain using the electrodes attached to the scalp while measuring the brain waves [1]. EEG waveforms can be sorted according to the frequency, shape, amplitude and the respective lobes of the scalp which is measured. The brain cognitive function such as attention, memory and problem-solving abilities can be evaluated through the EEG signal analysis [2]. Table 1 shows on how the brainwaves contribute to the state of mind which can be sorted by its frequency [3].

Table 1 - The wave frequency of the human brain and how its contribute to the human attention

Brain Wave	Frequency (Hz)	Affect to the human attention
Beta	14-30	Important for effective functioning throughout the day which associated with normal consciousness, high state of alertness, logic and critical reasoning
Alpha	8-13	The gateway of the subconscious mind where it heightens the imagination, visualization, memory, learning and concentration

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Theta	4-7	It is the realm of subconsciousness and experience vivid visualizations and exceptional insight
Delta	0.5-3	The gateway of unconscious mind which experienced in deep, dreamless sleep where awareness is fully detached
Gamma	31-50	Associated with burst of insight and high-level information processing and also related to selective attention

Attention is known very crucial including in driving to avoid the fatal accidents to be happen which can lead to severe injury or even death. According to the statistic from World Health Organization (WHO) for 2013, Malaysia is ranked the top three of the countries in the world with the deadliest road. The data presented shows that about 7,000 to 8,000 people died on roads every year and the data is consistent with the Malaysian Institute Road Safety Research (MIROS) that revealed a total of 7,152 people died in road accidents in Malaysia in the year of 2016 and about 80.6% of the road accidents are caused by the human error [4].

In recent years, there has been an increasing interest in developing the attention monitoring system for the driver to reduce the road accident. Mbouna et al. presented the attention continuous monitoring based on the visual analysis of eye state and the head pose approached using a single camera [5]. An android-based smartphone driver safety monitoring has been proposed by Lee and Chung which used a data fusion approach based on eye feature, heart rate variability, blood pressure, in-vehicle temperature and vehicle speed. The system is able to alert the driver when the dangerous states detected [6].

The purpose of this paper is to investigate the attention condition of the driver during driving to evade the possibility of road accidents using an EEG. However, the challenge is that to determine the attention level based as that the N170 morphology for everyone is unique. The determination of the attention level is very crucial as it will help to define the condition of the driver at all time during the driving. The behavior data from the driver performance (accident score which is collected from the driving simulator) during driving is needed as well to figure out the level of attention. Thus, an artificial intelligence expert system decision making, fuzzy rule based is proposed in this paper to find out the boundary of each level of attention to classify the attention of the driver.

The fuzzy system has proven its potential in relational databases, approximate reasoning, preference modelling and medical diagnosis [7]. A lot of research has been done in the area of integration with brain cognitive detector based on fuzzy logic approaches.

Lin et al developed an adaptive alertness estimation method based on EEG, power spectrum analysis and fuzzy neural network (FNN) as an online driver's alertness level monitoring system. They findings show that the mixture of ICA and FNN can accurately estimate driver's individual alertness level [8]. Nagpal and Upadhyay proposed the method of Sleep EEG classification using the fuzzy logic rule base model and able to identify the major stages of awake, slow wave sleep (SWS) and Rapid eye movement (REM). The paper proved that fuzzy was confirmed has potential to classifying the EEG signals [9]. Wu et al. demonstrated the combination of a EEG power spectrum estimation, principal component analysis (PCA) and fuzzy neural networks to estimate the driving performance of the driver and the results shows that their method is feasible to accurately predict the drowsiness level in a realistic driving simulator [10].

In this paper, a new method combining the simple averaging method and rule-based fuzzy system was presented to determine the attention level. The proposed method was performed in two stages: the feature extraction by extracting the mean of the complex EEG waveform and the attentiveness classification by using the Mamdani rule-based fuzzy system.

2. Methodology

2.1 Experimental Paradigm and Procedure

The experiments were carried out with normal health young adult of age between eighteen to thirty years old. A total of fifty subjects took part on voluntary basis and signed the informed consent prior to the experiment. The experiment was conducted on high fidelity in-lab driving simulator based on virtual reality technology to build 3D highway driving scene. The subjects were seated in front of the driving simulator and three electrodes of EEG were attached to the subjects. The locations of the electrodes are attached at three channels; Fp_z (forehead), C_z (centre of head) and O_1 or O_2(occipital lobe) as shown in Fig. 1. The raw data was collected, stored and processed with the help of data acquisition system, BIOPAC Inc. Framework Mp EEG 100c and the machine programming, Acqknowledge 4.2. (as shown in Fig. 2). The impedance of the BIOPAC is guaranteed underneath 5kΩ and the responses will be filtered using bandpass digital filter between 1 to 15 Hz to make sure that the alpha wave was captured. The recordings were done with the sampling frequency of 500 Hz.

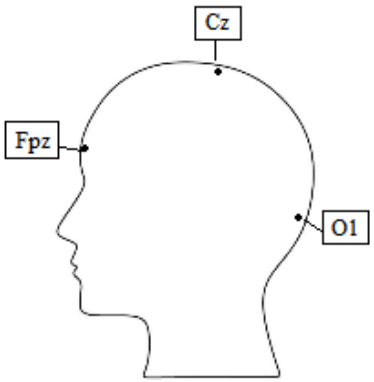


Fig. 1 – EEG electrode placement

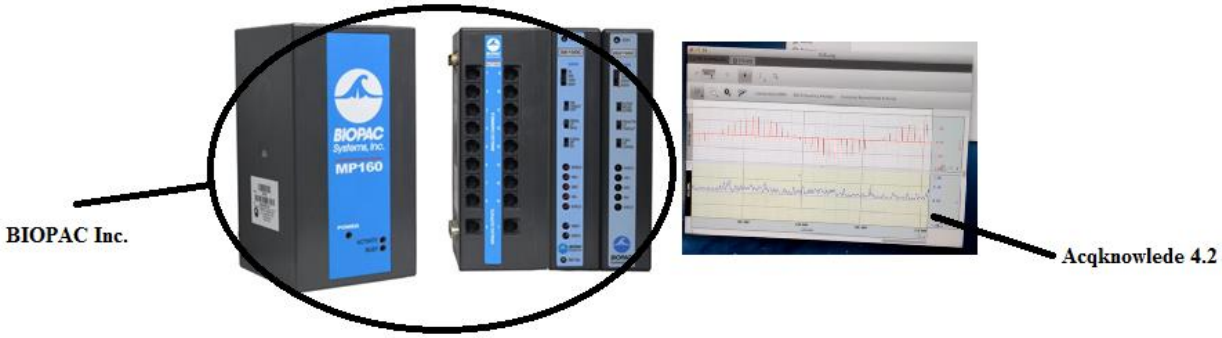


Fig. 2 – BIOPAC Inc. Framework and Acqknowledge 4.2 software used for data acquisition

This research work focuses on ERP technique to measure the human attention by using N170 ERP component waveform. Though it is not popular for attention measurement but previous researches have shown that it can measure the attention from the occipital lobe [11][12]. N170 is basically the negative peaks which occur between 130 ms and 200 ms after stimulus presentation.

The subjects are taken ten minutes training course prior to the experiment to get used of the driving simulator. Then, the subjects are given two different scenarios (with and without listening to the radio) as the stimulations during the long monotonous driving around twenty minutes respectively. Apart of it, the sound of 1 kHz tone was played throughout the experiment as a time-locked stimulus. Fig. 3 shows the experiment setup which conducted in the laboratory.

Fig. 3 – Experiment setup using driving simulator and EEG in laboratory

2.2 Feature Extraction

The system executing procedure is shown in Fig. 4. The subject will be driving the in-lab driving simulator while attached to the EEG electrodes. The raw EEG data were acquired continuously during the experiment in real time and

written inti CSV format before converting it into mat file for analysis purpose which designed by MATLAB. The recorded EEG data was segmented into response extending from 0 to 1s post-stimulus. The stimulus Event Related Potential (ERP) particularly N170 waveform are then extracted by finding the mean from the complex waveform and evaluate the morphology of the waveform to assess the driving performance and attention level. This method is known as simple moving average method which is the simplest yet convincing technique and useful for forecasting long-term trends [13].

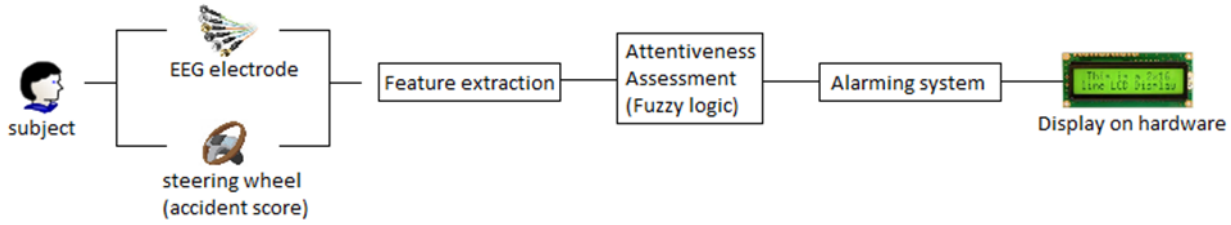


Fig. 4 – Experiment setup using driving simulator and EEG in laboratory

2.3 Attentiveness Assessment

The input of fuzzy membership function is designed by the region of features including both ERP N170 peak and accident score data. The membership function of EEG data (ERP N170 peak) is accordance with the attention level from the feature extraction results which can be divided into four categories, Large Negative (**LN**), Small Negative (**SN**), Small Positive (**SP**) and Large Positive (**LP**) as shown in Fig. 5. LN means that the attention level is in worst condition while LP defines as the current attention level is in best condition. The degree of accident score data is divided by three parts, low (**L**), mid (**M**) and high (**H**) as illustrated in Fig. 6.

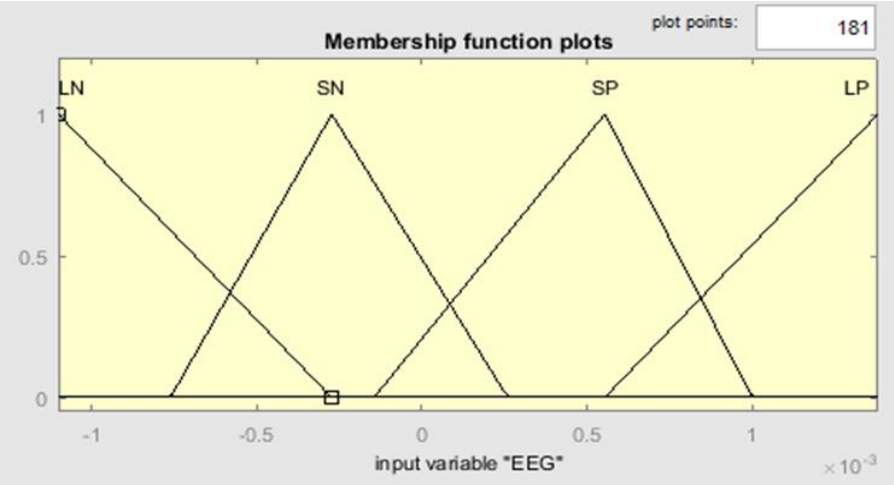


Fig. 5 – The membership function of attention level

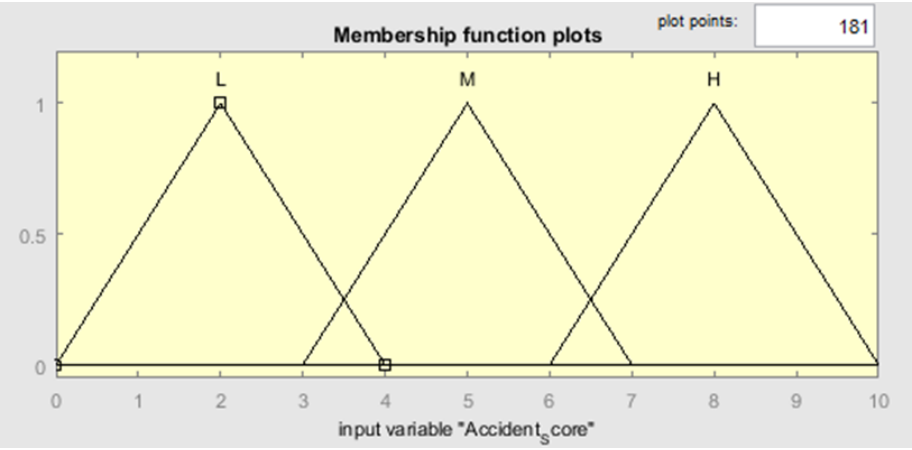


Fig. 6 – The membership function of accident score to show the driver performance during driving

The output of fuzzy membership function is developed accordance of to the attention level of the driver as shown in Fig. 7. It was divided by three attention condition; attentive (Good), begin of inattentive (Deficit) and inattentive (Bad). These three levels of attention condition will define the output of the alarm system to alert the driver if needed (for hardware application).

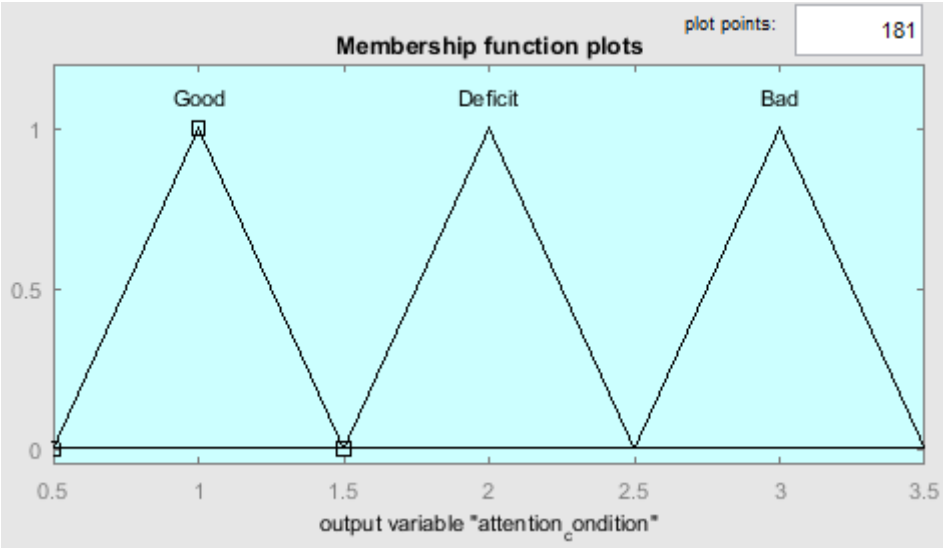


Fig. 7 – The output membership function of attention condition

2.4 Attention Level Determination

The output degree of the attention is divided into three types; one (1), two (2) and three (3). 1 means that the driver is attentive, 2 is denotes as the attention is started to decrease (begin of inattentive). Lastly 3 stated the subject is inattentive.

The fuzzy system is based on the fuzzy rules as shown below and the output of the attention level will be response accordance to the value of the output:

a) If attention is LP and accident score is L, then output will 1
b) If attention is LP and accident score is M, then output will 1
c) If attention is LP and accident score is H, then output will 2
d) If attention is SP and accident score is L, then output will 1
e) If attention is SP and accident score is M, then output will 2
f) If attention is SP and accident score is H, then output will 3
g) If attention is SN and accident score is L, then output will 2
h) If attention is SN and accident score is M, then output will 2
i) If attention is SN and accident score is H, then output will 3
j) If attention is LN and accident score is L, then output will 2
k) If attention is LN and accident score is M, then output will 3
l) If attention is LN and accident score is H, then output will 3

The rules are identified using a Mamdani's inference system based on the inferential matrix as shown in Table 2 to determine the output of the fuzzy system. The output is corresponding to the driver attention level which will be applied to the alarm system as hardware application in future.

Table 2 - The wave frequency of the human brain and how its contribute to the human attention

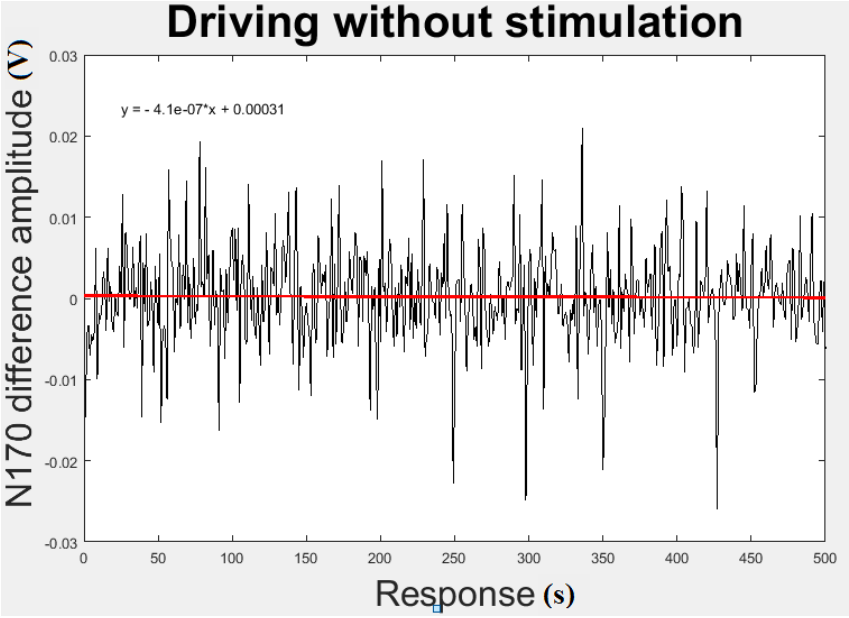
	LN	SN	SP	LP
L	Inattentive	Begin of inattentive	Attentive	Attentive
M	Inattentive	Inattentive	Begin of inattentive	Attentive
H	Inattentive	Inattentive	Inattentive	Begin of inattentive

3. Results and Discussion

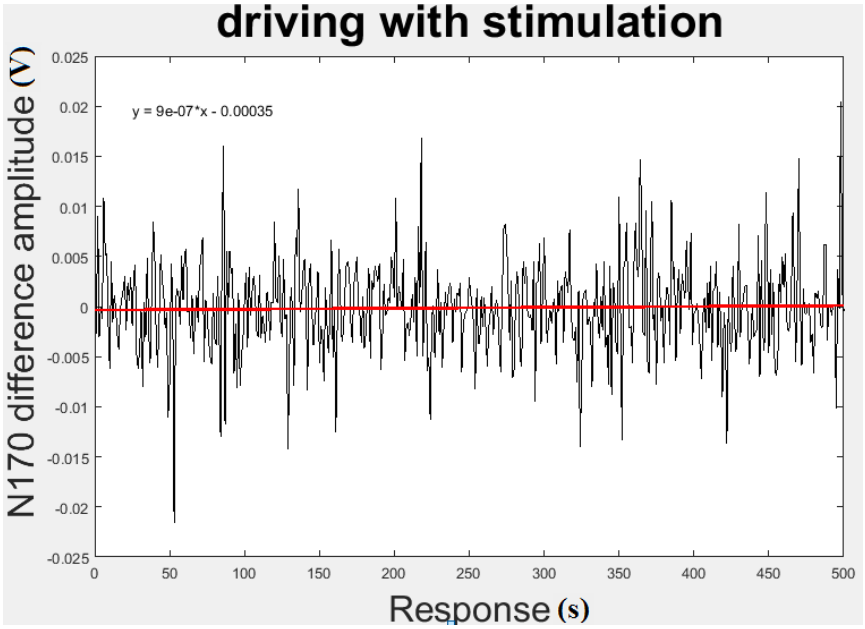
3.1 Analysis of Driver Attention with Different Stimulus

Prior to design the fuzzy logic system, the analysis on the N170 ERP peak data was performed to identify the effect of the stimulation on the driver attention based on the behavior of the N170 ERP waveform. In particular, the simple averaging techniques was used on the EEG features extracted from the data obtained, the N170 ERP wave.

Regression line analysis was used to predict the trend of the graph. Fig. 8(a) and Figure 7(b) show the results between two different stimuli during the experiment respectively.



(a) With no stimulation during driving



(b) With stimulation by listening to the radio during driving

Fig. 8 – The response of average N170 ERP wave between two different stimuli

Fig. 8(a) depicts that the driver attention is getting decreased over the time response (negative gradient from the regression line) while Fig. 8(b) indicates that the attention is slightly increased when listening to the radio during driving. It clearly can be seen from the trend of N170 wave amplitude increasing when listening to the radio during driving. The observation is based on the positive gradient of the regression line (mark in red line in the figure) This is apparently from these figures that listening to the radio during driving helps the driver to stay vigilance and focus on the road. The results from this data are consistent with the previous research discovered by Jonsson, I.-M. and Dahlback, N. where their assessment found that the combination of submissive and dominant speech helps driver performance [14]. This was also supported by other researcher [15][16]. In terms of percentage, the difference behavior of the driver attention is presented in Fig. 9.

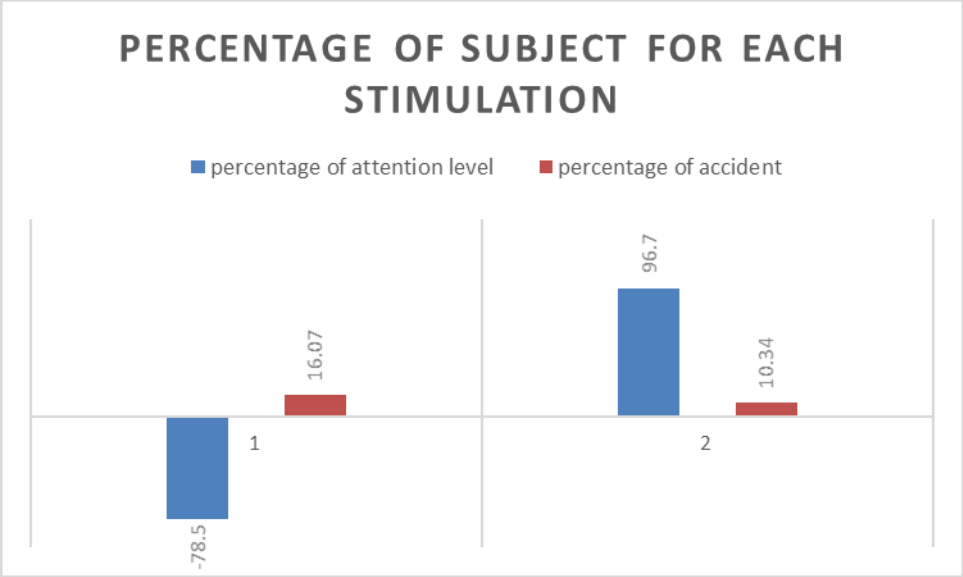


Fig. 9 – The percentage of the attention level and accident score for all subjects

Based on Fig. 9, driving with no stimulation is denoted as '1' while driving with stimulation is denoted as '2'. The different between both stimulations is apparently in Fig. 9 that, the percentage of subject that have degrading attention when driving without stimulation is 78.5% and the accident score is 16.07%. While the second graph shows that the percentage of subject able to increase their attention when listening to the radio during driving is 96.7% and the accident score down to 10.34%. These findings further support the idea of driving while listening to the radio is able to maintain the focus of the driver on the driving and successfully reduced the percentage of accident.

3.2 The Attention Level Determination

The results are from all the participants that volunteer to become the subjects of the experiment and their data are gathered to reduce the variability among the subjects so that the boundary of each level of attention can be defined along with the driver performance data from the driving simulator. The diagram of fuzzy logic output is presented from the EEG and driver performance data extracted shown in Fig. 10.

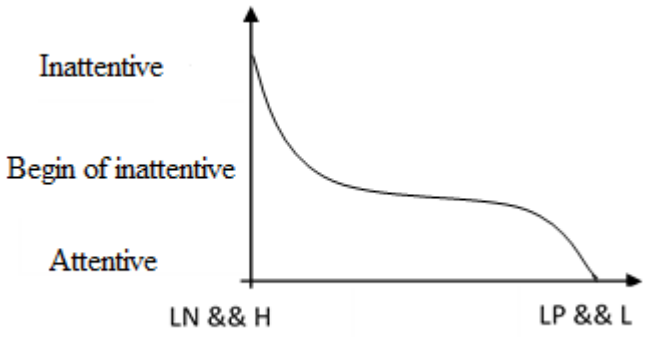
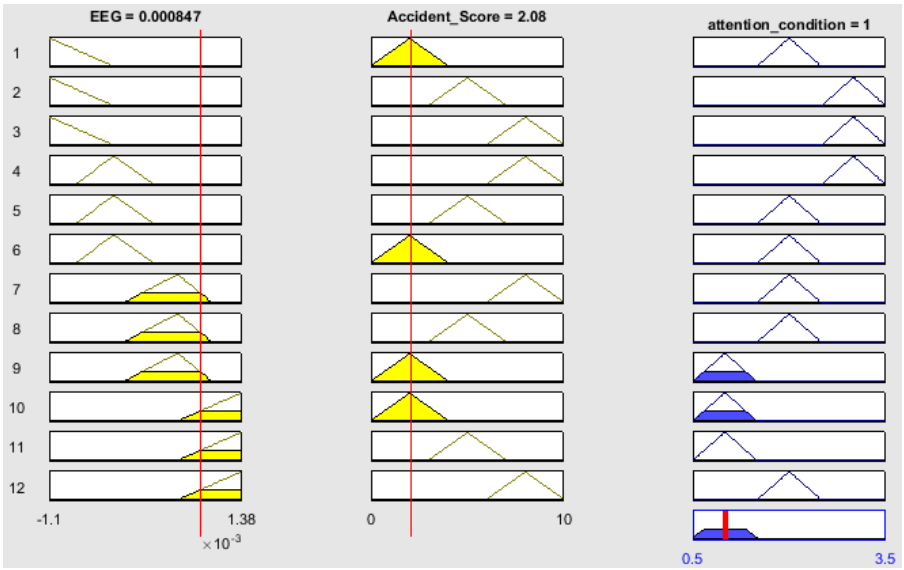
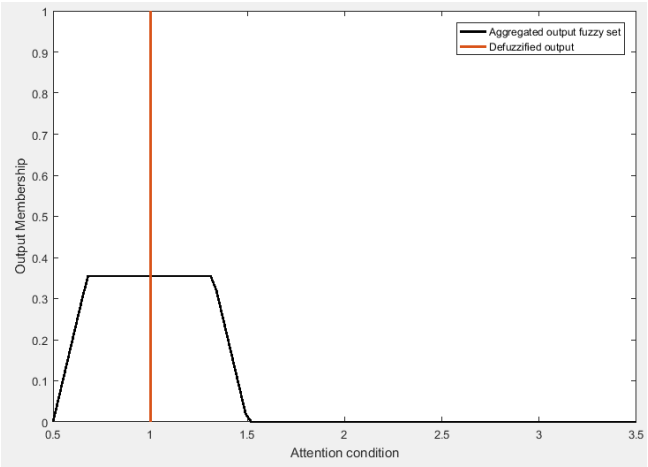


Fig. 10 – The diagram of the behavior of the driver attention based on the peak of N170 ERP wave and the driver performance data

Fig. 10 depicts how the attention level is defined from both of collected data, peak of N170 ERP wave and driver performance data (based on the accident score). The higher of the accident happen when the peak of N170 ERP wave decreased, then the attention level of the driver is down to inattentive condition and vice versa. From the analysis, the driver attention level is classified according to the fuzzy rules and the mean of each groups are calculated. As shown in Figure 8 the attention level is categorized into three level of attention i.e.; attentive, begin of inattentive and inattentive condition. The results on how the attention level is classified by using the fuzzy rule-based system are shown in Fig. 11, Fig. 12 and Fig. 13 for respective level of attention.



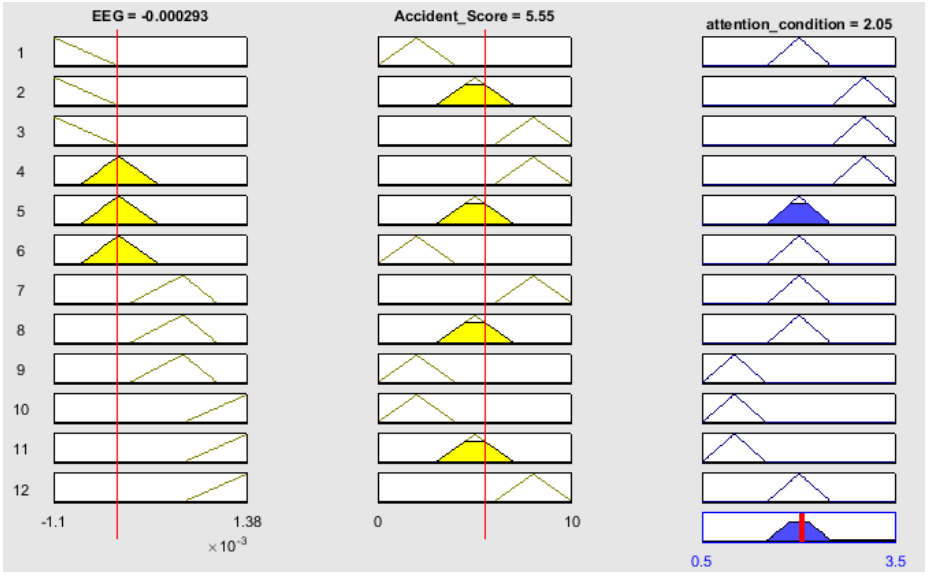
(a) Rule viewer



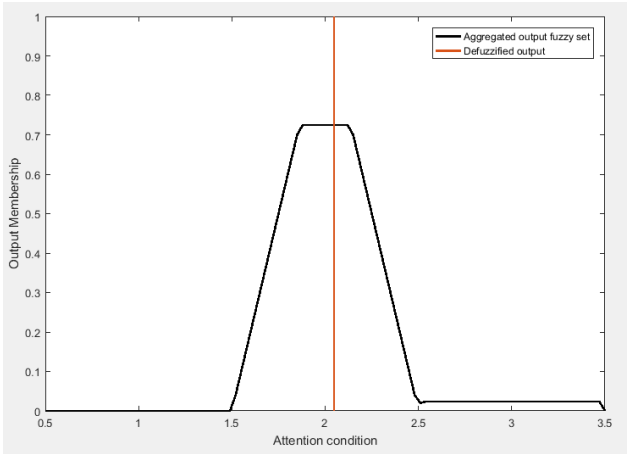
(b) Aggregated output fuzzy set and defuzzified output value

Fig. 11 – The output fuzzy set of attention level in attentive state

As shown in Fig. 11 (a), if the difference value of N170 ERP peak is positive value and the score of the accident is low then the attention condition weight score will be 1 which means the attention condition is in attentive behavior. In Fig. 11 (b), the intermediate results of aggregated output fuzzy set and the defuzzified output value is visualized from the rule viewer corresponds to the output variable. At this state, the driver is considered still vigilance and able to focus on the driving.



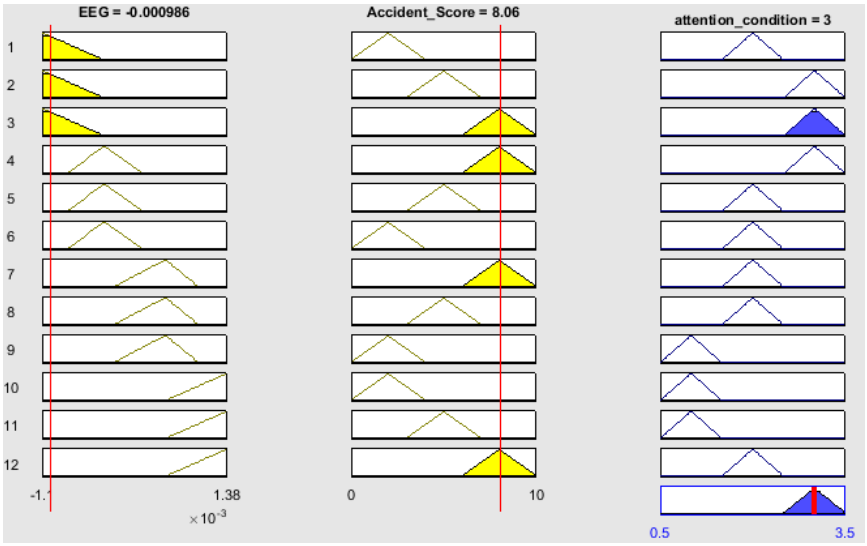
(a) Rule viewer



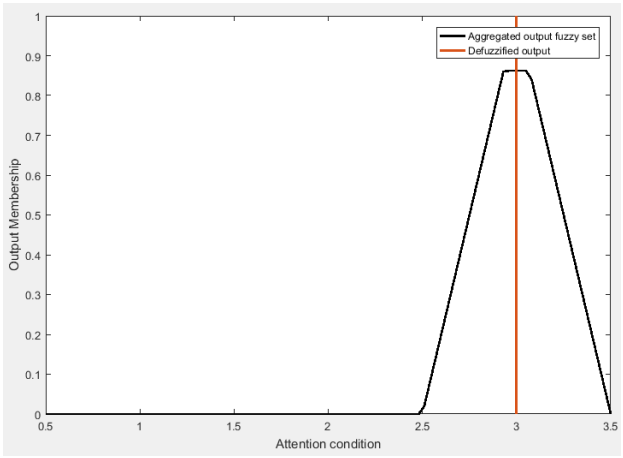
(b) Aggregated output fuzzy set and defuzzified output value

Fig. 12 – The output fuzzy set of attention level during the begin of inattentive

As can be seen in Fig. 12 (a), if the difference value of N170 ERP peak is within the middle threshold and the score of the accident is medium then the attention condition weight score will be 2 which means the attention condition is still considered good, but the attention is started to degrade or deficit. This is the time where the begin of inattentiveness. This can be clearly be visualized from Fig. 12 (b). Though the driver is considered still vigilance, but the warning alarm should be triggered at this time so that the attention may stay on the driving.



(a) Rule viewer



(b) Aggregated output fuzzy set and defuzzified output value

Fig. 13 – The output fuzzy set of attention level during inattentive

According to Fig. 13, let say the N170 ERP peak is within the inattentive boundary value and the accident score is high then the attention is considered in inattentive behavior. It is apparent from Fig. 13 (b) that the value of the output is 3 where the possibility of accident happen due to driver inattention is very high. If possible, at this time any sound alarm needs to be triggered to alert the driver and avoid the road accident to be occurred as the driver attentiveness is fall in inattentive level.

Overall, the surface viewer of the fuzzy rule-based system is presented in Fig. 14 which interprets the three-dimensional (3D) plot of the input-output relations in algebraic expression.

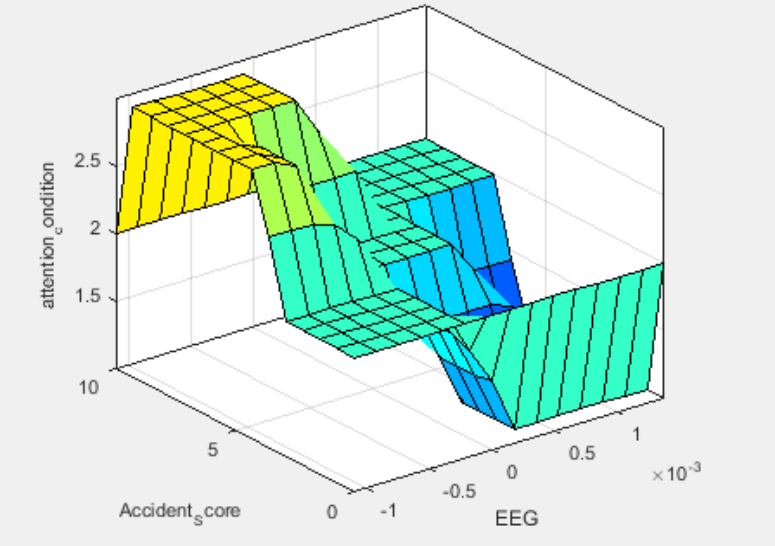


Fig. 14 – The surface viewer of attention relations

Fig. 14 represents the mapping from the amplitude difference of N170 ERP peak and the accident score to the driver attention condition during the driving (accident score from driving simulator). As the result, the diagram of each attention level determination is described in term of percentage as shown in Fig. 15.

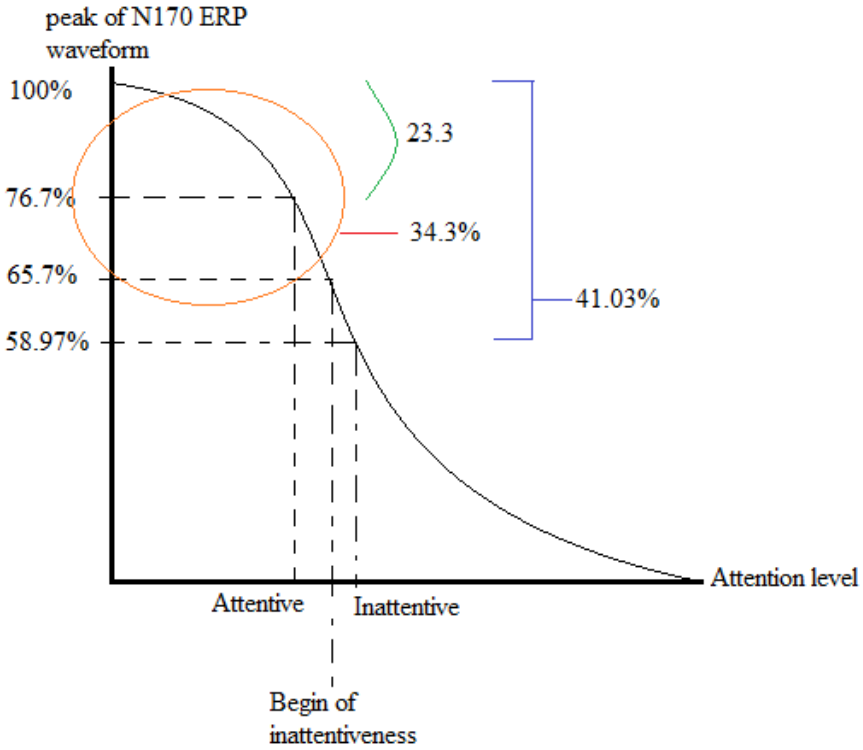


Fig. 15 – The surface viewer of attention relations

Fig. 15 shows the suggested boundary of each attention level in terms of percentage. As presented in Figure 15, it clearly shows that in term of percentage, the percentage is 23.3% or less decrements of N170 peak is associate to significant attentive. When the decrements reach the 34.3% of N170 peak, the subjects showed the inattentive behavior and most of the subjects have shown that, 41.03% of N170 peak decrements is significant inattentive. At this time, the possibility of accident occurs is high as the driver is not focusing on the road anymore.

As can be seen from the results above the level of attention can be obtained and classified by using fuzzy rule-based system. The suggested technique using the fuzzy rule-based system as the attention classification can be used in any of attention monitoring, in particular, the monitoring driver attention during driving to evade the road accident to be happened.

4. Conclusion

The objective of this paper is to classify the driver attention condition by using the techniques of fuzzy rule-based system. As revealed in Results and Discussion section, the attention level can be classified into three state which are attentive, begin of inattentive and inattentive. Furthermore, this paper found that listening to the radio during driving may help the driver to stay vigilance and reduced the road accident which is due to the loss of attention. As for future work, the development of inattention alarm system is required to helps the driver to stay vigilance and focus on the driving so that the road accident can be avoided.

Acknowledgement

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References

[1] Snyder, E. J. (1990). The electroencephalogram (EEG). Biomedical Instrument Technology, 24(4), 296–298.
[2] Aminuddin, M. M. M. & Nasir, H. M. (2017). Loudness Perception Differentiation Using Repeating Sinus Rhythm. MALTESAS Multi-Disciplinary Research Journal (MIRJO), 2(3), 47–54.
[3] Liu, N. H., Chiang, C. Y., & Chu, H. C. (2013). Recognizing the degree of human attention using EEG signals from mobile sensors. Sensors (Switzerland), 13(8), 10273–10286.
[4] Tang Ruxyn. (2017). Death Rates On Malaysian Roads Is 3rd Highest Globally, More Than China And India. says.com. [Online]. Available: http://says.com/my/news/malaysia-s-roads-among-the-world-s-most-dangerous-and-deadliest. [Accessed: 04-Jul-2018].
[5] Mbouna, R. O., Kong, S. G., & Chun, M. G. (2013). Visual analysis of eye state and head pose for driver alertness monitoring. IEEE Transactions on Intelligent Transportation System, 14(3), 1462–1469.
[6] Lee, B. G. & Chung, W. Y. (2012). Driver alertness monitoring using fusion of facial features and bio-signals. IEEE Sensor Journal, 12(7), 2416–2422.
[7] Nădăban, S. & Dzitac, I. (2014). Special types of fuzzy relations. Procedia Computer Science, 31, 552–557.
[8] Lin, Y., Zhang, W. J., Wu, C., Yang, G., & Dy, J. (2009). A fuzzy logics clustering approach to computing human attention allocation using eye gaze movement cue. International Journal of Human Computer Studies, 67(5), 455–463.
[9] Nagpal, C., & Upadhyay, P. K. (2015). Sleep EEG Classification Using Fuzzy Logic. International Journal of Recent Development in Engineering and Technology, 4(1), 6–12.
[10] Wu, R. C., Lin, C. T., Liang, S. F., Huang, T.Y. & Jung, T.P. (2004). EEG-Based Fuzzy Neural Network Estimator for Driving Performance, IEEE International Conference on Systems, Man and Cybernetics, 4034–4040.
[11] Crist, R.E., Wu, C.-T., Karp, C., and Woldorff, M.G. (2008). Face processing is gated by visual spatial attention. *Frontiers in Human Neuroscience*, 1 (March), 1–6.
[12] Kafshgari, N.N., Davoodi Kahaki, R., Moradi, M.H., and Younesi, A. (2014). An ERP study on visual attention to facial stimuli; N170 component. In: *2014 22nd Iranian Conference on Electrical Engineering (ICEE)*. IEEE, 1976–1979.
[13] Sreekrishna, R. R., Nalband, S., & Amalin Prince, A. (2016). Real time cascaded moving average filter for detrending of electroencephalogram signals, International Conference on Communication and Signal Processing, 745–750.
[14] Jonsson I.M., & Dahlbäck, N. (2014). Driving with a Speech Interaction System: Effect of Personality on Performance and Attitude of Driver, Human-Computer Interaction. Advanced Interaction Modalities and Techniques: 16th International Conference, HCI International 2014, Heraklion, Crete, Greece 417–428.
[15] Aminuddin, M. M. M., & Nasir, H. M. (2018). The Feasibility of Music and Talk Radio Program as a Focus Stimulant for Driver. International Journal of Human Technology Interaction, 2(1), 45–49.
[16] Super, S., & Aminuddin, M. M. M. (2016). Practicability of Meaningful Sound to Avoid Attention-Drifting Phenomenon While Driving. Advanced Science Letter, 22(9), 2138–2140.