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Raw EEG-based Fatigue and Drowsiness Detection: A Review

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Abstract **– One of the dreadful reason behind many accidents in the industry and on the road is the drowsiness of the operator who is operating the machine or vehicle, which finally result into loss of lives and economy. To reduce this factor many research has been conducted to identify the drowsy operators or drivers. This review is prepared on the researches for identification of driver's drowsiness and fatigue using raw EEG signals and ocular artifacts acquired using NeuroSky Mindwave Device.**

Keywords: Drowsiness, Fatigue, EEG, EOG, Brainwaves, Threshold, Filtering, Digital Signal Processing.

I. INTRODUCTION

Fatigue & drowsiness can cause lethal consequences while driving or operating heavy machines and it can be the cause of fatal crashes. According to National Sleep Foundation, 20% of pilots, 18% of train operators & 14% of truck drivers make a serious error due to fatigue & drowsiness [17]. According to some survey driver's fatigue is believed to account 35%-45% of all vehicle accident [37]. National Highway Traffic Safety Administration says that in United States of America at least 1500 people die and at least 40000 people get injured each year in crashes or accident related to fatigued or drowsy drivers/operators [2]. A case-control study of 571 drivers involved in road crashes shows that driving without sufficient sleep can make a driver drowsy and it would increase the risk of crash [4]. As the fatigue is the cause of major accident in industry & transportation its detection & prediction system attracted the academic and industrial interest for research and development in finding efficient methodology.

Fatigue is a state of mind where the capabilities of responding to any situation of our mind get degraded. Fatigue is a natural physiological state which is triggered by circadian rhythm and sleep deprivation and cause lack of ability of concentration, attention, focus, vigilance and facing difficulties to stay awake and sometime leads to micro sleep episodes where a person becomes unconscious for a fraction of a second up to 30 seconds [1]. Human brain operates using billions of inter-connected neurons inside it. While a human being changes his/her emotional state there appears some interaction pattern between the neurons and it creates a minuscule electrical discharge which is impossible to measure from outside scull. But the activity created by thousands of concurrent discharges can be aggregated into waves and it can be measured [53]. This wave patterns can be characterized by different amplitude and frequencies and known as Alpha, Beta, Gamma, Delta and Theta. This wave can be fetched from EEG (Electroencephalogram) and EOG (Electrooculogram) signals. EEG signals can be acquired from mind using brain computer interface devices and there are many providers available in market which manufactures this kind of device. Neurosky is one of them and providing relatively cheap EEG acquisition device with a dry electrode which is having a better price-performance ratio in fetching raw EEG signals.

To get the read out of the problem of identifying driver's fatigue in real-time scenario neurosky mindwave can be used as an interfacing device to acquire the signal of the human mind. After applying some filtration for separating the signal and then by some threshold the fatigue index can be identified.

II. BACKGROUND THEORIES & RELATED WORK

A. Neurosky® mindwave

The Neurosky® mindwave is a device which works as an EEG machine by the using the dry electrode for taking the readings of the brain & pass that outcome through an application that uses the data to read from it as it wishes.

Fig -1 Neurosky mindwave [53]

B. EEG (Electroencephalography)

An electroencephalogram (EEG) is a test which is used to detect the anomalous behavior related to electrical activity of the brain. It tracks & records brain wave patterns.

C. EOG (Electrooculogram)

An electrooculogram (EOG) is a technique which is used for measuring the corneo-retinal standing potential that exists between front and back of the human eye.

D. Different Values Of Gamma BrainWaves

Table 1:
EEG values of different waves [2]

Brain wave type	**Frequency Range**	**Mental state and condition**
Delta	0.1Hz to 3Hz	deep, dream less slip
Beta	4Hz to 7Hz	creative,recall,fantasy
Alpha	8Hz to 12Hz	relaxed ,but not drowsy
Low Beta	12Hz to 15Hz	relaxed yet focused, integrated
Midrange Beta	16Hz to 20Hz	Blinking
High Beta	21Hz to 30Hz	alertness, agitation
Gamma	30Hz to 100Hz	motor function, high mental activity

E. Filtering

Filtering in terms of Digital Signal Processing stands for some multiple frequency bandpass filters which only allows to pass the signals which matches with specific frequencies.

F. Thresholding

If we would like to limit the signal to certain parameters then the threshold is used so nothing happens until the signal passes the threshold.

III. LITERATURE REVIEW

Many researchers have attempted to develop continuous fatigue monitoring system. Here is the observation summarization of each & every research done.

Mr. Hamzah Al-Zu'bi along with his team has stated a method that measures the effect of fatigue in real-time depending only on the EEG signal of the subject and totally independent of the application type in contrast to ASTiD. This system requires low cost of implementation comparing to other system because it is based on inexpensive neurosky mindwave signal acquisition device. But this study was performed only on three trials and reflects high accuracy so it is necessary to check whether it is providing same accuracy in every situation or not. This system works well but can be made more reliable by degrading its false alarm rate [1].

Mr. Giovanni and his team have introduced the more reliable solution with false alarm rate in DROWTION: Driver Drowsiness Detection Software Using MINDWAVE. They have stated that when the average value of low alpha is below 0.7, high alpha is below 0.6 and theta is below 0.7, it is called normal conditions. If the rate is degraded then it will introduce the fatigue index. According to the authors accuracy of DROWTION application in normal condition is 68.11% [2]. This system is single electrode base system and no filtering is used for specific signal improvement so accuracy is very low.

Mr. Jian He and his team created a noninvasive real-time driving fatigue detection technology based on left prefrontal Attention and Meditation EEG. They have measured driver's fatigue with K-nearest neighborhood algorithm with the correlation coefficient of subject attention & meditation and it was providing the specificity of 90.43%. This system was having more accuracy but the time delay was very high because of complex K-nn algorithm [3].

Mr. Chee-Keong and his team have developed a mobile driver safety system, analysis of single channel on drowsiness detection with the lowest 2 seconds of latency and 31% of probability of detection per second accuracy. In this research

they have differentiate the oculo artifacts and also states the ice state in the consideration of fatigue index measurement. But it was having a high false alarm rate [4].

Mr. Chih-Jer Lin and his team created an embedded system and stated the research in Development of a real-time drowsiness warning system based on an embedded system that the brainwave signals can be acquired in real-time and fatigue identification system can also be developed for real-time via RF. It was a cost effective method to implement real-time fatigue identification but less accurate and less robust because it was programmed in PIC-UC while many advanced board are available in market with cheap rate and more functionalities [5].

So, in general there is scope of improvement in accuracy, latency, false alarm rate in different-different methods and still there is a scope of research in the area to improve the ability of Raw EEG-based Fatigue and Drowsiness Detection.

IV. RESEARCH GAP & CONCLUSION

After observing many research methodology for EEG based driver fatigue detection using mindwave it seems that there are many systems which have been implemented with capacity of detection or identification of driver's drowsiness and fatigue in low cost and more accuracy. But still there is a scope of improvement by minimizing false alarm rate, higher accuracy on gamma brainwave signals and effective threshold. By improving these three factors a more accurate real-time system of raw EEG based fatigue and drowsiness detection can be implemented.

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