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Drowsy or Not?Early Drowsiness Detection utilizing Arduino Based on Electroencephalogram (EEG) Neuro-Signal

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ABSTRACT

The adverse effect of sleepy driving is a big concern and is closely related to numerous near-misses and driving accidents. Detection of drowsiness using wearable sensors leads to attempts to identify driver sleepiness by incorporating emerging technology for real-time sleepiness detection. This paper presents a wearable pre-frontal single-channel Electroencephalogram (EEG) tool that will determine the state of the mind of the driver automatically, drowsy which focus on the transition from awake to asleep and non-drowsy. A driving experimental setup was designed and conducted using 10 participant participants. The system is integrated with an alarm system which will activate when the brain activity fluctuates that utilized Arduino module. Collected data included the continuous driving time prior to detection of drowsiness. Numerical labels 1 and 0 are applied to the performance of the system. A value of 1 is given to the point at which the participant is already in the drowsy state and 0 to the attention state (non-drowsy). The results of all the trails made were compared to the output of the expected and actual results. The error explains whether the system was able to provide a correct output or not. Generally, the accuracy gathered 93.33%.

Key words : Drowsiness, Attention, Meditation, Electroencephalogram (EEG), Arduino

1. INTRODUCTION

The adverse effect of sleepy driving is a big concern and is closely related to numerous near-misses and driving accidents in the transport industry. Notwithstanding these dangers, drivers tend to drive even when they are sleepy. Adult drivers admitted to driving a car while asleep according to National Sleep Foundation[1]. This incident typically takes place in the early morning hours and in the middle of the day, often during long travel hours. Demand for continuous service often requires staff to be alert during the night. Extended sleeplessness during the night can lead to misalignment between internal biological functions and social needs, which contributes to sleepiness during and after work. Therefore, the adverse effect of sleepy and sleepy driving is a major concern[2].

Several studies have define driver drowsiness make use of the vehicle-based, behavioral and physiological measures [3]. Vehicle-based measures apply to a variety of parameters, such as lane location deviations, steering wheel motions, acceleration pedal pressures, etc., which are continuously tracked and any change in these that crosses the defined threshold indicates a substantially increased probability that the driver is in drowsy state. Behavioral interventions apply to the behavior of the driver. This includes yawning, eye closing, eye blinking, etc. Camera is used in tracking these parameters and the driver will be notified if any of the signs are observed. Physiological measures refer to the association between physiological signals such as ECG, EMG, EoG and EEG [4].

Based on studies, vehicle-based interventions are a poor indicator of output error risk due to sleepiness based on studies. In fact, these metrics are not unique to sleepiness. This used two measures: Standard Lane Location Deviation (SDLP)and Steering Wheel Movement (SWM). These operates only in very specific circumstances. This is because it can only work reliably in specific environments and is too dependent on the geometric characteristics of the road. Meanwhile, vision-based make use of light. However, this revealed that this was the main downside to the use of this approach due to standard cameras do not perform well at night. Some researchers used active illumination using an infrared (LED) in order to address this limitation. Yet, while these operate relatively well at night, daytime LEDs are known to be less robust[4].Researchers have recently tried to establish a range of fatigue detection and counter-measurement techniques in which EEG signal is a major contributor. Moreover, these techniques have been found to be even more effective, as the reproducibility of data has been found to be more precise compare toother techniques in biomedical area [5].

Electroencephalogram (EEG) is characterized as electrical activity of the alternating form determined by metal electrodes and conductive media from the surface of the scalp. It is a device that relies on the adhesion of the scalp receptors, the main instrument used to track brain function. Evaluation drowsiness detection has been applied to products, driver alertness evaluation and management of office environments. Assessment human brain activity is the process of measuring the level of sleepiness. This is a system that depends on the adhesion of the sensors to the scalp, the key instrument used to monitor brain activity[6]. The approach of wearing the cap with multiple sensors while driving has practical disadvantages[7] which add significant restrictions on the movement of the driver. Previous research shows that the use of low-cost portable drowsiness monitoring systems in the quantification of drowsy states. In addition, it is beneficial to carry out realistic studies with goals as varied as assessing classroom mental commitment, film assessment and assessment of the office environment [8]. With these, this study proposed a solution that would use a wearable system capable of detecting whether or not the driver is drowsy but would not restrict the movement of the driver.

The aims to develop a wearable pre-frontal single-channel EEG tool that will automatically determine the state of the mind of the driver. The output is whether the driver is drowsy which focus on the transition from awake to asleep and non-drowsy. The system is integrated with an alarm system which will activate when the brain activity fluctuates. The system will be acquired brainwave and the signal will be processed to determine if drowsy or not. To tests its performance, an off-line investigation was made from the set-up experiment.

2. REVIEW OF RELATED LITERATURE

The EEG monitoring system monitors the human cognitive state and provides a biofeedback. Many previous researchers found that occipital midline is an important way of discriminating against the influence of sleepiness and alertness. Based on this property, a BCI system was developed which consisted of EEG electrodes which detected drowsiness. A driver sleepiness prediction system integrated with a wireless and wearable EEG tool and an effective prediction model were made possible [9].Another study is based on electroencephalography. This is evaluating a driver's sleepiness level directly from cerebral activity. The purpose is to estimate and provide timely alerts to avoid performance quality declines and to inhibit accidents related to drowsiness[2].

An approach that utilized Google Glass states that drowsiness detection using wearable devices leads to the efforts of identifying driver drowsiness by introducing new approach for real-time drowsiness detection. Since drivers often underestimate the level of drowsiness, this software allows the driver to better assess the level of danger might occur, this approach provide an importance implications for safety driving[1].Another approach was the development of Perceptual Function Integration System to recognize the alertness of the driver that uses spectral features from multiple independent brain sources. The study of brain spectral dynamics offered empirical proof that the activities of specific cortical outlets were closely linked to alertness changes. System performance showed reliability and improved accuracy as much as 88% higher than any single-source technique[10]. In addition, an integrated device drowsiness monitoring scheme incorporating behavioral information motion through an IMU sensor and physiological information coming from brain activity through a single EEG electrode has been introduced and tested. This results in a wearable device capable to detect 5 different levels of drowsiness with accuracy of 95.2%[11]. Standalone wearable driver drowsiness system was also developed incorporated with a smart watch. The design was completely standalone and distraction-fee. The goal is to determine the degree of drowsiness based on actions extracted from the motion data gathered from the smart watch's built-in motion sensors, such as the accelerometer and the gyroscope. Results state that it is an effective, safe, and distraction-free system [12]. Other application is detection and classification methods for epileptic seizures based on EEG signals [13].

In conducting the different approach of drowsiness detection, the Arduino Board used number of application and research. As of today, this is one of the freeware electronic kits that work with easy-to-use hardware and software. These applications are road accident detection with warning system [14], accident prevention incorporated with IoT [15] and utilization of image processing [16], used to advance the process in agriculture[17], featured in door security[18] and different home appliances such as controlling the fan speed[19] as some of the examples.

3. TECHNICAL DESIGN

3.1 Block Diagram

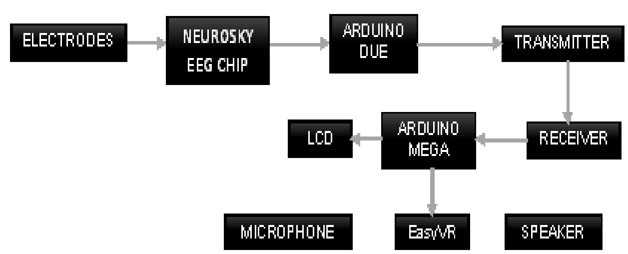

Figure 1: Block Diagram

The electrodes were used to measure the strength of brain waves. The Electroencephalograph (EEG) reads the frequency of brain waves coming from the electrodes. Arduino was used for signal processing and will also determine the if patient/driver is drowsy or not. Output is displayed in an LCD.

3.2 Hardware Design

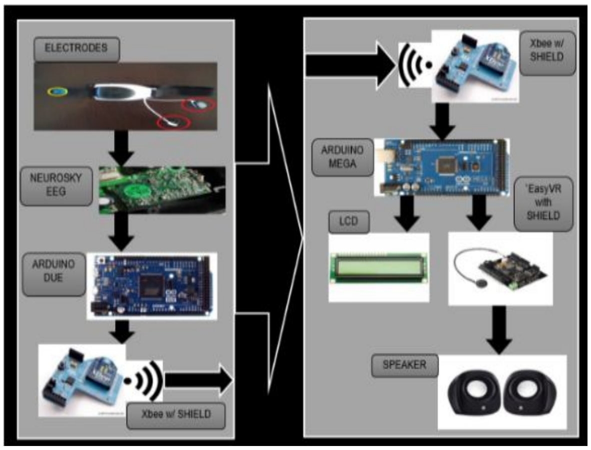

Figure 2: Hardware Design of the System

Materials and components in the left were used for data acquisition while on the right were used to process the signal and evaluate the output.

3.3 Materials and Components

The following are the materials and components used in successfully developing the system.

A. NeuroSky Electroencephalogram (EEG) Sensor

EEG was used in the processing of brain signals. The electrodes were mounted in both the lobe of the ear and one in the forehead.The sensor output raw data brainwave signals and attention and meditation level of brain activity.

B. Xbee Wi-FiModule

Xbee Shield serves as transmitter and receiver module of the system. The module was used to provide a wireless connection between the sensors and signal processing module.

C. Easy VRShield

This module is a multipurpose speech recognition device designed to bring specific features to any program. This module was attached to the Arduino Mega within the built-in signal-processing used to accept voice data when a driver is required to respond.

D. Arduino Modules

An open-source platform used to process the gathered brainwave. Arduino Due and Arduino Mega was integrated in the system. Arduino Due is attached in the wireless headsetmodule that will process the measured signal and Arduino Mega will compute and determine if drowsy or not.

E. Speaker

Used to output the pre-recorded data (questions) the system will be provided to the driver to answer.

F. Liquid Crystal Display (LCD)

This panel used to display the computed data, brainwave readings and current status of the system interactively.

3.4 EEG Signal Acquisition

The eSense was measured using a broad range of brain waves in both time and frequency domains, along with alpha and beta waves. To determine whether the output is drowsy or not, attention and meditation ratings were used. Attention level rating which indicates the intensity of a user’s level of mental “focus” or “attention” utilized an unsigned one-byte value. This occur during the intense concentration and directed state but stable mental activity. Meditation level rating which indicates the level of a user's mental "calmness" or "relaxation" used unsigned one-byte value. Meditation is related to reducing the operation of active mental processes in the brain, and it has been known for a long time that closing one's eyes takes away the mental activities that process images from the eyes, so closing one's eyes is also an successful method of raising the level of meditation. Both attention and meditation values range from 0 to 100.Below are the placement of the sensors and actual prototype.

Figure 3: Electrodes – Forehead

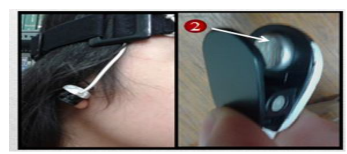

Figure 4: Electrodes – Earlobes

Figures 3 and 4 display the location of the sensors. It consisted of a dry sensor and had an electronic circuit specially designed. Figure 3 is placed on the forehead and upper part of the eyebrow in order to precisely acquire brainwaves. Figure 4 is the baseline sensor that needs to be clipped onto both earlobes that serves as the ground.

Figure 5: Actual Prototype

Figure 5 displays the prototype. Power bank (left) was used as a power source for a wireless headset module (middle) and an signal processing module (right).

4. TEST APPROACH

4.1 Experimental Set-up

The following are the actions taken in the execution of the experiment. For the collection of data, every step was strictly followed. First, the driver needs to wear the wireless headset module correctly while seated in a comfortable chair. The given time to test is a minimum of 30 minutes or less to determine the driver's state of mind. The projector backdrop was designed to imitate the front car window so that the driver could easily feel driving on a monotonous lane. Along with this is the adjustment of the temperature and lighting of the test environment to allow the dozing to take place. Lastly, to optimize prospects for useful results, experiments were performed early in the afternoon after lunch.

4.2 Driving Task

The test consisted of 10 participants (drivers), composed of male and female. Each participant was instructed to look directly at the computer monitor and perform like in the actual driving. A typical car-following tasks on a straight two-lane highway have been used to test driving activity. Participant is required to respond by answering pre-recorded questions whenever the system detects that the brainwave value has reached the meditation level.

4.3 Data Acquisition and Analysis

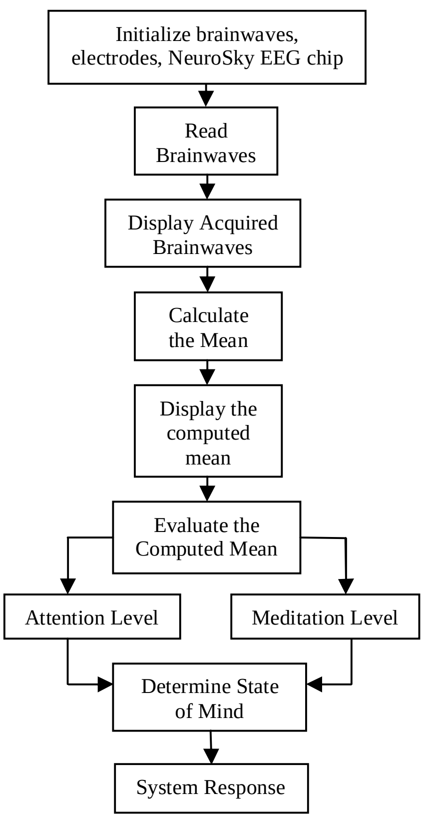

Figure 6: Data Acquisition and Analysis Procedure

Figure 6 shows the procedures of brainwaves acquisition and analysis made. The participant should properly wear the sensor module. Once positioned, the device must first create a wireless link between the wireless headset and the embedded monitoring module for the sensor to start data acquisition. The wireless sensor in the headset will transmits the transmitted signal to the controlled device through a wireless network. The obtained brainwaves frequency will be pre-processed by converting the data to numeric data types. Acquired brainwaves values will be computed and the mean value will be determined. The mean value will be compared to the given NeuroSky eSense meter every 5 seconds to determine the current status of the participants. If the measured mean of the meditation values drops between 40-60 eSense values, the system will throw a sound in the form of a pre-recorded query. The participant is expected to respond by turning the head, eyes blinking or make other body movement. A beep sound is produced as an indication that a response if needed. Whenever no response is received before 5 seconds, when the next calculated mean will be determined, the system will generate an alarm sound to prompt the alertness of the participant. If the average computed meditation value falls between 60-100 eSense values, the device will automatically generate an alarm sound. This indicates that the person is comfortable, the body is alert, but the mind is not focused on the task. On the other hand, if the measured attention value falls below 60 eSense values, the machine will continue to read brain waves.

The following figures demonstrated graphically the output of the testing. The waveform generated represents the brainwave signals from the brainGrapher application.

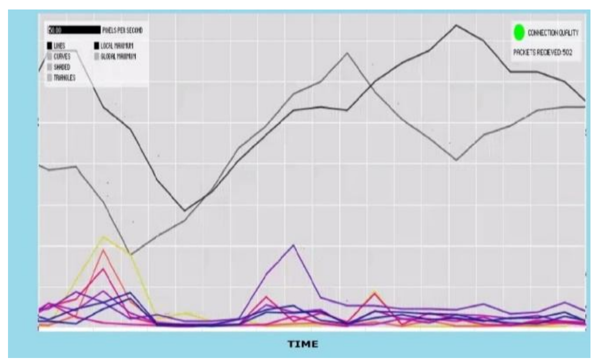

Figure 7*:* Line grapah ofNeuroSky eSense mapping at 26 minutes 14 seconds time frame

Figure 7 illustrates the frequency band at time 26 minutes and 14 seconds time frame. It also shows the network link and data transmission efficiency, the level of the line graph and the meditation level of the Nuerosky eSense meter. The green light indicates the accuracy of the sensors.

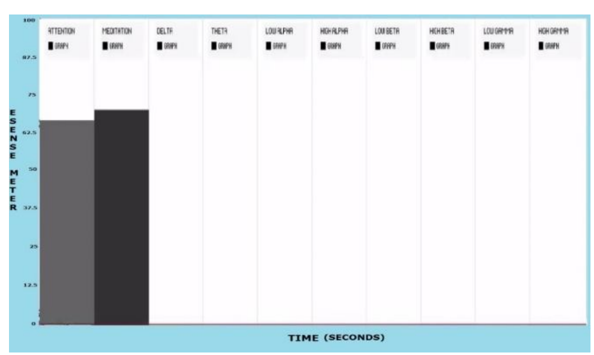

Figure 8*:* Historgram of NeuroSky eSense mapping at 26 minutes 14 seconds time frame

The sampled signal for the duration of 26 minutes and 6 seconds to 26 minutes and 14 seconds is presented in 5 seconds of the test results. The result shows that the meditation level has reached almost 70 eSense values. This indicates that the strength of the brain waves occurring during that time was the Beta wave. This means that this is the dominant signal during this time.

5. EXPERIMENTAL RESULTS AND DISCUSSION

Three trials were made to each participant within the set timeframe and the values were displayed via LCD. It also displays the captured values of attention and meditation. Shown bellow are the results of testing made.

Table 1: Interpretation of Data

Time	Attention Rating	Meditation Rating	Interpretation	Brain Wave
23 mins 6 secs	60	59	Attention level is dominant	Beta
23 mins 11 secs	74.5	50	Attention level is dominant	Beta
24 mins 20 secs	59	57	Attention level is dominant	Beta
24 mins 26 secs	52.5	50	Attention level is dominant	Beta
25 mins 24 secs	39.5	62.5	Meditation level is dominant	Alpha
25 mins 30 secs	45	98.5	Meditation level is dominant	Alpha
26 mins 6 secs	74	74.5	Meditation level is dominant	Alpha
26 mins 14 secs	70	8	Attention level is dominant	Beta

Presented in table 1, the signals were recorded for more than 3 minutes test data from the 30-minute time frame. During testing, the generated values of attention and meditation together with the output visualization where compared to the clinical result conducted. This is to validate the accuracy of the system. The recorded data of attention and meditation ratings were based on the acquired data after 5 seconds.

Table 2: Summary of Test Results

# of Trials	Computed Mean		Expected Output	Actual Output	Error
	Attention	Meditation			
1	21	26	0	0	0
2	48.4	40.4	0	0	0
3	34.2	45	1	1	0
4	42.4	30.4	0	0	0
5	56.2	25.2	0	0	0
6	91	45	1	1	0
7	49	30.4	0	0	0
8	31	25.2	0	0	0
9	40	45	1	1	0
10	46	40	0	0	0
11	46.7	30.7	0	0	0
12	45.0	59.4	1	0	-1
13	35.2	45.4	1	1	0
14	38.9	34.8	0	0	0
15	91.3	34.8	0	0	0

Shown in table 2 is the numerical labels 1 and 0 are applied to the performance of the system. A value of 1 is given to the point at which the participant is already in the drowsy state and 0 to the attention state (non-drowsy). The results of all the trails made were compared to the output of the expected and actual results. The error explains whether the system was able to provide a correct output or not. Generally, the accuracy gathered 93.33% based on the number of trials made.

6. CONCLUSION

The study presents a wearable pre-frontal single-channel Electroencephalogram (EEG) tool that will determine the state of the mind of the driver automatically, drowsy which indicated the meditation and non-drowsy which indicates the attention state. The techniques successfully illustrate the expected signals and generate the equivalent values. The accuracy of the system was interpreted using the numerical labels 1 and 0.A value of 1 is given to the point at which the participant is already in the drowsy state and 0 to the attention state (non-drowsy).The recorded data of attention and meditation ratings were based on the acquired data after 5 seconds. The results of all the trails made were compared to the output of the expected and actual results. The error explains whether the system was able to provide a correct output or not. Generally, the accuracy gathered 93.33%.

REFERENCES

1. J. He, W. Choi, Y. Yang, J. Lu, and X. Wu, **Detection of driver drowsiness using wearable devices : A feasibility study of the proximity sensor**, *Appl. Ergon.*, vol. 65, pp. 473–480, 2017. https://doi.org/10.1016/j.apergo.2017.02.016
2. R. P. Balandong, R. F. Ahmad, S. M. Ieee, and M. N. Mohamad, **A Review on EEG-Based Automatic Sleepiness Detection Systems for driver**, *IEEE Access*, no. March, 2018.
3. J. Gabhane, D. Dixit, P. Mankar, R. Kamble, and S. Gupta, **Drowsiness Detection and Alert System : A Review,** vol. 6, no. Iv, pp. 236–241, 2018. https://doi.org/10.22214/ijraset.2018.4043
4. A. Sahayadhas, K. Sundaraj, and M. Murugappan, **Detecting Driver Drowsiness Based on Sensors: A Review**, pp. 16937–16953, 2012.
5. O. Sinha, S. Singh, A. Mitra, S. K. Ghosh, and S. Raha, **Development of a Drowsy Driver Detection System Based on EEG and IR-based Eye Blink Detection Analysis.** Springer Singapore, 2018. https://doi.org/10.1007/978-981-10-7901-6_34
6. M. Teplan, ***Fundamentals of EEG measuremen****t,Meas. Sci. Rev.*, vol. 2, no. 2, pp. 1–11, 2002.
7. V. Saini, **Driver Drowsiness Detection System and Techniques : A Review**, *Int. J. Infin. Innov. Technol.*, vol. 5, no. 3, pp. 4245–4249, 2014.
8. P. S. Electroencephalogram, **Portable Drowsiness Detection through Use of a Prefrontal Single-Channel Electroencephalogram**, pp. 1–19, 2018.

9. P. K. Stanley, **E mbedded based D rowsiness D etection using EEG S ignals**, *IEEE Int. Conf. Power, Control. Signals Instrum. Eng.*, pp. 2596–2600, 2017.
10. C. Chuang, C. Huang, L. Ko, and C. Lin, **An EEG-based perceptual function integration network for application to drowsy driving,***Knowledge-Based Syst.*, vol. 80, pp. 143–152, 2015. https://doi.org/10.1016/j.knosys.2015.01.007
11. V. J. Kartsch, S. Benatti, P. Davide, D. Rossi, and L. Benini, **A sensor fusion approach for drowsiness detection in wearable ultra-low- power systems,***Inf. Fusion*, vol. 43, no. November 2017, pp. 66–76, 2018.
12. B. Lee, B. Lee, and W. Chung, **Standalone Wearable Driver Drowsiness Detection System in a Smartwatch**, *IEEE Sens. J.*, vol. 16, no. July, pp. 5444–5451, 2016. https://doi.org/10.1109/JSEN.2016.2566667
13. S. Panda, S. Mishra, M. R. Senapati, and R. E. College, **Detection and Classification Methods for EEG Epileptic Seizures**, *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 8, no. 6, pp. 4–13, 2019. https://doi.org/10.30534/ijatcse/2019/40862019
14. T. Kalyani, S. Monika, B. Naresh, and M. Vucha, **Accident Detection and Alert System**, *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 4, pp. 227–229, 2019.
15. J. Ramasamy, **An Intelligent Accident Detection Information System using IoT**, *Int. J. Eng. Adv. Technol.*, no. 1, pp. 3978–3982, 2019.
16. M. S. A. Vigil, K. V. S. Charan, D. S. Santosh, and E. B. Reddy, **Automatic Driver Drowsiness Detection and Accident Prevention System using Image Processing**, *nternational J. Innov. Technol. Explor. Eng.*, no. 12, pp. 4614–4617, 2019. https://doi.org/10.35940/ijitee.L3845.1081219
17. V. M. Reddy and I. A. Babu, **Crop Selection in Agriculture Lands using Internet of things with ARM**, *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 8, no. 1, pp. 42–44, 2019. https://doi.org/10.30534/ijatcse/2019/0981.32019
18. A. S. Alon, I. Journal, A. S. Alon, C. D. Casuat, M. A. F. Malbog, and J. N. Mindoro, **SmaCk: Smart Knock Security Drawer Based on Knock-Pattern using Piezo-electric Effect**, *Int. J. Emerg. Trends Eng. Res. Available Online http//www.warse.org/IJETER/static/pdf/file/ijeter16822020.pdf SmaCk Smart Knock Secur. Draw. Based Knock-Pattern using Piezo-electric Eff.*, vol. 8, no. February, pp. 339–343, 2020. https://doi.org/10.30534/ijeter/2020/16822020
19. A. S. Alon and J. A. B. Susa, **Wireless Hand Gesture Recognition for an Automatic Fan Speed Control System: Rule-Based Approach**, 2020 16th IEEE International Colloquium on Signal Processing & Its Applications (CSPA), Langkawi, Malaysia, 2020, pp. 250-254.