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Design and Implementation of a Smart System for Assistance of Sleepy Driver Using ECG EEG and other Physiological Signals

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ABSTRACT

In this paper we have designed a smart system for the assistances of driver who is in the nap during the driving of a vehicle and we will also determine the stage of sleep for the deciding whether the driver is again in the condition of driving or not because we have seen that these nap conditions has cost us 1000s of lives lots of people have lost their lives because of these nap like states of their driver. In our design the nap is detected by the analysis of ECG, EEG EOG,EMG and respiratory signals generated by driver`s body in the earlier researches many researchers also tried to detect these nap conditions only through EEG and EOG or any other combination of above signals but not all the signals were analyzed at the same time, in our design we have analyzed all the signals at the same time because in application which is going to be used in the real time situations like driving the accuracy of system should be the highest priority parameter above all other parameter like cost of the system complexity of the system etc. Because a little bit of wrong information sometime may cost too many lives. In this design we have setup a circuit that will perform the real time acquisition of ECG,EEG,EMG,EOG and respiratory signals and after that those signals are analyzed using MATLAB in order to detect the nap, using EOG signals we can calculate the duration of eye blink and if the eye blink duration is continuously keeps increasing and cross a certain value which is greater than normal it indicates that the driver may be in nap and the EMG signals will help in deciding the facial expressions like sleep ,at the same time EEG,ECG ,and respiratory signals are also analyzed and they will help us to determine the confirmation about sleep and the stage of the sleep also going to be determined ,once the driver's condition is determined then on the basis of this a control signal will be generated and given to the GSM module and that will send a message with the information of location to the owner of the vehicle and also a alarm will ring in the vehicle.

Keywords : SREM, EEG, ECG, MATLAB, EOG, EMG.

I. INTRODUCTION

In now days we can see that in all over world the traffic on roads is increasing drastically so it has become very important to have safe equipment for the safety on roads during the ride or travel most often we see that lots of road accidents are the result of some silly mistake made by driver for example we can consider a situation where a driver becomes little bit sleepy we call this condition as nap[3], this condition is the transition of the states between the sleeping and active state, if a driver is in the nap during the driving the chances of accidents becomes more and more high because of the nap the reflexes of the driver becomes slow so he may lost the control over vehicle.

In many earlier researches people tried to detect these nap like conditions by applying many different algorithms Dong Qian[1] has analysed the EEG and applied the BCDC algorithm whereas Yash S. Desai[16] has studied the findings of EEG and EOG for the detection of nap, also all these people have got the satisfactory results as we , but if we are designing an application for the real time situation like driving and suppose our system detects that the person is in the nap and we want to pass this information to owner of the vehicle then the accuracy of our system becomes very important because the impact of these information is directly going to affect the owners mood so a single set of wrong information can be panic for the owner hence in our design first we will monitor the alertness of driver with the analysis of EEG,EMG and EOG, once the nap is detected by these signal we will turn on the alarm in the vehicle and at the same time we have analysed the ECG and respiratory signal values of that time and if those values also indicates towards the condition like sleep then the nap is confirmed and the stage of sleep is also determined and now a message on owners mobile will be delivered with information of location of the vehicle and stage of the sleep.

In our design we have collected the EEG and EOG data by putting the EEG sensors on scalp [2], ECG and respiratory signals are captured by putting a chest strap and for analysing the facial expression we have put the EMG sensors on face of the driver now all these signal are given to the control and processing through data acquisition card and the control signals are generated accordingly.

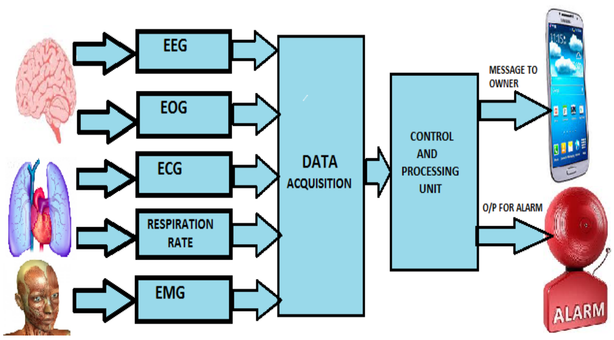

Fig. 1 Smart System Architecture

II. NAP

In now a days the life style of peoples are becoming more and more busy and the result of these busy schedules can be seen on the daily life activities of the human beings and due to the increase pressure of very busy life style sometimes peoples do not get enough time for completing the sleep and the effect of this overnight can be seen on next day's activities of that person, person may feel the drowsiness all the time and some time he may get involved in to sleep and this short duration of sleep that is the transition period between active and sleep state is termed as the nap[4].

Suppose that person is driving a vehicle then these conditions may become dangerous so it becomes very important to detect this condition, if we are not able to detect these situations very soon the chances for the road accidents are increased with very high rate, in the following points we are discussing some stats related to the accidents which are caused by the un-alertness of the driver [5]

- The adults having the age between18-29 are much more likely to drive during the nap or drowsiness.
- Men are more likely to have drowsiness or nap during drive in compare to women and they fall in sleep almost twice of women does.
- Shift workers are more likely to face this issue rather than regular workers.
- According to National highway traffic safety administration per year approximate 100,000 road accidents occurs due to the nap during the drive.
- Approximate 1550 deaths per year are the result of the driving during nap.
- Approximate 71000 people per year get injuries due to nap.
- An estimated total cost of $ 1.25 billion is damaged due to these accidents.

III. SYSTEM ARCHITECTURE

The architecture of the proposed system is shown in Fig. 1. The human brain is connected to EEG sensor and EEG Signals are captured by 14 EEG channels(0.05-200Hz) and are sampled at the rate of 1000Hz , the ECG and respiration rate data is collected through a Polar T 31 chest strap sensor[6] and we have sampled these ECG signals 500 Hz sampling frequency, for the facial expressions we have used MA 400-18 EMG sensor all these sensors read the signals from the human body and send these signals to control and processing unit via DAC where the MATLAB is used for the analysis of these signals and after this control unit will generate the control signals for the alarm and GSM module.[7]

A. Analysis of EEG signals during stage-1 sleep

EEG signals are the measurement of the electrical activity of the brain and each EEG wave form reflects the cortical electrical activity of brain, typically these signals are of low power and have the voltages in the range of micro volts, and these signals are characterized in to four different waves on the basis of the frequency.

Delta waves: these are the slowest waves and have the highest amplitude among all other waves, the frequency of these waves is around 3 Hz or below generally these wave appears in 3rdand 4th stage of sleep

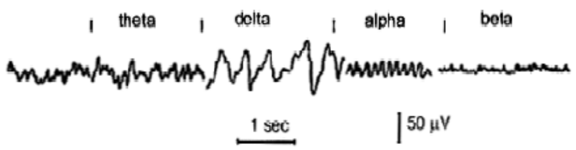

Fig. 2Different types of waves produced by EEG.

Theta waves: These are the waves having the frequency range between 3-7.5 and have the amplitude less than that of delta waves these waves appears during the “slow” activity phase of the person during the awake stage these waves becomes abnormal.

Alpha waves: These waves are of slightly higher frequencies if we compare with theta and delta waves the frequency range of these waves is between the 7.5-13 and these waves having the very low amplitude generally these appears during the relaxed state with closed eyes these waves disappears when we open the eyes or become alert by anyhow like we involve us in any thinking etc.

Beta wave: These waves in EEG are having the highest frequency and the range of frequency is 14 Hz or grater, the amplitude of these waves is minimum among all, generally these types of waves appears during the anxious Stages.

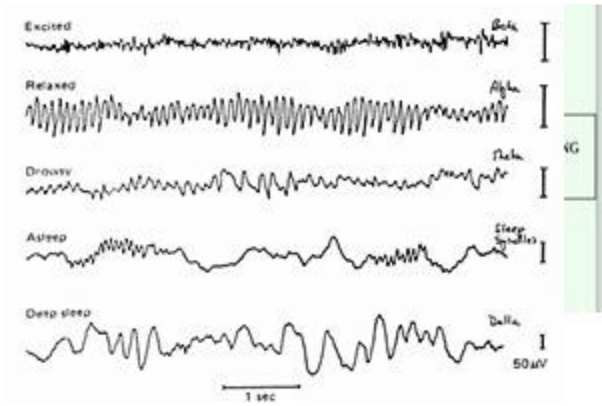

Fig. 3 Sleep Stages: Measures [9]

Since different waves present in the EEG can differentiate the various stages of a person as we have seen in above discussion so we can use these waveform as the indicator of the condition in which a person is feeling drowsiness or he is in the nap, if he or she is in the nap we can differentiate the various stages of the sleep on the basis of these signals, for detecting these conditions we have designed a algorithm in the MATLAB that will identify the current stages of the person with the help of these signals.

In the figure 2 we have differentiated various Stages of sleeps on the basis of EEG signals produced by their brain we have seen that if the person is in the deep sleep the waves produced by their brain are much slower and having the low amplitude in this state the alertness of the person is minimum as the alertness of the person is increase the frequency of the wave pattern produced by the human beings is keeps increasing and the amplitude is constantly keeps decreasing and finally it reaches the minimum at that time the pattern is having the maximum frequency and the stage of the person is determined as the excited state[8]

The state of nap which is the stage 1 of the sleep is the transition state between the alertness and sleep hence we have detected the time at which the attenuation in the frequency of alpha waves is appears[9] and these frequencies are trying to get closer towards the theta wave activity but the problem is that alpha waves indicates more than one physical condition hence only relaying on the EEG could result in less accurate system hence we have designed a algorithm that includes other parameters also.

B. Analysis of EOG signals

Electrooculography is a physiological signal used for the measurement of the electrical activity or the potential difference produced between the cornea and retina of the human eye, this potential dissimilarity is produced due to the occurrence of the nerves which are inside the retina and this is to be compared from the front side of the eye, eye movement will correspondingly produces a voltage ranges to 16μV and 14μV per 1° in horizontal and vertical way [10].

As we already know that eye blinking mechanism releases a little bit of water in the eye which generates moisture to the eye by the irrigation in form of tears and it works as lubricants for the eyes secrete. The upper part of our eye which is termed as eyelid in our eyes works for the suction all around the eyes which covers the portion from the tear duct and spreads up to entire eyeball. It keeps out our eyes from drying. Blinking mechanism also help us in protecting the eye from irritations. Eyelashes which are the hairs attached from the upper and lower eyelids which generate the line, works against the dust and few other materials in the protection to eyes. Eyelashes are the main reason that why lots of irritants fails to reach our eyeball. The blinking procedure of our eye is controlled by the help of various muscles. The teorbicularisoculi and "levatorpalpebraesuperioris" muscles are the main muscles which controls the opening and closing of our eyes in upper eyelid. The muscle named as orbicularis-oculi acts in the eye the closing of eye, while in the contraction of our eyes the levatorpalpebrae muscle acts and opens the eye. The muscles which are responsible for the widening of the eye in the upper and 2- lower eyelids are Muller's, or the superior tarsal muscles. All these above discussed muscles are not only crucial in the blinking pattern, but these are also significant in many other works like winking and squinting. [11].

Four to five electrodes are required to detect the Eye movement all these EOG electrodes are going to act as transducers we have placed two electrode towards the outside of the eye and next two electrodes are placed below and above the eyes. Now we have placed a reference electrode. Generally every blink interval takes 2-10 second and we calculate the blink speed on the basis of that. This value may be different for every individual and we calculated the blink rate by averaging at-least 10 blinks. After this we have to calculate and monitor the blinking speed continuously when this blinking duration crosses a certain limit we detects that the driver is the nap.

C. Analysis of EMG signals

Electromyography is a concern with the diagnosis procedure to evaluate the health of muscles and the nerves that control the signals. Machine neurons send electrical signals that results muscles to decrease or increase in size. An EMG converts these signals into graphs, numerical or sound values that a specialist translates orally. EMG signal analysis is performed using an electromyogram [12].EMG signals are used in this project because during sleep these signals should be weak and when sleep paralysis occurs these signals behaves as constant signal.

Analysis of ECG signals

ECG or Electrocardiography is a method used to monitor our cardio vascular system. During the each and every heartbeat our heart generates a small amount of voltage variation or say electrical signal. The produced electrical signal is the electrophysiological depolarization of our heart muscles. We measure this electrical activity of heart by placing some electrodes over the skin of our chest. Recently ECG is the main method used in the diagnosis of cardio vascular diseases for a long term

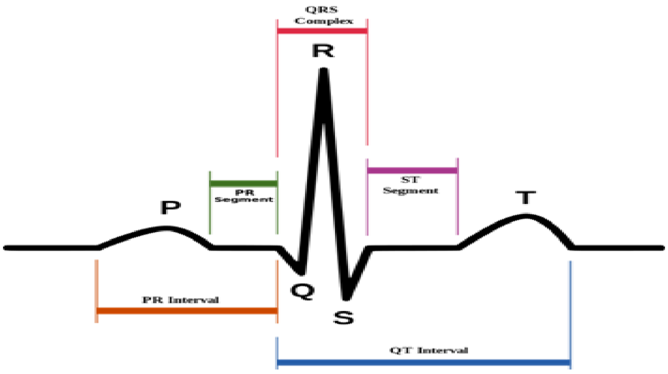

Fig. 4An ECG waveform with labeled segments

We have selected the NREM REM and waking state of human beings or the analysis of ECG signals in our study we have divided the ECG signals in various segments we have done this segmentation on the basis of polysomnographic criteria. Now we have calculated R-R interval in these signals further we have resample these signals at 2 Hz after performing the interpolation using MATLAB signal processing tool. After this we have calculated the HRV of all these ECG signals recorded for duration of 15 Minutes and we identified the various state of sleep and waking state using this HRV.

D. Analysis of respiratory signals

In our study we have seen that during the sleep our breathing also shows significant changes. We have identified that whenever a person is in the waking state his breathing pattern continuously shows some variations since the breathing is disturbed by the various parameters like speech, emotions, movement etc. When the state of person changes from waking state to sleeping state simultaneously the respiration pattern also changes, during the nap the respiration becomes quite regular and an overall increase in the rate of respiration is also occurs [15].

IV. NAP DETECTION ALGORITHM

Nap detection worked on the basis of comparison of all the signals which are received by placed electrodes on human body. It is working as the following:

These three signals (EEG, EOG, and EMG) are compared by data acquisition using MATLAB. on the basis of this a control signal is given to alarm and also if person is detected in the sleep again all the signals are going to be checked one more time with ECG and respiratory signal [17] and if person is confirmed in sleep a microcontroller based GPS system will send this message to owner of the car In this project the data should be read in real time so first the system must be aware about some specific values. Which includes that EEG signals during nap in various cases here the practical is implemented on some people so that we can analyse various cases of EEG waves during SREM (Slow Rolling Eye Movement) sleep.

EOG signals is for confirmation of SREM sleep because in some cases it was found that the data can be same as SREM sleep as the time when person is not in sleep condition. EMG signal given the final decision that whether the muscles of test body is moving or not, if the muscles are not moving it shows that the person is in deep sleep. When all the data matches frequently just about 30-40 sec then the response sends as positive [18] all the analysis has been done on the basis of these algorithms and blow an alarm. Again check that weather the person is still in the sleep and this time it also check for the ECG and respiratory signal for the confirmation and hence if the person is detected in nap it will send a message to the owner of car and also blow the alarm.

Algorithm Nap detection using Physiological signals

- Place the electrodes for the detection of ECG EEG, EOG, EMG and respiratory signals.
- Compare the signals (EEG, EOG and EMG) by data acquisition system
- Sends the information to the control unit for positive response.
- Control unit transmits the information to receiver by using any communication medium.
- Again check if the alarm will off in a set delay then make a decision
- If yes then again check the ECG and respiration signals and sends information to the user by GSM using microcontroller.
- If no then again repeat the operation.

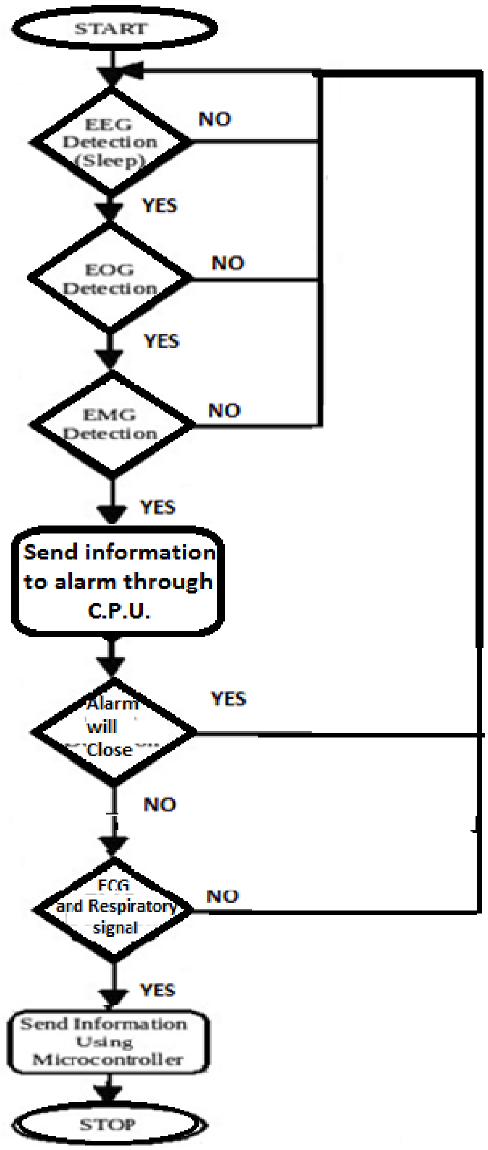

Fig. 5 Flowchart of Nap detection using Physiological signals

Nap Detection algorithm handles the condition of nap and also detects the stage of the paralysis if the condition is not true this will not respond.

Nap Detection flowchart is shown in Fig-5. If there is no nap detected, the program will not send any information to the given system. Otherwise if nap is detected, the current signal of detected nap will be processed by Nap Detection algorithm.

V. EXPERIMENTS AND RESULTS

Here the screen-shot of the recorded EEG,EOG,EMG,ECG and respiratory waves during sleep of stage 1 that is nap, Fig-6 shows sensor position on scalp for EEG and for ECG and respiratory signals the sensor is placed on chest.

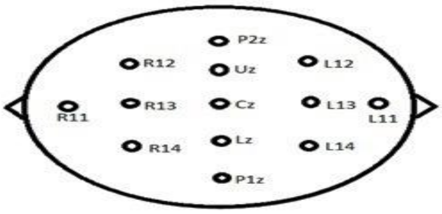

Fig. 6 Sensor Positions on the scalp for the Smart System.

VI. SIMULATION RESULTS & DISCUSSIONS

Here the waveform recorded by electrodes shown in below screen-shots. Fig. 7 shows the electro-oculogram signals which represent the movements of eyeballs when the person is sleeping in SREM stage and struggling for opening his/her eyes. These waveforms are recorded during sleep when the person is feeling nap and at the same time the electromyogram recorded the signals of muscles movement which is shown in Fig. 8, shows that there is a constant waveform received in electromyogram which shows constant movement in person's muscles just like in that state.

In Fig. 9 shows the signals recorded by eight electrodes in which the person is in SREM (Slow Rolling Eye Movement) Sleep after the normal sleeping stages like stage1, stage2 sleep stages. These upper four signals are recorded by left portion of scalp and other four are from right portion of scalp.

In Fig. 10 and Fig. 11 slows how that how ECG and respiratory signal output indicates towards the nap or in the 1st stage of the sleep if the person is in the deep sleep these signals will going to be more slower means as the persons sleep gets deeper the respiration rates increases and heart rate variability output gets slower.

When all the signals are recorded at the same time in the database the real-time system performs the analysis that the result that the value lies in the range of SREM sleep, at that time the signal received at the control unit and control unit sends the result to the receiver by any communication module or any indicator or alarm.

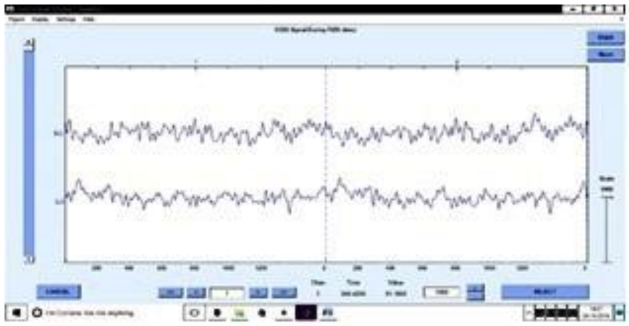

Fig. 7 EOG waveforms received by electrode R11 and L11

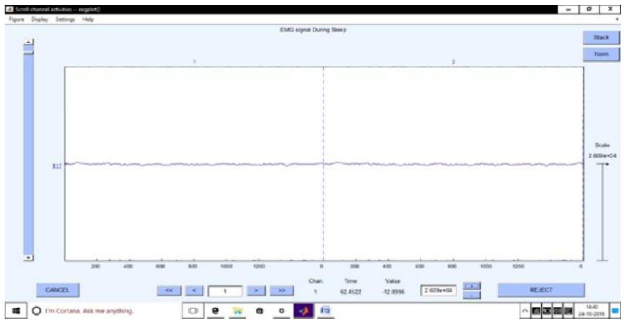

Fig. 8 EMG waveform received by electrode R12

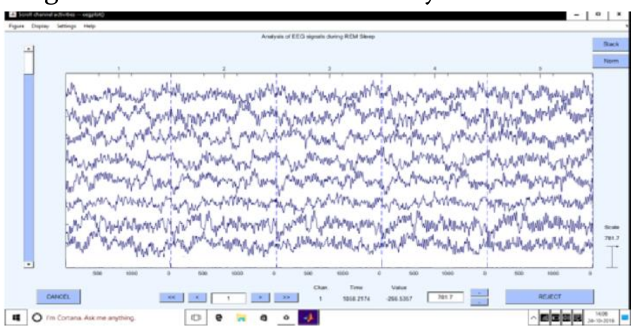

Fig. 9 EEG waveform received by eight electrodes, five of them placed on centre line, three are from left and right portion of head.

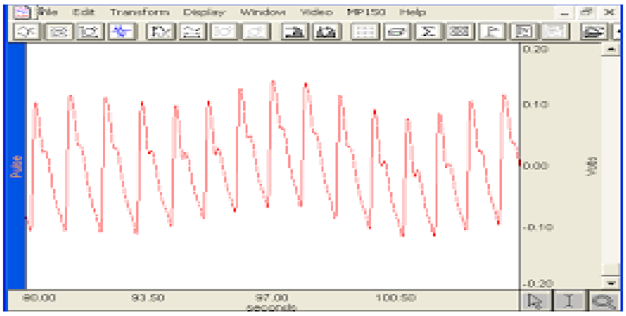

Fig.10 Respiratory rate during nap by chest strap sensor

Fig.11 ECG waveform during the nap by polar T31 sensor

When all the data matches simultaneously the data acquisition system alerts the microcontroller or control unit that now the person is in sleep paralysis state and microcontroller alerts the person by using a communication medium like GSM communication, and send him/her a message that now the person who is in observation is in sleep paralysis.

VII. CONCLUSION

An approach for the detection of nap is detection is developed and its solution is provided by sending the information to the owner of the car and to the driver so that the person can be out of his/her sleep or nap during drive and hence he or she can drive safely.

VIII. ACKNOWLEDGEMENT

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