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Automatic Sleep Scoring Stages using Real-Time EMG Signals

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***Abstract*: Sleep is completely regarded as obligatory component for an individual's prosperity and is an extremely important element for the overall mental and physical well-being of an individual. It is a condition in which physical and mental health of an individual are in condition of halt. The conception of sleep is considered extremely peculiar and is a topic of discussion and it has attracted the researchers all over the world. Proper analysis of sleep scoring system and its different stages gives clinical information when diagnosing on patients having sleep disorders. Since, manual sleep stage classification is a hectic process as it takes sufficient time for sleep experts to perform data analysis. Besides, mistakes and irregularities in between classification of same data can be recurrent. Therefore, there is a great use of automatic scoring system to support reliable classification. The proposed work provides an insight to use the automatic scheme which is based on real time EMG signals. EMG is an electro neurological diagnostic tool which evaluates and records the electrical activity generated by muscle cells. The sleep scoring analysis can be applied by recording Electroencephalogram (EEG), Electromyogram (EMG), and Electrooculogram (EOG) based on epoch which is defined as a period of 30 second length segments, and this method of sleep scoring system is also called polysomnography test or PSG test. The standard database of EMG signals was collected from different hospitals in sleep laboratory which gives the different stages of sleep. These are Waking, Non-REM1 (stage-1), Non-REM2 (stage-2), Non-REM3 (stage-3), REM. The main motive of the proposed work is the synchronization of EEG, EMG, EOG in order to understand different stages of sleep when they are simultaneously recorded. The procedure can be useful in clinics, particularly for scientists in studying the wakefulness and sleep stage correlation and thus helps in diagnosing some sleep disorders.**

***Keywords*: Polysomnography test (PSG), Sleep scoring system, Sleep stages.**

1. Introduction

A. Sleep Scoring System

Sleep is an important aspect for person's good health and is appraised as an essential element for both physical and mental ability of an individual. Sleep is virtual detachment of a human being from his surroundings. It is a condition in which both physical and mental functions of a human being are in a state of halt. The conception of sleep is intended to be extremely curious and it has attracted the scientists all over the world [1].

Long time sleep insufficiency or sleep disorders prompts various diseases of kidney, heart, etc and enlarges the possibility of diseases like diabetes, high blood pressure as well as strokes. These diseases are called as passive diseases. The source of distress and discomfort which an individual experience are as sleep insomnia, sleep walking, narcolepsy and nocturnal breathing. Thus, disorders caused by inappropriate sleep need to be handled [2].

Sleep scoring system is of great significance in the study of sleep medicine and has gained name in the research of sleep. Automatic sleep scoring system has been undertaken by the visual investigation of polysomnograms (PSG). PSG test is the conduction of various physiological signals like EOG (Electrooccularogam), EMG (Electromyogram), EEG (Electroencephalograph) which when recorded only for a short period of time known as epoch and analyzed gives us different stages of sleep [3], [4].

B. Sleep Scoring Stages

The normal sleep classification depends on the epochs which are scored as wakefulness, Rapid Eye Movement (REM), Non-Rapid Eye Movement (NREM). These are the fundamental three stages of sleep. Furthermore, NREM provides the classification of sleep into four stages. These NREM stages are scored according to the various signals recorded in that particular epoch [5]. The sleep scoring stages are defined as follows:

- *Wakeful stage:* This stage is also termed as stage 0. This stage is the condition of an individual when he/she prepares to sleep. Here, in this stage body is at rest and in a relaxed state with closed eyes and the Electromyography signals of the subject is seen high or may be in moderate range depending upon the muscle tension.
- *Stage 1:* this stage is comes after some time is passed in stage 0 and the Electromyography signals of the subject would be lower as compared to previous stage.
- *Stage 2:* this is the progression of the subject in the condition of sleep and the Electromyography signals value further decreases when compared to previous stage.
- *Stage 3:* The Electromyography signals in this stage gets

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reduced due to relaxed muscles and REM are negligible in this case.

- *Stage 4:* This stage records a moderate value of Electromyography signals and the subject may be termed asleep.
- *REM Stage:* In this stage, the Electromyography signals demonstrates muscle tones which may be called as twitches or infrequent short tones of distal muscle along with momentary activities arisen from blood pressure or from the heart beating frequency [6], [7].

C. Electromyography Signals (EMG)

Electromyography signals are also called as bio signals. Bio signals or myoelectric signals are acquired from skin surface representing some physical variable of interest. EMG signals are normally a function of time and can be described in respect of its amplitude, frequency and phase. Electromyography signals are unique bio medical signal which records the activity of muscles in the electric form during its contraction and relaxation. EMG signals can be measured with the help of instrument called an electromyography there by yielding a record known as electromyogram. Proper analysis of the EMG signals help in the diagnostic procedures undertaken to assess the health of a motor nerves and the activities controlled by them [8].

The contraction and relaxation of muscles are always controlled by nervous system. Thus, EMG signal being a complicated signal is also controlled by the nervous system and is dependent on muscles having anatomical and physiological properties [9]. A muscle can be represented by particular cells in the form of packs which are capable of withdrawal and unwinding. The EMG signal measures the muscle response and thus helps in studying the skeletal muscle. The skeletal muscle tissue linked to the bone and its constriction is in control of supporting and movement of skeleton. Skeletal muscle filaments are all around supplied with neurons for its contraction. This specific kind of neuron is called a motor neuron. The EMG signals which are collected from the muscles involve sophisticated methods for the purpose of detection, noise, reduction, analyses and processing as well as classification [10].

2. Material Methods

The real time implementation was used for the development of the research.

A. Equipment's and Devices

There were interfacing between the polysomnography and personal computers.

- Data collected for the studying of sleep stages were recorded through device called polysomnography device. The data was recorded for the period of seven hours for each subject. These data which were variant was collectively first grouped by sleep experts and plysomnography software device.
- A designed biomedical device designed for computation of physiological signals especially during phases of sleep.

B. Materials

Electroencephalogram (EEG)
Electromyogram (EMG)
Electrooculogram (EOG)

- Sleep Electroencephalogram Recognition NN (SRNN): enables to detect a variety of essential characteristic features in EEG waveform.
- Sleep Stage Diagnosis NN (SSNN): enables to diagnose different stages of sleep.
- Contextual Diagnosis NN (CDNN): for stimulating the correct decision rate by considering contextual.
- Relation of performance of characteristic waves.

3. Results

Sleep plays a key role in quality of life, good health and protects physical and mental health of human being throughout their life. There are so many peoples who are experiencing such sleep disorders which affect their day to day life. These sleep disorders are sleep apnea, sleep insomnia and narcolepsy etc. The analysis of sleep stages are thus useful for diagnosis and treatment of such type of disorders need to be implemented.

A. Parameters

Electroencephalogram (EEG): The electrical activity of brain can be evaluated by using EEG test. The electrical activity of brain is the communication between the brain cells through electrical impulses.

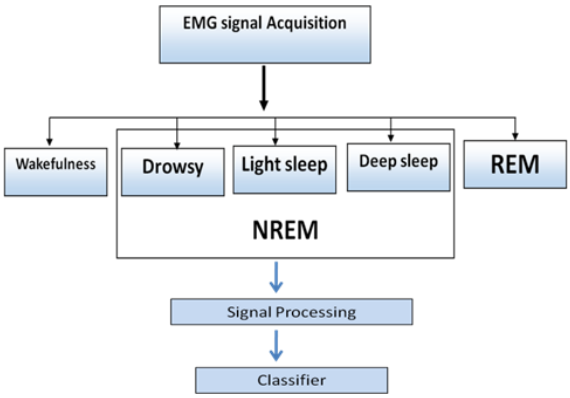

Fig. 1. Electromyogram

The brain wave patterns are tracked and recorded by using EEG. The electrodes which are small flat discs are attached to scalp with the help of wires for analyzing electrical impulses in the brain to send signals to the computer for recording. The impulses in EEG recording will have wavy lines along with valleys and peaks. With the help of these waveforms, doctors are able to access if the patterns are normal or abnormal. Any abnormalities found will be sign of seizures or brain disorders.

Electromyogram (EMG): It is a diagnostic examination for evaluating and controlling the health condition of muscles as well as nerve cells (motor neurons). The translation of the signals into numbers or graphs is done by EMG thus helping doctors in the process of diagnosing. If person visits the doctors with the symptoms of nerve or muscle disorder which include

tingling, numbness or unexplained weakness in the limbs, the doctor will suggest an EMG since its results will assist the doctor in diagnosing the disorder of the muscles, nerves or the disorder which is affecting the connection amidst the muscle and nerve.

Electrooculogram (EOG): This method is used to measure the corneo-retinal standing potential which is present amid back and front of human eye. The resultant signal is called EOG. EOG is usually applied for diagnosing the ophthalmological issues and for recording the movements of the eyes. For measuring the movements of the eyes the electrodes are placed either below or above the eye or to the right or left of the eye. When the eye moves from centre to any one of the electrodes, the positive side of the retina will be seen while the other electrode will see the negative side of the retina, hence developing a potential difference between the electrodes. The potential difference which is recorded will be measure of position of the eye.

B. EMG Signal Acquisition

The standard database of real time EMG signal was collected from various hospitals. The EMG signals were obtained from different volunteer subjects whose ages ranged from 25 to 45 years. The mean age of the group was 35 years. All the subjects involved in study were passed by neurological tests and were found of normal intelligence. Surface sub mental Electromyography signal was recorded using two electrodes which were placed below the subject's chin. For EMG signal, 8000 samples/sec. were taken. The different stages of sleep are mentioned as:

Wakefulness-Stage W or Awake: It is a stage where subject is about to sleep. At least 50% of the alpha waves present in the EEG recordings are the distinctive features of this stage. The alpha waves are generally in the range of 8 to 13 Hz, but 9 to 11 Hz for adults. EMG may be high or moderate.

Fig. 2. Alpha waves

NREM-Stage 1 (Drowsy): The drowsy stage is where the mixed frequency waves with low amplitude on the EEG are in the range of 4 to 7 Hz. Slow eye movements shown on the EOG can also be observed. EMG is slightly elevated, yet it is still lower than during stage W. the stage is marked drowsy only when a minimum of 50% of the alpha rhythm is replaced by the low- amplitude mixed- frequency waves.

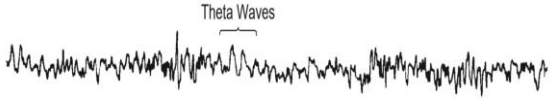

Fig. 3. Theta waves

NREM-Stage 2 (Light sleep): For this stage, it is mandatory that the k- complexes and sleep spindles should appear within the frequencies of 13 to 16 Hz. They convolute along with the theta frequency waves of 12 to 14 Hz as illustrated in figure 4.

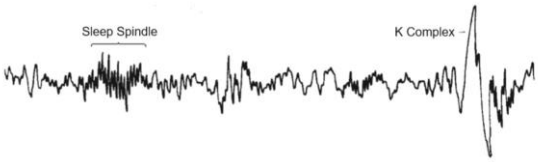

Fig. 4. Sleep spindles and K complex

This stages ends when it changes to either N3, W, REM. It is changed to W or N1 if the stages of N2 is not met or an arousal is observed in the EEG. In this stage the major body movements (MBM) can be observed which is generally followed by mixed frequency waves of lower amplitude and slow eye movements.

NREM-Stage 3 (Deep sleep): In N3 stage the presence of the slow waves which occur at least in 20% of the epoch is atypical sign that the sleep is at this stage. The sleep spindles are not significant at this stage and k- complexes are deliberated as slow waves. The activities of EOG and EEG are similar with the only difference being the change in amplitude of EMG which is relatively low.

REM: The name of R originates in the REM which is caught on EOG and they are the unequivocal indication of this stage. REM are conjugate, sporadic, and sharp waves with the deflection at the initial stage. The span of these waves is commonly shorter than 500ms. On EEG saw tooth waves can shown up as they can go before REM. These triangular toothed waves are in frequency of 2 to 6 Hz. Other than saw tooth waves additionally theta waves inside the scope of 4 to 7 Hz and less continuous alpha waves can appear.

Fig. 5. Saw tooth waves occurring in REM sleep

Signal processing: The original signal acquired from EMG need to be manipulated that is required for the classification to get the classified data. The signals are processed to remove corrupt signals, extraction of crucial information and to predict values. Different sleep stages with the activity of brain are shown in figure 6.

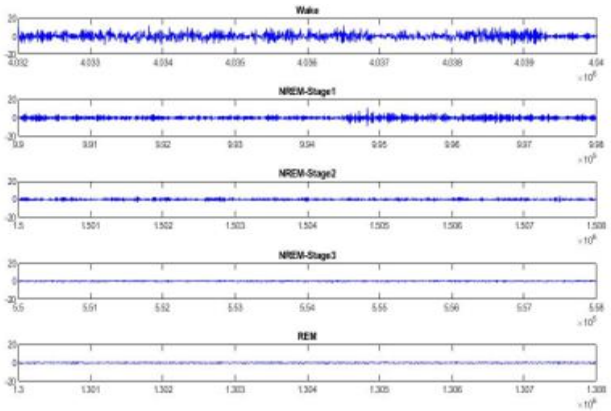

Fig. 6. Different sleep stages with the activity of brain

4. Discussions

Synchronizing the signals of EEG, EMG, EOG has proved an effective alternative approach to ascertain the various stages of sleep. The utilization of EMG and EOC excluding artifacts from concurrent EEG signals was prosperous and thus it may be helpful in processing of all EEG signal studies. Several methods being initiated but the usage of an automated system always have some advantage over standardized conventional methods and terminology involved with the estimation of sleep stages. Most of these terminologies may include physiological stress on the subject which is being observed and it also requires specialists with advance level of expertise and use of an expensive polygraphs. The estimation of sleep stages by R- K (Rechtschaffen and Kales) have found as 82.6% for non-Rapid Eye Movement stages, 38.3% for Rapid Eye Movement stage, 70.5% for Awake stage [11]. In this case, the estimation of Rapid Eye Movement stage seems to be quiet low. An effort [12] of qualitatively clarifying the relation between sleep stages and heart rate are in fact considered not authentic categorization of sleep stages. Procedures [13] regarding the relationship between sleep stages and body movements were believed to be impractical in estimating the stages of sleep. Such non- invasive methods [14] that uses static charge sensitive bed does not define all types of sleep stages. The methods determined from movements of body measured by infra-red sensors and extensive classifier has been prosperous in classifying the sleep stages. The aim of work by Akin et al. [15] and Kurt et al. [16] was to calculate the assertive level and to compute drowsy level respectively. However, in proposed work the motive is to classify the sleep stages using EEG, EMG, EOG simultaneously when recorded.

5. Conclusion

The aim of the work was not only to look at the outcomes obtained by comparison of techniques, however to present a strategy that utilizes EEG, EMG, EOG signals. In present work, the primary objective is the estimation of sleep stages using EEG, EMG, EOG when simultaneously recorded. The method can be useful for scientists in analyzing the wake and sleep correlation and in diagnosing disorders of sleep.

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