Estimation of Consciousness of Human Mind Using Wavelet Transform

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Abstract

This paper introduces a two non-invasive electrode based electroencephalography (EEG) scheme to pick-up the bio-potential (generated by the neuron network of human brain) for the assessment of consciousness level. With the help of a suitable algorithm (developed by us), processed in LabVIEW environment, real-time β-wave (frequency range 13-30 Hz.) is extracted (representing the consciousness level of the brain activities) from the complex bio-signal and reproduced on the computer monitor. The data array is further processed in MATLAB platform using Daubechies wavelet transform (dB 6, level 9) to cross check the results of interpretation of one's awareness level as obtained from LabVIEW environment. The results provided by our proposed device are in good agreements with the actual physiological actions of the subjects' brain and supported by the clinicians.

Key-Words: Electrodes, EEG, β-wave , consciousness ,Level of consciousness, Daubechies wavelet transform, dB6**.**

1. Introduction

EEG is a graphical record of the electrical activity of the brain. Three types of brainwaves are associated with different levels of arousal: theta waves occur during sleep, alpha waves are associated with wakefulness, and beta waves with excitement. EEGs can be used to monitor the effects of exercise since there is a close correlation between certain EEG wave patterns and fatigue or overtraining. They are also used to determine the extent of injuries inflicted to the head (for example, after a knockout in boxing).An electroencephalogram (EEG), also called a brain wave test, is a diagnostic test which measures the electrical activity of the brain (brain waves) using highly sensitive recording equipment attached to the scalp by fine electrodes.[8] This paper is based on the estimation of consciousness or awareness of human mind. In biomedical sense, consciousness is the abnormal generation and propagation of action potential of neurons. The action potential (AP) from neurons has been recorded with microelectrodes. The brain activities are different for different stages of human mind; like alert stage, relax stage, drowsy stage etc.[7] *Propofol induction reduces the capacity for neural information integration: implications for the mechanism of consciuosness and general anesthesia:* The cognitive unbinding paradigm suggests that the synthesis of neural information is attenuated by general anaesthesia. Here, we analyzed the functional organization of brain activities in the conscious and anesthetized states, based on functional segregation and integration. Electroencephalography (EEG) recordings were obtained from 14 subjects undergoing induction of general anaesthesia with propofol. We quantified changes in mean information integration capacity in each band of the EEG. After induction with propofol, mean information integration capacity was reduced most prominently in the γ band of the EEG ($p = .0001$). Furthermore, we demonstrate that loss of consciousness is reflected by the breakdown of the spatiotemporal organization of γ waves. We conclude that induction of general anaesthesia with propofol reduces the capacity for information integration in the brain. These data directly support the information integration theory of consciousness and the cognitive unbinding paradigm of general anaesthesia.[11] [2]

Background

A non-invasive system was developed by **Konkan Railway Corporation Limited** after the accident which was happened on Sainthia Station, Birbhum on 19th July, 2010. At least 60 people were killed in that accident. The main reason of that accident was the unconscious mind of the pilot. The signalman in-charge at the station claimed to have heard the station master trying to alert the driver of the Uttar Banga Express via walkie-talkie, but got no response. The guard, when questioned said that the driver did not respond to him on the walkie-talkie. The basic principle of their system was measuring the skin impedance between the skin surface electrodes, placed on the pilot's wrist. Depending upon the consciousness of the pilot/driver the skin impedance changes. The change of impedance is picked up by two skin surface electrodes, followed by a signal conditioning circuit. But their system gives erroneous result due to dirt, moisture etc. present in the pilot's hand, causing an increased impedance of the cell giving erroneous indications. The pilots have to drive train for a long time on railway track and the possibilities of presence of dirt and moisture in pilot's hand become greater. This is the main drawback of their system.

2. Theory

The bio-electric potential generated by the neuronal activity of brain is recorded by the electroencephalography (EEG). The brain's electrical charge is maintained by billions of neurons. Neurons are electrically charged (or "polarized") by membrane transport proteins that pump ions across their membranes. Neurons are constantly exchanging ions with the extracellular milieu, for example to maintain resting potential and to propagate action potentials. Ions of similar charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their neighbours, who push their neighbours, and so on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal on the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push or pull voltages between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG. The neuronal activities responsible for different stages of human brain are different. These neuronal activities were studied in terms of electrical signal to discriminate the different stages. Here, two non-disposal skin surface electrodes were used for collecting the signal from human brain and for differentiating the consciousness of the human mind. An alert person usually displays an unsynchronized high-amplitude EEG signal. [8][15] In this approach the bio-potential is collected by a sensor, reusable non-invasive skin surface electrode. Information lies in the frequency of the waves collected by the electrodes. At rest, relaxed and with the eyes closed, the frequency of these waves is 8-12 Hz (cycles/sec). This 'alpha' activity is believed to reflect the brain in 'idling' mode, because if the person then either opens the eyes, or does mental arithmetic with the eyes closed, these waves disappear, to be replaced by irregular patterns (so-called *desynchronized activity*). In normal sleep there is characteristic higher voltage activity, in patterns which vary according to the level of sleep.

Standard Waveforms

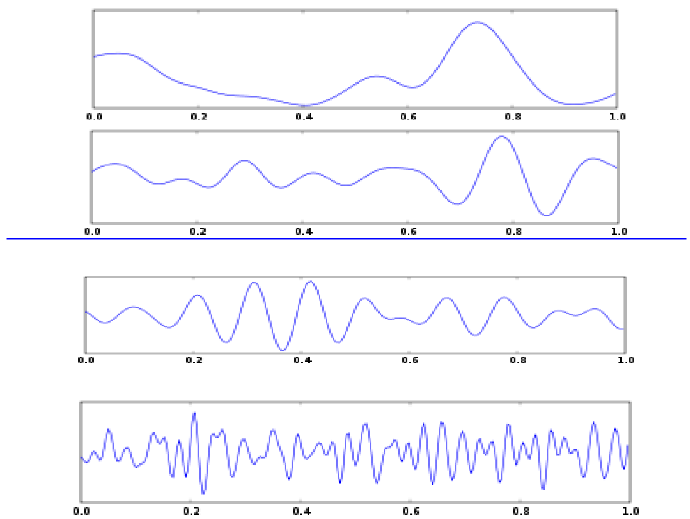

Figure 1(a) delta waves,(b)theta waves,(c) alpha waves,(d) beta waves

The Block Diagram of this system is shown below:

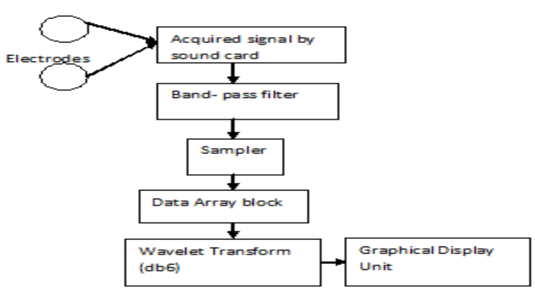

Figure 2: Block diagram of the system

3. Sensors

Brain cells communicate by producing tiny electrical impulses, also called brain waves. These electrical signals have certain rhythms and shapes, and EEG is a technique that measures, records, and analyzes these signals to help make a diagnosis. Electrodes are used to detect the electrical signals. They come in the shape of small discs that are applied to the skin surface. The bio-potential, generated by the neurons, are collected by two non-disposal skin surface Ag-AgCl electrode. One of the electrodes is placed on the surface of subject's forehead with the conducting paste. This electrode is actually responsible for the extraction of signal from forehead. Another electrode is placed on the ear-lobe. This electrode is working as reference electrode.

Figure 3: Figure of used electrodes during the experiment.

4. Signal conditioner

The signal conditioner block consists of an amplifier circuit, followed by a filter circuit. The signals collected from the human brain are in the range of microvolt. This voltage will be first amplified by an amplifier. After that, the amplified signal will be fed to an active band pass filter to eliminate the unwanted noise signals. However, EEG signals are not easily obtained. This is due to the signals' electrical characteristics. They are extremely weak signals, in the range of 1 – 160 μVpp. They are band limited to a very low frequency range, 0Hz - 100Hz for EEG. These signals are so small that they exist in the level of ambient noise. Our objective is concerned about the frequency range 'Beta' (13 - 30 Hz).

i. Filter design

Our target is to design an Active band pass filter whose bandwidth is 13 -30 Hz. f1=13Hz and f2=30Hz

5. Wavelet Transforms (Db6)

The word *wavelet* has been used for decades in digital signal processing and exploration geophysics. The equivalent French word *ondelette* meaning "small wave" was used by Morlet and Grossmann in the early 1980s. A **wavelet** is a wave-like oscillation with amplitude that starts out at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. As a mathematical tool, wavelets can be used to extract information from many different kinds of data, including - but certainly not limited to - audio signals and images. Sets of wavelets are generally needed to analyze data fully. A set of "complementary" wavelets will deconstruct data without gaps or overlap so that the deconstruction process is mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss. A wavelet is a mathematical function used to divide a given function or continuous-time signal into different scale components. Usually one can assign a frequency range to each scale component. Each scale component can then be studied with a resolution that matches its scale. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies (known as "daughter wavelets") of a finite-length or fast-decaying oscillating waveform (known as the "mother wavelet"). Wavelet transforms have advantages over traditional Fourier transforms for representing functions that have discontinuities and sharp peaks, and for accurately deconstructing and reconstructing finite, non-periodic and/or non-stationary signals. Wavelet transforms are classified into discrete wavelet transforms (DWTs) and continuous wavelet transforms (CWTs). Note that both DWT and CWT are continuous-time (analog) transforms. They can be used to represent continuous-time (analog) signals. CWTs operate over every possible scale and translation whereas DWTs use a specific subset of scale and translation values or representation grid.

6. Daubechies Wavelets

are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function (also called father wavelet) which generates an orthogonal multi-resolution analysis. The procedure starts with passing this signal (sequence) through a half band digital low pass filter with impulse response h[n]. Filtering a signal corresponds to the mathematical operation of convolution of the signal with the impulse response of the filter. The convolution operation in discrete time is defined as follows:

$$x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k].h[n-k]$$

A half band lowpass filter removes all frequencies that are above half of the highest frequency in the signal. For example, if a signal has a maximum of 1000 Hz component, then half band lowpass filtering removes all the frequencies above 500 Hz. After passing the signal through a half band lowpass filter, half of the samples can be eliminated according to the Nyquist's rule. Half the samples can be discarded without any loss of information. In summary, the low pass filtering halves the resolution, but leaves the scale unchanged. The signal is then sub sampled by 2 since half of the number of samples are redundant. This decomposition halves the time resolution since only half the number of samples now characterizes the entire signal. At every level, the filtering and sub sampling will result in half the number of samples (and hence half the time resolution) and half the frequency band spanned (and hence doubles the frequency resolution). Figure shown below illustrates this procedure, where x[n] is the original signal to be decomposed, and h[n] and g[n] are low-pass and high pass filters, respectively. The bandwidth of the signal at every level is marked on the figure 4.

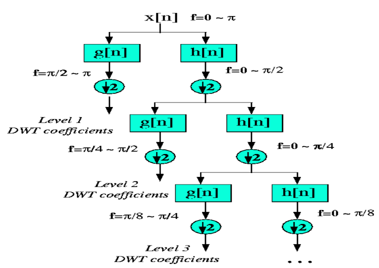

Figure 4

7. SIMULATION TOOLS

For the decomposition of the acquired EEG signal from human brain here, we used Lab VIEW 2009 software. In Lab VIEW platform we used the Daubechies wavelet transform, dB6 to get the de-composited bio-logical signal. We used graphical indicator in the labview platform to show the output responses of the system. There were a number of graphical indicators in the front panel of the labview which were used to plot the signal pattern. MatLab 7.0 is also used to cross check the results of interpretation of one's awareness level as obtained from Lab VIEW environment. [5]

8. Results And Discussions

In this paper, the samples have taken different types of drug to estimate the consciousness of their brain. The following types of drug and alcohol were being used during the experiment:

Heroin: Heroin is an opiate drug that is synthesized from morphine, a naturally occurring substance extracted from the seed pod of the Asian opium poppy plant. Heroin usually appears as a white or brown powder or as a black sticky substance, known as "black tar heroin."

Locally Made Alcohol (Lma): Locally produced moonshine is known in India as tharra, and also (among other names) as desi, latta, gawathi, Haathbhatti, desi daru, hooch, Potli, kothli, dheno, mohua, chullu, Narangi, Neera, kaju, cholai, Saaraayi and santra. It is made by fermenting the mash of sugar cane pulp in large spherical containers made from waterproof ceramic (terra cotta). However, it is dangerous, mainly because of the risk of alcohol or copper formaldehyde poisoning.

Whisky: Whisky or whiskey is a type of distilled alcoholic beverage made from fermented grain mash. Different grains are used for different varieties, including barley, malted barley, rye, malted rye, wheat, and corn. Whisky is typically aged in wooden casks, made generally of charred white oak. Whisky is a strictly regulated spirit worldwide with many classes and types. The typical unifying characteristics of the different classes and types are the fermentation of grains, distillation, and aging in wooden barrels.

Cannabis: Cannabis a genus of flowering plants that includes three putative varieties, *Cannabis sativa, Cannabis indica* and *Cannabis ruderalis*. These three taxa are indigenous to Central Asia, and South Asia. *Cannabis* has long been used for fibre (hemp), for seed and seed oils, for medicinal purposes, and as a recreational drug. Industrial hemp products are made from *Cannabis* plants selected to produce an abundance of fiber.

The signal patterns for Heroin addicted subject before taking drug*:*

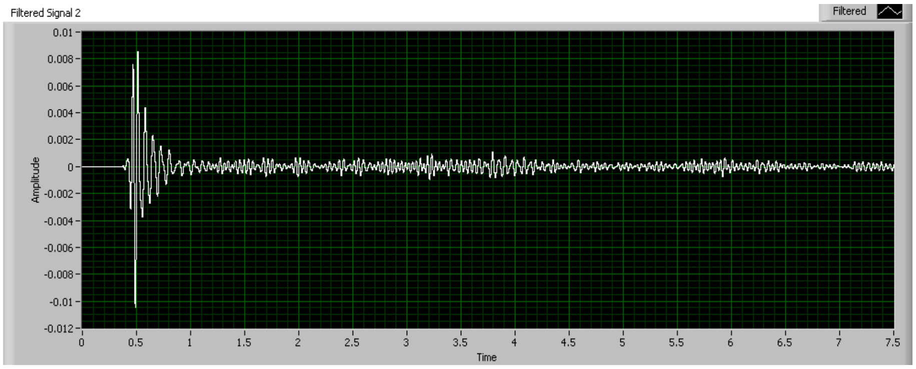

Figure 5(a): signal pattern before taking drug.

The signal patterns for Heroin addicted subject after taking drug:

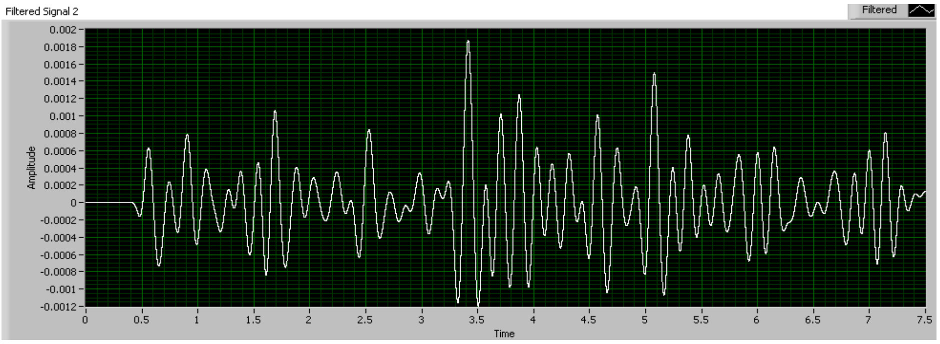

Figure 5(b): signal pattern after taking drug.

From the above two Figures we can see that the peak-peak voltage after taking drug goes down from the signal pattern, generating at normal stage.

The signal patterns for Cannabis addicted subject before smoking cannabis.

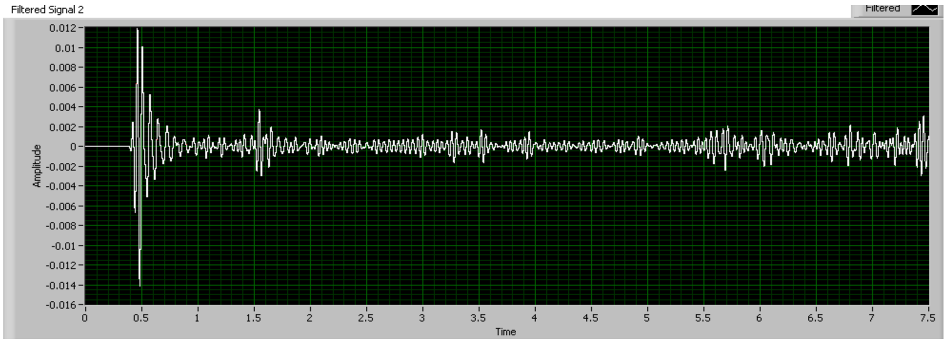

Figure 6(a): The signal patter at normal stage.

The signal patterns for Cannabis addicted subject after smoking cannabis.

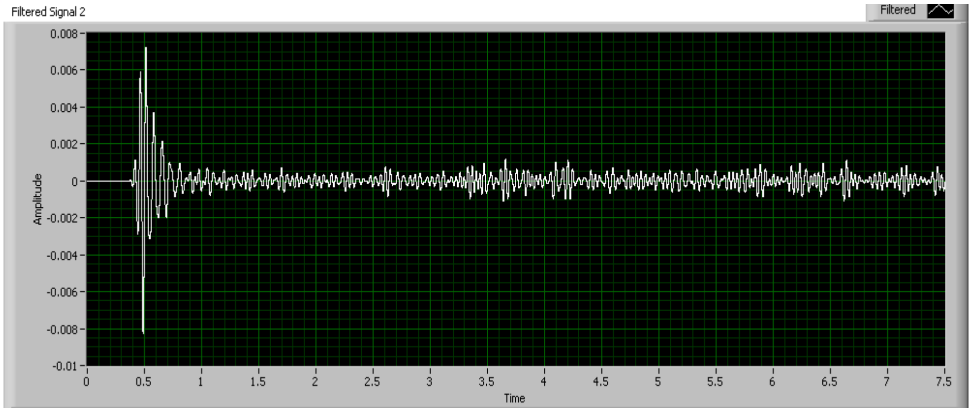

Figure 6(b): The signal patter after smoking cannabis.

In this case also the peak to peak voltages of the signal, related to the conscious stage are going down from the peak to peak voltages of the signal pattern which was extracting after smoking cannabis.

The signal pattern of subject 3 before drinking alcohol:

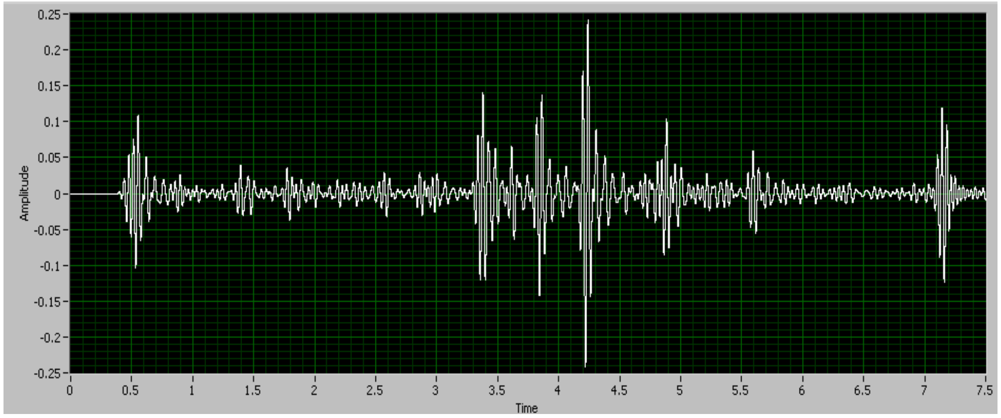

Figure 7(a): signal pattern at normal condition

The signal pattern of subject 3 after drinking alcohol*:*

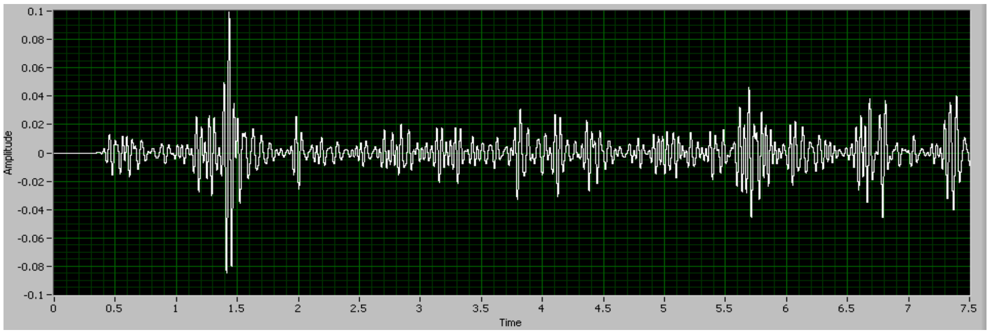

Figure 7(b): signal pattern after drinking alcohol

The peak to peak voltages decrease when the subject was drunk from the peak to peak voltages of the signal pattern, generating at normal condition.

9. CONCLUSION

The method which we adopted provides adequate information about the awareness level of the subject. Results obtained using our method was supported by the neurologists. To improve the performance further we will study the possibilities of implementing algorithm of adaptive filter to this system.The proposed method can be used as a safety measure in railways, airways, and roadways to measures the consciousness level of the pilot/ driver.

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