Digital Analysis Of EEG Brain Signal

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Abstract

Electroencephalography is the neurophysiologic measurement of the electrical activity of the brain using electrodes placed on the scalp. The resulting traces are known as electroencephalogram (EEG) and they represent an electrical signal from a large number of neurons. The EEG is a brain non-invasive procedure frequently used for diagnostic purpose. Instead of electrical currents the voltage differences between different parts of the brain are observed. The EEG consists of a set of multi-channel signals. The pattern of changes in signals reflects large-scale brain activities. In addition the EEG also reflects activation of the head musculature, eye movements, interference from nearby electric devices, and changing conductivity in the electrodes due to the movements of the subject or physicochemical reactions at the electrode sites. In the proposed work advance signal processing technique like Fast Fourier Transform and Independent Component Analysis are used to analyze the various brain activities. Both the techniques are applied to single trail multi-channel EEG data. The Fast Fourier transform is to determine the power content of the frequency band and estimate the frequency component while independent component analysis performs the blind source of separation of statistically independent source and separates the components for their periods of activation.

Introduction

Electroencephalography is a medical imaging technique that reads scalp electrical activity generated by brain structures. The electroencephalogram (EEG) is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media. The EEG measured directly from the cortical surface is called electrocortiogram while when using depth probes it is called electrogram. Thus electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with virtually no risk or limitation. When brain cells are activated, local current flows are produced. EEG measures mostly the currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. Differences of electrical potentials are caused by summed postsynaptic graded potentials from pyramidal cells that create electrical dipoles between soma (body of neuron) and apical dendrites. Brain electrical current consists mostly of Na+, K+, Ca++, and Cl- ions that are pumped through channels in neuron membranes in the direction governed by membrane potential the detailed microscopic picture is more sophisticated, including different types of synapses involving variety of neurotransmitters. Only large populations of active neurons can generate electrical activity recordable on the head surface. Between electrode and neuronal layers current penetrates through skin, skull and several other layers. Weak electrical signals detected by the scalp electrodes are massively amplified, and then displayed on paper or stored to computer memory. Due to capability to reflect both the normal and abnormal electrical activity of the brain, EEG has been found to be a very powerful tool in the field of neurology and clinical neurophysiology. The electrical signals generated by the brain represent not only the brain function but also the status of the whole body. The electrical nature of the human nervous system has been recognized for more than a century. It is well known that the variation of the surface potential distribution on the scalp reflects functional activities emerging from the underlying brain .This surface potential variation can be recorded by affixing an array of electrodes to the scalp, and measuring the voltage between pairs of these electrodes, which are then filtered, amplified and recorded [1]. Evoked potentials or event-related potentials (ERPs) are significant voltage fluctuations resulting from evoked neural activity. Evoked potential is initiated by an external or internal stimulus [2]. Mental operations, such as those involved in perception, selective attention, language processing and memory, proceed over time ranges in the order of tens of milliseconds. Whereas PET and MRI can localize regions of activation during a given mental task, ERPs can help in defining the time course of these activations amplitudes of ERP components are often much smaller than spontaneous EEG components, so they are not to be recognized from raw EEG trace. They are extracted from set of single recordings by digital averaging of epochs of EEG time-locked to repeated occurrences of sensory, cognitive, or motor events. The spontaneous background EEG fluctuations, which are random
relatively to time point when the stimuli occurred, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only that activity which is consistently associated with the stimulus processing in a time-locked way. The ERP thus reflects, with high temporal resolution, the patterns of neuronal activity evoked by a stimulus [4]. EEG wave’s classification is achieved using an accurate and highly distinguishable technique. The method makes use of both the discrete wavelet transform as well as the discrete Fourier transform. Specially, wavelet transform is used as a classifier of the EEG frequencies. In addition, the filtered EEG data are used as input to the wavelet transform offers a perfect success in the rejecting undesired frequencies and permits the discrete wavelet transform levels to discriminate the EEG waves only [3]. EEG signals are considered not to be deterministic and they have no special characteristics like ECG signals. In addition, when the Fourier transform is applied to successive segments of an EEG signal, the obtained spectra are observed to be time varying. This indicates that the EEG signal is also non-stationary. The spectral analysis based on the Fourier transform classical method assumes the signal to be stationary, and ignores any time-varying spectral content of the signal within a window [3].

EEGLAB, runs under the cross-platform MATLAB environment for processing collections of single-trial and/or averaged EEG data of any number of channels. Available functions include EEG data, channel and event information importing, data visualization, preprocessing, independent component analysis (ICA) and time/frequency decompositions including channel and component cross-coherence supported by bootstrap statistical methods based on data resampling. EEGLAB functions are organized into three layers. Top-layer functions allow users to interact with the data through the graphic interface without needing to use MATLAB syntax. Menu options allow users to tune the behavior of EEGLAB to available memory. Middle-layer functions allow users to customize data processing using command history and interactive pop functions [5].

Decomposition of the EEG signal using ICA is a recently developed and practical technique for EEG data analysis. ICA method determines source signals from their mixture. This analysis allows us to understand the sources of EEG signal. The simple example with the real EEG data is considered in order to resolve the sources of the artifacts and the sources of useful signal. It is also emphasized the clinical significance of each component and hence the importance of ICA method in clinical practice [8-9].

Autoregressive (AR) spectral estimation techniques are known to provide better resolution than classical periodogram methods when short segments of data are select for analysis. It has been observed that the energy in the EEG data segment is concentrated not in the beginning but somewhere in between the initial and the final positions thus confirming fact that EEG is a mixed delay signal. This position where the energy is concentrated has been obtained with the help of least squares wave shaping filter. It is also shown that the knowledge of the position where the energy in the signal is concentrated can be used in making a better spectral estimation of short segments of EEG data [10]. Single-channel blind source separation (BSS) technique can be used to decompose a single-channel recording of brain activity into its constituent components. This technique is used to identify and isolate rhythmic components underlying the recordings. In practice it is feasible to use band-pass filtering of a known fixed frequency band for monitoring [11]. Decomposition of single-trial multi-channel EEG recordings onto temporally independent and spatially stationary source signals, as well as identification and possible removal of artifacts EEG recordings are carried out [12].

The EEG signal indicates the electrical activity of the brain. They are highly random in nature and may contain useful information about the brain state. However, it is very difficult to get useful information from these signals directly in the time domain just by observing them. They are basically non-linear and non-stationary in nature. Hence, important features can be extracted for the diagnosis of different diseases using advanced signal processing techniques. The effect of different events on the EEG signal, and different signal processing methods used to extract the hidden information from the signal. Linear, frequency domain, time-frequency and non-linear techniques like correlation dimension (CD), largest Lyapunov exponent (LLE), Hurst exponent (H), different entropies, fractal dimension (FD), Higher Order Spectra (HOS), phase space plots and recurrence plots are described [13].

The rest of the paper is organized as follows. Section 2 provides details of EEG recording and measurements techniques. Section 3 gives proposed EEG signal analysis schemes. The Section 4 discusses results and conclusions are drawn in section 5.

Methods

1. EEG RECORDING AND MEASUREMENT An EEG
is measured non-invasively using small electrodes that are attached to the surface of the scalp. The number of electrodes can vary from one to 256. The electrodes are placed at certain predefined positions according to the international 10/20 system or variants of that system. The weak electrical activity detected by the electrodes ranges from 5 to 100 µV, and the frequency range of interest is between 1-40 Hz. The EEG recording can provide clues about the physical and mental state of the subject [2].

2.1 Action Potentials

The information transmitted by a nerve is called an action potential and are caused by an exchange of ions across the neuron membrane and action potential is a temporary change in the membrane potential that is transmitted along the axon. It is usually initiated in the cell body and normally travels in one direction. The membrane potential depolarizes, producing a spike. After the peak of the spike the membrane re-polarizes. The potential becomes more negative than the resting potential and then returns to normal. The action potentials of most nerves last between 5 and 10 milliseconds. The conduction velocity of action potentials lies between 1 and 100 m/s. Action potential are initiated by many different types of stimuli; sensory nerves respond to many types of stimuli, such as chemical, light, electricity, pressure, touch and stretching. On the other hand, the nerves within the brain and spinal cord are mostly stimulated by chemical activity at synapses. A stimulus must be above a threshold level to set off an action potential. Very weak stimuli cause a small local electrical disturbance, but do not produce a transmitted action potential. As soon as the stimulus strength goes above the threshold, an action potential appears and travels down the nerve.

The spike of the action potential is mainly caused by opening of Na channels. The Na pump produces gradients of both Na and K ions. Both are used to produce the action potential; Na is high outside the cell and low inside. Excitable cells have special Na and K channels with gates that open and close in response to the membrane voltage. Opening the gates of Na channels allows Na to rush into the cell, carrying positive charge. This makes the membrane potential positive, producing the spike. When the dendrites of a nerve cell receive the stimulus the Na+ channels will open. If the opening is sufficient to drive the interior potential from −70 mV up to −55 mV, the process continues. As soon as the action threshold is reached, additional Na+ channels open. The Na+ influx drives the interior of the cell membrane up to approximately +30 mV. The process to this point is called depolarization. Then Na+ channels close and the K+ channels open. Since the K+ channels are much slower to open, the depolarization has time to be completed. Having both Na+ and K+ Channels open at the same time would drive the system towards neutrality and prevent the creation of the action potential. Having the K+ channels open, the membrane begins to re-polarize back towards its rest potential [9]. The re-polarization typically overshoots the rest potential to a level of approximately −90 mV. This is called hyper polarization and would seem to be counterproductive, but it is actually important in the transmission of information. Hyper polarization prevents the neuron from receiving another stimulus during this time, or at least raises the threshold for any new stimulus. Part of the importance of hyper polarization is in preventing any stimulus already sent up an axon from triggering another action potential in the opposite direction. In other words, hyper polarization ensures that the signal is proceeding in one direction. After hyper polarization, the Na+/K+ pumps eventually bring the membrane back to its resting state of −70 mV the nerve requires approximately two milliseconds before another stimulus is presented during this time no action potential can be generated [9].

2.2 Evoked Potentials

Evoked potentials or event-related potentials (ERPs) are significant voltage fluctuations resulting from evoked neural activity. Evoked potential is initiated by an external or internal stimulus. ERPs are suitable methodology for studying the aspects of cognitive processes of both normal and abnormal nature. Mental operations, such as those involved in perception, selective attention, language processing, and memory, proceed over time ranges in the order of tens of milliseconds. Amplitudes of ERP components are often much smaller than spontaneous EEG components, so they are not to be recognized from raw EEG trace. They are extracted from set of single recordings by digital averaging of epochs of EEG time-locked to repeated occurrences of sensory, cognitive, or motor events. The spontaneous background EEG fluctuations, which are random relatively to time point when the stimuli occurred, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only that activity which is consistently associated with the stimulus processing in a time-locked way. The ERP thus reflects, with high temporal resolution, the patterns of neuronal activity [9].

2.3 EEG Activity

EEG activity can be broken down into 4 distinct frequency bands namely beta activity > 13 Hz, alpha
activity 8 Hz-13 Hz, theta activity 4 Hz-7 Hz, delta activity < 4 Hz. Beta activity is a normal activity present when the eyes are open or closed. It tends to be seen in the channels recorded from the centre or front of the head. Some drugs will increase the amount of beta activity in the EEG. Alpha activity is also a normal activity when present in waking adults. It is mainly seen in the channels recorded from the back of the head. It is fairly symmetrical and has amplitude of 40 µV to 100 µV. It is only seen when the eyes are closed or reduce in amplitude when the eyes are open. Theta activity can be classed as both a normal and abnormal activity depending on the age and state of the patient. In adults it is normal if the patient is drowsy. However it can also indicate brain dysfunction if it is seen in a patient who is alert and awake. In younger patients, theta activity may be the main activity seen in channels recorded from the back and central areas of the head [21].

Delta activity is only normal in an adult patient if they are in a moderate to deep sleep. If it is seen at any other time it would indicate brain dysfunction. Abnormal activity may be seen in all or some channels depending on the underlying brain problem. Gamma is the frequency range approximately 30–100 Hz. Gamma rhythms are thought to represent binding of different populations of neurons together into a network for the purpose of carrying out a certain cognitive or motor function.

2.4 Conventional Electrode Positioning

The International Federation of Societies for Electroencephalography and Clinical Neurophysiology has recommended the conventional electrode setting (also called 10–20) for 21 electrodes. Often the earlobe electrodes called A1 and A2, connected respectively to the left and right earlobes, are used as the reference electrodes. The 10–20 system avoids both eyeball placement and considers some constant distances by using specific anatomic landmarks from which the measurement would be made and then uses 10 or 20% of that specified distance as the electrode interval. The odd electrodes are on the left and the even ones on the right. For setting a larger number of electrodes using the above conventional system, the rest of the electrodes are placed in between the above electrodes with equidistance between them. For example, C1 is placed between C3 and Cz represents a larger setting for 75 electrodes including the reference electrodes based on the guidelines by the American EEG Society. Extra electrodes are sometimes used for the measurement of EOG, ECG, and EMG of the eyelid and eye surrounding muscles. In some applications such as ERP analysis and brain computer interfacing a single channel may be used. In such applications, however, the position of the corresponding electrode has to be well determined [4].

Fig. 1: Labels for points according to 10-20 electrode placement system.

The Fig. 1 represent a label points, A = Earlobe, C = central, Pz = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital. The positions are determined by dividing the skull into perimeters by connecting few reference points on human head. Reference points are notation, which is at the top of the nose; level with the eyes, and inions, place on the middle on the back of the head. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals.

2.5 EEG Recording Techniques

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste, usually after preparing the scalp area by light to reduce impedance due to dead skin cells. Many systems typically use electrodes, each of which is attached to an individual wire. Some systems use caps or nets into which electrodes are embedded; this is particularly common when high-density arrays of electrodes are needed. Electrode locations and names are specified by the international 10–20 system for most clinical and research applications. This system ensures that the naming of electrodes is consistent across laboratories. In most clinical applications, 19 recording electrodes are used. A smaller number of electrodes are typically used when recording EEG from neonates. Additional electrodes can be added to the standard set-up when a clinical or research application demands increased spatial resolution for a particular area of the brain. High-density arrays can contain up to 256 electrodes more-or-less evenly spaced around the scalp. Each electrode is connected to one input of a differential amplifier; a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times, or 60–100 dB of voltage gain). Most EEG systems these days, however, are digital, and the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter [13, 20].

2.5.1 Recording Electrodes

The EEG recording electrodes and their proper function are critical for acquiring appropriately high quality data for interpretation. Many types of electrodes exist, often with different characteristics. Basically there are four types of electrodes are used namely disposable electrodes, reusable disc electrodes, headbands and electrodes caps, saline
based electrode – needle electrodes. The EEG recording can last from anything between 15 minutes to 1 hour or longer depending on the situation. Typically the patient will be lying down or sitting relaxed in a chair. Most of the recording is taken with the eyes closed, although the patient will be frequently asked to open them for short periods. As it is known from tomography different brain areas may be related to different functions of the brain. Each scalp electrode is located near certain brain centers, e.g. F7 is located near centres for rational activities, Fz near intentional and motivational centers, F8 close to sources of emotional impulses. Cortex around C3, C4, and Cz locations deals with sensory and motor functions. However the scalp electrodes may not reflect the particular areas of cortex, as the exact location of the active sources is still open problem due to limitations caused by the non-homogeneous properties of the skull, different orientation of the cortex sources, coherences between the sources. High impedance can lead to distortions which can be difficult to separate from actual signal. It may allow inducing outside electric frequencies on the wires used or on the body. Impedance monitors are built in some commercially available EEG devices. In order to prevent signal distortions impedances at each electrode contact practically, impedance of the whole circuit comprising two electrodes is measured, but built in impedance checks usually display results already divided by two. Physical references can be chosen as vertex (Cz), linked-ears, linked-mastoids, contra lateral-ear, C7 reference, bipolar references, and tip of the nose. Reference-free techniques are represented by common average reference, weighted average reference, and source derivation. Each technique has its own set of advantages and disadvantages. The choice of reference may produce topographic distortion if relatively electrically neutral area is not employed [13, 20].

2.5.2 Amplifiers and Filters
The signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters. Amplifiers adequate to measure these signals have to satisfy very specific requirements. They have to provide amplification selective to the physiological signal, reject superimposed noise and interference signals, and guarantee protection from damages through voltage and current surges for both patients and electronic equipment. The basic requirements that a biopotential amplifier has to satisfy are: i) the physiological process to be monitored should not be influenced in any way by the amplifier, ii) The measured signal should not be distorted, iii) the amplifier should provide the best possible separation of signal and interferences, and iv) the amplifier has to offer protection of the patient from any hazard of electric shock.

Proper design of the amplifier provides rejection of a large portion of the signal interferences. The desired biopotential appears as the differential signal between the two input terminals of the differential amplifier. The amplifier gain is the ratio of the output signal to the input signal. In order to provide optimum signal quality and adequate voltage level for further signal processing, the amplifier has to provide a gain of 100-100,000 and needs to maintain the best possible signal-to-noise ratio. In order to decrease an impact of electrically noisy environment differential amplifiers must have high common-mode rejection ratios (at least 100 dB) and high input impedance (at least 100 M Ohms). The common-mode rejection ratio is the ratio of the gain of differential mode over the gain of the common mode. When computers are used as recording devices, channels of analog signal are repeatedly sampled at a fixed time interval and each sample is converted into a digital representation by an analog- to-digital (A/D) converter. The A/D converter is interfaced to a computer system so that each sample can be saved in the computer's memory [13, 20].

2.5.3 Artifacts
Among basic evaluation of the EEG traces belongs scanning for signal distortions called artifacts. Usually it is a sequence with higher amplitude and different shape in comparison to signal sequences that doesn’t suffer by any large contamination. The artifacts in the recorded EEG may be either patient-related or technical. Patient-related artifacts are unwanted physiological signals that may significantly disturb the EEG. Technical artifacts, such as AC power line noise, can be decreased by decreasing electrode impedance and by shorter electrode wires. The most common EEG artifact sources can be classified in two minor body movements such as EMG, ECG, eye movement and sweating. Secondly 50/60 Hz, impedance fluctuation, cable movement broken wires contact, low battery, too much electrode. Excluding the artifacts segments from the EEG traces can be managed by the trained experts or automatically. For better discrimination of different physiological artifacts, additional electrodes for monitoring eye movement, ECG and muscle activity may be important. For multichannel montages, electrode caps are preferred, with number of electrodes installed on its surface commonly used scalp electrodes consist of Ag-AgCl disks, 1 to 3 mm in diameter, with long flexible leads that can be plugged into an amplifier. AgCl electrodes can accurately record also very slow changes in potential.
Needle electrodes are used for long recordings and are invasively inserted under the scalp [11].

2.5.4 EEG analysis and clinical use

The EEG reports consist of a number of different sections. The recordist may prepare a report describing the type of activity seen in the record together with changes produced by deep breathing and photic stimulation. With an increase in the number of long recordings being carried out, many departments make use of detection algorithms such as spike and seizure detection. Although it is still necessary for the clinician to review the complete record, such programmers will mark and highlight sections of interest. The most efficient method of implementing these algorithms is for the detection to be carried out on-line. Other methods of analyzing EEG data include power spectrum analysis. A Fast Fourier Transform (FFT) is performed on sections of EEG data to determine the power content of the four main frequency bands. The resulting waveforms can be displayed as a brain map which will show the scalp distribution of the power within each frequency band. The amplitude of the different waveforms at a single point can also be displayed in a similar format. This type of display provides a more objective analysis of the EEG activity compared to a subjective visual analysis by a physician. Simultaneous video monitoring of the patient during the EEG recording is becoming more popular. It allows the physician to closely correlate EEG waveforms with the patient’s activity and may help produce a more accurate diagnosis.

The EEG is frequently used in the investigation of sleep disorders especially sleep apnoea. EEG activity together with other physiological signals such as heart rate, airflow, respiration, oxygen saturation and limb movement are measured simultaneously. These recordings are usually carried out overnight although some sleep studies can be carried out in the department during the day under strictly controlled conditions. A routine clinical EEG recording typically lasts 20–30 minutes and usually involves recording from scalp electrodes. Routine EEG is typically used in the clinical circumstances like; i) To distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope, sub-cortical movement disorders and migraine variants, ii) to differentiate organic encephalopathy or delirium from primary psychiatric syndromes such as catatonia, and iii) to serve as an adjunct test of brain death. At times, a routine EEG is not sufficient, particularly when it is necessary to record a patient while he/she is having a seizure [13, 20].

2.6 Representation of the EEG Channel

The combination of all electrodes with reference and ground this representation of electrode is called montage [13].

Bipolar Montage

Each channel represents the difference between two adjacent electrodes. The entire montage consists of a series of these channels. For example, the channel Fp1-F3 represents the difference in voltage between the Fp1 electrode and the F3 electrode. The next channel in the montage, F3-C3, represents the voltage difference between F3 and C3, and so on through the entire array of electrodes. EEG machines use a differential amplifier to produce each channel or trace of activity. Each amplifier has two inputs. An electrode is connected to each of the inputs. Differential amplifiers measure the voltage difference between the two signals at each of its inputs. The resulting signal is amplified and then displayed as a channel of EEG activity.

Referential Montage

Each channel represents the difference between a certain electrode and a designated reference electrode. There is no standard position for this reference; it is, however, at a different position than the recording electrodes. Midline positions are often used because they do not amplify the signal in one hemisphere vs. the other. Another popular reference is linked ears, which is a physical or mathematical average of electrodes attached to both earlobes and mastoids.

Average Reference Montage

The outputs of all of the amplifiers are summed and averaged and this averaged signal is used as the common reference for each channel. Average reference derivation activity from all the electrodes are measured, summed together and averaged before being passed through a high value resistor. The resulting signal is then used as a reference electrode and connected to input 2 of each amplifier and is essentially inactive. All EEG systems will allow the user to choose which electrodes are to be included in this calculation.

Fig. 2:- Average reference derivation

Laplacian Montage

Each channel represents the difference between an electrode and a weighted average of the surrounding electrode. When analog EEG is used, the technologist switches between montages during the recording in order to highlight or better characterize certain features of the EEG [13].

2.7 Principle of EEG Diagnosis

The EEG signal is closely related to the level of consciousness of the person. As the activity increases, the EEG shifts to higher dominating frequency and lower amplitude. When the eyes are closed, the alpha
waves begin to dominate the EEG. When the person falls asleep, the dominant EEG frequency decreases. In a certain phase of sleep, rapid eye movement called (REM) sleep, the person dreams and has active movements of the eyes, which can be seen as a characteristic EEG signal. In deep sleep, the EEG has large and slow deflections called delta waves. No cerebral activity can be detected from a patient with complete cerebral death. Fig. 3 shows various EEG activities [13].

Fig. 3: EEG activity is dependent on the level of consciousness.

3 THE PROPOSED EEG SIGNAL ANALYSIS SCHEMES

EEG signals are the signatures of neural activities. They are captured by multiple-electrode EEG machines either from inside the brain, over the cortex under the skull, or certain locations over the scalp and can be recorded in different formats. The signals are normally presented in the time domain, but many new EEG machines are capable of applying simple signal processing tools such as the Fourier transform to perform frequency analysis and equipped with some imaging tools to visualize EEG topographies. There have been many algorithms developed so far for processing EEG signals. The operations include, but are not limited to, time-domain analysis, frequency-domain analysis, spatial-domain analysis, and multiway processing. Also, several algorithms have been developed to visualize the brain activity from images reconstructed from only the EEGs. Separation of the desired sources from the multisensor EEGs has been another research area. This can later lead to the detection of brain abnormalities such as epilepsy and the sources related to various physical and mental activities.

Spectral estimation helps in finding the pulse rhythms present in the EEG signal. The short segment of EEG data is analyzed for spectral parameters such as location and amount of spectral energy. The main objective of using prediction methods is to find a set of model parameters that best describe the signal generation system. Such models generally require a noise-type input. We need wavelet transform (WT) to analyze non-stationary signals, i.e., whose frequency response varies in time. Fourier transform (FT) is not suitable for non-stationary signals; wavelet transform decomposes a signal onto a set of basis functions called wavelets. The proposed work uses fast Fourier transform and ICA for the analysis of ECG brain signals.

3.1 Fast Fourier Transform (FFT)

Mathematical transformations are applied to signals to obtain further information from that signal time-domain signal as a raw signal and a signal that has been transformed by any of the available mathematical transformations as a processed sign almost of the signals in practice, are time-domain signals in their raw format. That is, whatever that signal is measuring, is a function of time. In other words, when we plot the signal one of the axes is time (independent variable), and the other (dependent variable) is usually the amplitude. When we plot time-domain signals, we obtain a time-amplitude representation of the signal. This representation is not always the best representation of the signal for most signal processing related applications. In many cases, the most distinguished information is hidden in the frequency content of the signal. The frequency spectrum of a signal is basically the frequency components of that signal. The frequency spectrum of a signal shows what frequencies exist in the signal. Spectral analysis of a signal involves decomposition of the signal into its frequency components. In other words, the original signal can be separated into its sub spectral components by using spectral analysis methods. Among spectral analysis techniques, Fourier transform is considered to be the best transformation between time and frequency domains because of it being time shift invariant. The Fourier transform pairs are expressed as. Let x0... xN-1 be complex numbers. The DFT is defined by the formula

\[ \text{Where and } N = \text{Length } x(n) \]

This means that by using Fourier transform, the frequency components that the EEG signal includes can be estimated. The peak frequency bands of these peaks may indicate a pathological case such as epilepsy, tumors [22].

3.2 independent Component Analysis (ICA)

Independent component analysis (ICA) is a relatively recent method for blind source separation (BSS), which has shown to outperform the classical principal component analysis (PCA) in many applications. In particular, it has been applied for the extraction of ocular artifacts from the EEG, where principal PCA could not separate eye artifacts from brain signals, especially when they have comparable amplitudes ICA performs BSS of statistically independent sources, assuming linear mixing of the sources at the sensors, generally using techniques involving higher-order statistics or temporal decorrelation. In the standard, noise free, formulation of the ICA problem, Fig. 4: Independent Component Analysis model

In Fig. 4 its observed signals x(t) are assumed to be a linear mixture of an equal number of unknown but statistically independent source signals s(t), i.e., ICA assumes the existence of n signals that are linear mixtures of m unknown independent source signals. At
time instant \( i \), the observed n-dimensional data vector
\( x(i) = [x_1(i) \ldots x_n(i)]^T \) is given by the model
\[
x(i) = As(i)
\]
where both the independent source signals \( s(i) = [s_1(i) \ldots s_m(i)] \) and the mixing matrix \( A = [a_{kj}] \) are
unknown. Other conditions for the existence of a
solution are (1) \( n = m \) (there are at least as many
mixtures as the number of independent sources), and
(2) up to one source may be Gaussian. Under these
assumptions, the ICA seeks a solution of the form
\[
s(i) = Bx(i)
\]
Where \( B \) is called the separating matrix.
ICA separates EEG signals including artifacts into
independent components based on the characteristics
of the data, without relying on the availability of one or
more clean reference channels for each type of artifact.
This avoids the problem of mutual contamination
between regressing and regressed channels. ICA-based artifact removal can preserve all of the
recorded trials, a crucial advantage over rejection-based methods when limited data are
available, or when blinks and muscle movements
occur too frequently, as in some subject groups.
Unlike regression methods, ICA-based artifact removal
preserve data at all scalp channels, including
frontal sites [8].

3.4 Overview of EEGLAB
EEGLAB is an interactive matlab toolbox for
processing continuous and event-related EEG, MEG
and other electrophysiological data incorporating ICA,
time/frequency analysis, artifact rejection,
event-related statistics, and several useful modes of
visualization of the averaged and single-trial data.
EEGLAB provides an interactive graphic user interface
(GUI) allowing users to flexibly and interactively
process their high-density EEG and other dynamic
brain data using (ICA) and/or time/frequency analysis
(TFA), as well as standard averaging methods.
EEGLAB offers a wealth of methods for visualizing
and modeling event-related brain dynamics, both at
the level of individual EEGLAB 'datasets' and/or
across a collection of datasets brought together in an
EEGLAB study set [5]

Results

2 RESULTS
4.1 Datasets and Channel Activities
Two datasets are shown in Table 1 and Table 2 which
are acquired from SVS Medical College, Hyderabad,
India. The outcomes of these data sets when loaded
to EEGLAB are shown in Fig. 5 and Fig. 6. Data set 1:

![Fig. 5: Channel activities for datasets 1](image1)

![Fig. 6: Channel activities for datasets 2](image2)

4.2 Channel Location Selection
Electrode location are placed according the 10-20
system. The earlobe electrodes called A1 and A2,
connected respectively to the left and right earlobes,
are used as the reference electrodes. The 10–20
system avoids both eyeball placement and considers
some constant distances by using specific anatomic
landmarks from which the measurement would be
made and then uses 10 or 20% of that specified
distance as the electrode interval.

![Fig. 7: FPz Channel activity for data set 1](image3)

![Fig. 8: Fz Channel activity for dataset 2](image4)

4.3 Results of FFT
A Fourier Transform is performed on the section of
EEG data to determine the power content of the
frequency band .The resulting waveform can be
displayed as a brain map which will shows the scalp
distribution of the power within each frequency band
and the frequency component that the EEG signal
include can be estimated. Fig. 9 and Fig. 10 shows the
power spectrum of FPz and Fz channel location and to
study the power spectrum for both location ,there is
sharp edges in frequency band ,its indicate the eye
component is present during the attention and mental
process.

![Fig. 9: Power spectrum of FPz channel location for
data set 1](image5)

![Fig. 10: Power spectrum of Fz channel location for
data set 2](image6)

4.4 Results of ICA
ICA performs the blind source separation of
statistically independent source and its assume the
neural activity contributing to EEG signal are the
spatially stationary through time and its ICA
decompose at 32 and 21 scalp electrode

![Fig. 11: Channel activity when remove the baseline
activity from dataset 1](image7)

![Fig. 12: Channel activity when remove the baseline
activity from data set 2](image8)
4.4.1 Datasets with its Independent Components

Simulation shows that ICA derives a component accounting for their joint occurrence and separate component accounting for their period of activation. Fig. 13 and Fig. 14 shows Channel activities when we apply the ICA algorithm for dataset 1 and dataset 2, its removes the independent component from the data and shown as red in Fig. 13 and Fig. 14.

Fig. 13: Channel activities of dataset 1 and its component.
Fig. 14: Channel activities of dataset 2 and its component.

4.4.2 Event Related Potential

Simulation result shows the amplitude of ERP component much smaller than spontaneous EEG component and it’s reflecting only stimulus processing activity. Fig. 15 and Fig. 16 shows the event related potential for channel location FPz and Fz and its shows trail ERP with eye component in EEG pattern from dataset 1 and dataset 2.

Fig. 15: Event related potential for FPz of dataset 1.
Fig. 16: Event related potential for Fz of dataset 2.

Conclusions

Electroencephalography belongs to electro biological imaging tools which is widely used in medical and research areas. Signal processing and machine learning based method play crucial role in modern cognitive neuroscience research for better understanding of various brain function such as cognitive, emotion, memory and attention. EEG based measurement is most common used due to its good temporal resolution, low cost and non invasive but due to the noisy and non stationary and non linear characteristics of these function is a higher challenging job automated computerized analysis of these signal has great advantage in medical diagnostic as well as rehabilitation engineering for designing brain computer interface system. The advances signal processing techniques has been used for detection and separation of brain signals. The Fourier Transform is used to detect the brain activities in power spectrum and analysis of the EEG pattern whiles its fail to separate the component like eye blinking. To overcome this problem another technique independent component analysis is used to separate accurately the eye blink component in the channel location in FP1 and Fp2 position. Localization of brain signal sources is another direction of further future research. This may be achieved by developing new algorithm for the localization of the sources with in the brain and to visualize and understand the macroscopic brain dynamics.

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Authors Contribution(s)

Tested and compared two methods for ECG brain signals.

References


Illustrations

Illustration 1

table

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<tr>
<th>Channel per frame</th>
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<td>Events</td>
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<td>Sampling rate</td>
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<td>Channel Location</td>
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<td>ICA weight</td>
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</table>

Channel per frame 21
Frame per epoch 150000
Epoch 1
Events 1
Sampling rate 250
Epoch start Time (sec.) 00.00
Epoch and time 599.996
Average reference yes
Channel Location yes
ICA weight yes

Table 1: Data set 1 of visual attention task. Table 2: Data set 2 of mental task.
Illustration 2

Fig. 1: Labels for points according to 10-20 electrode placement system.
Fig. 4: Independent Component Analysis model

Fig. 5: Channel activities for datasets 1
Fig. 7: FPz Channel activity for data set 1.

Fig. 8: Fz Channel activity for dataset 2.

Fig. 9: Power spectrum of FPz channel location for dataset 1.
Fig. 10: Power spectrum of $F_z$ channel location for dataset 2.

Fig. 11: Channel activity when remove the baseline activity from dataset 1.

Fig. 12: Channel activity when remove the baseline activity from dataset 2.
Fig. 13: Channel activities of dataset 1 and its component.

Fig. 14: Channel activities of dataset 2 and its component.
Fig. 16: Event related potential for Fz of dataset 2.
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