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Using ICA Neuroimaging Techniques to Detect Neurological Abnormalities.

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ABSTRACT

EEG (Electroencephalogram) measures electrical potentials on the scalp surface that occur as a result of dynamic brain function. This paper presents the method to extract EEG Data and various methods used to perform EEG Neuroanalysis, and why the author has chosen to work on ICA method. EEG data is collected by placing sensors on a person's scalp at different positions, amplifying data by 100db, digitizing it with a sampling rate of 256HZ and using BLUETOOTH Technology to wirelessly transmit it to the computer. EEGLAB, a C library and tool integrated in MATLAB, has been described. The methodology used to obtain the EEG datasets and implement both ICA methods on the data has been presented. Baseline wander and power line interference were also removed from baseline wander and power line interference from the EEG data. The time taken for ICA and FAST ICA has been compared. Finally, neurological abnormalities were detected abnormalities in brain, using ICA, by detecting spikes and sharp waves in EEG.

Keywords: EEGLAB, ICA, Artifacts, Whitening, Sphering

INTRODUCTION

EEG (Electroencephalography) 1 measures electrical potentials on the scalp surface that occur as a result of dynamic brain function. The procedure involves placing multiple sensors on the scalp. These sensors have the ability to measure potential changes with microvolt sensitivity.

One challenge of using scalp-based data is that each sensor is actually measuring surface potential changes caused by a superposition of underlying signals from various sources within the brain, as well as extra brain sources. These signals are transmitted to the scalp via volume conduction through various tissue and bone structures. Each sensor is actually receiving a mixture of different signals, and a given EEG signal is obtained from sensors, and at different intensities.

The hardware used, does introduce some power line interference in the EEG waveforms. Also, one neuron in brain does not influence 1 sensor, but many sensors at a time, so channel data are dependent on each other. Infomax and Fast ICA, mathematically remove these problems.

The signal mixtures at each sensor can be separated into several independent components. Some of these will correspond to artifacts such as eye blinks, heartbeats and in some cases, the experimental apparatus. Independent Component Analysis (ICA) is a mathematical technique for extracting components, where the extracted components describe temporally independent activities from spatially fixed overlapping sources. Sources corresponding to artifacts can then be removed from the signal mixtures to facilitate further analysis of the EEG data.

The big advantage of using ICA over other methods is that, it helps in parallelizing the analysis, that is, individually, neuroanalysts can analyse individual channel, as each channel is independent of each other.

By combining the high-resolution data provided by dense- array EEG with sophisticated data analysis techniques such as ICA, researchers are developing ways to 'see' into the neurophysiological and

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cognitive processes within the brain. Section 2 describes the methods used to extract the EEG signal s from the brain and display EEG on computer. Component Analysis. Section 3 shows a table of 22 channels. Section 4 shows the block diagram and work done by the author. Section 6 describes the software to be used. Section 7 describes what are the signs of brain abnormalities, and how they are detected using ICA methods. Section 8 describes the applications and future scope.

EEG data extraction

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 abrasion to reduce impedance due to dead skin cells.The sensor is known as ENOBIO.Some systems use caps or nets into which electrodes are embedded; this is particularly common when high-density arrays of electrodes are needed.Each electrode is connected to one input of a differential amplifier (one amplifier per pair of electrodes); a common system reference electrode is connected to the other input of each differential amplifier.

The amplification is about 1,000–100,000 times, or 60–100 dB of voltage gain. Most EEG systems ever, are digital, and the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter. Analog-to-digital sampling typically occurs at 256-512 HZ in clinical scalp EEG; TI-MSP 430 is the processor used for digital conversion and filtering. The digital EEG signal is stored electronically and can be filtered for display. Typical settings for the high-pass filter and a low-pass filter are 0.5-1 HZ and 35–70 HZ, respectively. The high-pass filter typically filters out slow artifact, such as electrogalvanic signals and movement artifact, whereas the low-pass filter filters out high- frequency artifacts, such as electromyographic signals. An additional notch filter is typically used to remove artifact caused by electrical power lines (60 HZ in the United States .This EEG data is then transmitted wirelessly to a computer,using BLUETOOTH Technology. A typical adult human EEG signal is about 10μ V to 100 μV in amplitude when measured from the scalp and is about 10– 20 mV when measured on computer.

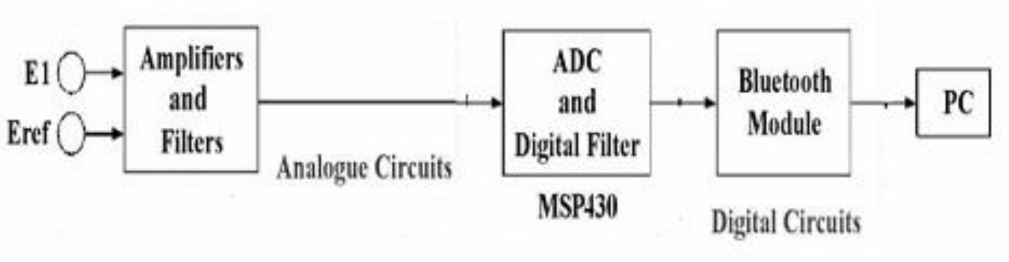

Fig.1.Figure shows the extraction and Wireless transmission of EEG

ICA (Independent Component Analysis)

Initially, EEG Neuroimaging was performed using clustering methods. Now, clustering could not handle large datasets, and also, the individual channel data was dependant on each other.

Cross Validation method, divided he data into 2 subsets, and the 2 subsets were independent of each other, but this method too was very time taking.

Independent Component Analysis (ICA)[2] is a mathematical technique for extracting components, where the extracted components describe temporally independent activities from spatially fixed overlapping sources. Sources corresponding to artifacts can then be removed from the signal mixtures to facilitate further analysis of the EEG data.

One form of ICA is encapsulated in the both ICA methods, first described in and implemented in MATLAB. FastICA works by searching for a weight matrix that maximizes the non-gaussianity of the resultant components[4]. Any mixture of non-gaussian random variables will be more gaussian than the variables themselves (Central Limit Theorem of Statistics). Therefore, it is possible to use non-gaussianity as a measure of statistical independence.

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The phases of execution of FAST ICA are:

Start processes on head and remote nodes

1. Load parameters and replicate to workers
2. Load data and distribute amongst workers
3. Optionally whiten the data
4. Load parameters and replicate to workers
5. Output components, weights, sphering matrix

Channels Used in ICA

For the first study, on the applicability of ICA on electroencephalogram, the EEG consists of 22 signals, recorded by unipolar electrodes at a sampling rate of 250Hz[5].

For the second part of the study the polysomnographic data used in the study were collected at the Asklepios Clinic, Gauting, Munich, Germany. The sampling rates of the channels are presented below.

Signal	**Unit**	**Sampling Freq.**
EEG --- C4/A1	µV	125 Hz
EEG --- C3/A2	µV	125 Hz
EOG RIGHT F4/A1	µV	125 Hz
BODYPOS HANDY F3/A2	"	125 Hz
EMG CHIN P4/P3	µV	250 Hz
ECG --- Ecg	µV	125 Hz
RESP FLOW Fp2/Cz	"	25 Hz
RESP FLOW Fp1/Cz	"	25 Hz
RESP FLOW Fz/Cz	"	25 Hz
RESP THORAX Thrx	µV	25 Hz
RESP ABDOMEN Abdm	µV	25 Hz
SOUND RAW Snd	µV	250 Hz
SAO2 SCHWARZ Oxi	%	25 Hz
EMG TIBIALR T4/T6	µV	250 Hz
EMG TIBIALL T3/T5	µV	250 Hz
BODYPOS SCHWARZ Pos	"	25 Hz
CPAP SCHWARZ Prss	mBa	25 Hz

TABLE 1: 22 Eeg Channels

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Work Done

Proposed Block Diagram

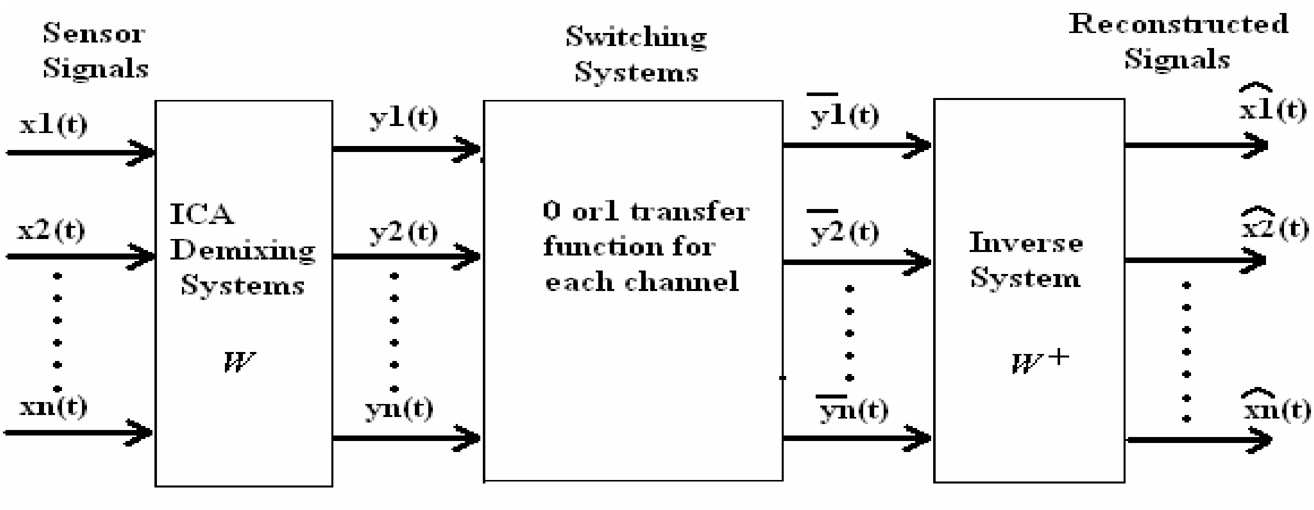

Fig.2.Block Diagram

Objective of Work

The objective of work is to collect EEG reports and use Infomax and Fast ICA methods for analyzing a large set of EEG data samples and separate most mixed components that explain the observed data. The reduction in execution time provided by Fast ICA was one of the primary motivators for this research. Also, raw EEG data, which looks similar for all persons, is analyzed using both methods, and a better output is obtained which shows abnormalities clearly.

Proposed Experimental Work

The tasks of ICA are:

1. Obtain input data, in the form of a matrix x.
2. Search for a weight matrix W such that will unmix the whitened signal mixtures x into a set of independent source signals s.
3. Compute covariance matrix, sphering matrix, to make data uncorrelated with each other.
4. Apply the transfer Functions to an Inverse system, to obtain the reconstructed sensor signals.

Infomax uses Linear Transformation methods, where the direction of data vectors, and the angle between the previous and new weights, is taken for calculation. Fast ICA is a fixed point algorithm, which involves simple matrix operations, thus making it faster than infomax. Depending upon the configurations of the system, Fast Ica takes less than half the time taken by Fast ICA.

The execution time of both methods was measured after implementing them, and proved that, Fast ICA is faster.

But, in some cases, after observing the waveforms produced by both methods, Infomax output looks more accurate than Fast ICA.

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Software Design

MATLAB programs were developed for both Infomax and Fast ICA , using commands in MATLAB. Using tic and toc commands, the time taken for analyzing has been calculated. Also, the codes for removing baseline wander and power line interference, have been developed in MATLAB. Using MATLAB plot and subplot commands, individual patient's data can be observed. 325 patients' data is uploaded on MATLAB directory.

EEGLAB[3] is a Matlab toolbox distributed under the free GNU GPL license for processing data from electroencephalography(EEG), magnetoencephalography MEG and other electrophysiological device. Along with all the basic processing tools, EEGLAB implements independent component analysis (ICA), time/frequency analysis, artifact rejection, and several modes of data visualization. EEGLAB allows users to import their electrophysiological data in about 20 binary file format from standard EEG manufacturer, preprocess it, visualize activity in single trials, and perform ICA. Artifactual ICA components may be subtracted from the data. Alternatively, ICA components representing brain activity may be further processed and analyzed. EEGLAB also allow users to group data from several subjects, and to cluster their independent components. EEGLAB may be downloaded at http://sccn.ucsd.edu/eeglab.

MATLAB programs were developed for both Infomax and Fast ICA , using commands in MATLAB.

Detection of Abnormalities.

ICA extracts the independent components from the data and makes it artifact free. Soon, the raw data, which looks similar for most persons, looks accurate and proper for each patient.

Spikes and Sharp waves are the main indications of any abnormality. The presence of spikes indicates the presence of idiopathic (primary) epilepsy in a patient. The presence of sharp waves indicates that the patient is suffering from Symptomatic epilepsy, which is not genetic.

Spikes are narrow waves with high amplitude. Their sudden occurrence in an otherwise smooth EEG waveform indicates that the person is abnormal.

Sharp waves are broader waves, with negative amplitude; they also indicate that the person is suffering from epilepsy.

Likewise, using the frequency of occurrence of spikes and sharp waves, a person's neurological condition can be detected.

Applications

ICA is a mathematical technique for extracting independent components. Sources corresponding to artifacts are then removed from the signal mixtures to facilitate further analysis of the EEG data. So, the ways to observe the neurophysiological processes within the brain become simple because of ICA.

Fast ICA provides a significant advantage over the existing MATLAB-based algorithms in two ways: execution time and data size. The reduction in wall-clock time provided by ICA was one of the primary motivators for the ICA research. However, an equally significant feature of ICA is its ability to handle much larger data sets than MATLAB can handle.

Work Done and Results

EEG data from 325 patients were collected from [6].This has been loaded on MATLAB directory, for further processing. The data consists of 2500 columns, that is, the number of samples. Also,

The data were subdivided the entire data into 6 subplots, for the important 6 channels, and represented them.

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Each patient's independent data can be observed. Also, baseline wander and power line interference has been removed.

The execution time of both algorithms was measured. The average execution time of Infomax ICA was 2.18 s, whereas FastICA required 0.53 s, corresponding to a computational speedup of approximately 4.1×. FastICA therefore provided substantially faster execution while preserving effective component separation. The processed EEG signals were further analyzed to identify epileptic abnormalities based on spikes and sharp waves.

Also, the author has worked on detecting the type of epilepsy that some patients are suffering from, by observing the pattern of spikes and sharp waves.

CONCLUSION

The ICA class of techniques and parallel implementations of FAST ICA Algorithm and INFOMAX has been described by the author. Indeed, one active area of neuroscience research is the comparison of different ICA algorithms as applied to EEG. Different algorithms are appropriate for different assumptions about the EEG data and the underlying signals.

INFOMAX uses fractional values for the whitening and sphering matrices. FAST ICA uses only decimal values, which makes computations easy, and less time taking, but the resolution is little reduced.

It is being planned to increase the usability of HiPerSAT by increasing the performance of the existing algorithms, and by implementing additional ICA methods.

Also, to make online extraction of EEG possible, the author are working on coding the programs in TURBO C, C++

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