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EXTRACTION AND PLOTTING OF SPECTRAL AND TEMPORAL FEATURES OF EEG RHYTHMS

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Abstract— Despite the medical community's astronomical expansion, understanding the activity of the human brain remains a challenging work for medical specialists, and the quantum of difficulty in treating conditions like epilepsy grows without any limits. As a result, an automatic system that can plot brain waves will be of tremendous assistance to the medical industry in mapping the same with human emotions and the collected information may be utilized to heal and prevent neural disorders using Machine Learning. In this work, the brain waves are obtained in the form of EEG waves and the same is denoised and filtered using renewed techniques and features such as temporal and spectral. These are extracted from the EEG data and fruitful insights are obtained from the same.

Keywords: ***Brain, Medical, EEG, Machine Learning***

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I. INTRODUCTION

One of the most challenging tasks in developing brain computer interface (BCI applications) is the design of systems that translate the mental imagination of movements to commands without the use of any peripheral nervous system. There are a variety of BCI fields that include brain science, neural engineering, rehabilitation, and brain technology. Developers of BCI systems often use robots and other devices that are fully capable of controlling their mental intentions. One of the most challenging tasks in developing these systems is analyzing the electrical properties of brain waves. These are referred to as brain waves and consist of various rhythmic components. The four major components of brain waves are delta, theta, alpha, beta, and gamma. These are the frequencies that are responsible for carrying the information contained in the overall electrical activity of the brain. To filter out the various ranges of signals coming from the sensors, each component is individually designed to be filtered. In order to implement BCI, the developers need to extract the various rhythmic components of brain waves. During the recording of an electroencephalogram (EEG), the physiological noises generated by the brain are also added. This process is very challenging, as the brain waves are not only carrying the information, they also contain other signals. The effective extraction of these brain waves is very important to the clinical implementation of the BCI.

Thus, rhythmic components of collected brain waves are employed to create a brain computer interface (BCI). Physiological sounds are inadvertently mixed in with pure brain activity data during EEG recording. The extraction of the rhythmic component (RCE) from a noisy EEG is difficult, yet the successful extraction of the brain waves is a critical stage in using the EEG in clinical diagnosis and/or BCI implementation. Apart from just extracting the rhythmic components, advanced techniques are applied furthermore to extract the spectral and temporal data which in turn will be of great use in the healthcare industries. An EEG is a test that detects abnormalities in your brain waves, or in the electrical activity of your brain. During the procedure, electrodes consisting of small metal discs with thin wires are pasted onto your scalp. The electrodes detect tiny electrical charges that result from the activity of your brain cells.

The charges are amplified and appear as a graph on a computer screen, or as a recording that may be printed out on paper. Your healthcare provider then interprets the reading. During an EEG, your healthcare provider typically evaluates about 100 pages, or computer screens, of activity. He or she pays special attention to the basic waveform, but also examines brief bursts of energy and responses to stimuli, such as flashing lights. Evoked potential studies are related procedures that also may be done. These studies measure electrical activity in your brain in response to stimulation of sight, sound, or touch. The EEG is used to evaluate several types of brain disorders. When epilepsy is present, seizure activity will appear as rapid spiking waves on the EEG. People with lesions of their brain, which can result from tumors or stroke, may have unusually slow EEG waves, depending on the size and the location of the lesion. Wherein this project concentrates on anxiety, traumic disoders, post-traumatic stress, psychotic disorders, depression, bipolar disoders, personality disoders, to stabilize mental strength etc, and since there are several

signals coming from an EEG data, a filter called Butterworth is used in the process.

A Butterworth filter is a type of signal processing filter designed to have a frequency response as flat as possible in the passband. Hence the Butterworth filter is also known as "maximally flat magnitude filter". The frequency response of the Butterworth filter is flat in the passband (i.e. a bandpass filter) and roll-offs towards zero in the stopband. The rate of roll-off response depends on the order of the filter. The number of reactive elements used in the filter circuit will decide the order of the filter. The inductor and capacitor are reactive elements used in filters. But in the case of Butterworth filter only capacitors are used. So, the number of capacitors will decide the order of the filter. Here, we will discuss the Butterworth filter with a low pass filter. Similarly, the high pass filter can be designed by just changing the position of resistance and capacitance. While designing the filter, the designer tries to achieve a response near to the ideal filter. It is very difficult to match results with the exact ideal characteristic. We need to use complex higher-order filters to achieve the characteristic near to the ideal characteristic.

If you increase the order of the filter, the number of cascade stages with the filter is also increased. But in practice, we cannot achieve Butterworth's ideal frequency response. Because it produces excessive ripple in the passband. In Butterworth filter, mathematically it is possible to get flat frequency response from 0 Hz to the cut-off frequency at -3dB with no ripple. If the frequency is more than the cut-off frequency, it will roll-off towards zero with the rate of -20 dB/decade for the first-order filter. If you increase the order of the filter, the rate of a roll-off period is also increased. And for second-order, it is -40 dB/decade. The quality factor for the Butterworth filter is 0.707.The below figure shows the frequency response of the Butterworth filter for various orders of the filter.

A Power Spectral Density (PSD) is the measure of signal's power content versus frequency. A PSD is typically used to characterize broadband random signals. The amplitude of the PSD is normalized by the spectral resolution employed to digitize the signal. For vibration data, a PSD has amplitude units of g2/Hz. While this unit may not seem intuitive at first, it helps ensure that random data can be overlaid and compared independently of the spectral resolution used to measure the data. This article explains how this is done. To understand a Power Spectral Density (PSD), it is helpful to understand some limitations of an auto power function when analyzing data with differing spectral resolutions. When the energy of the signal is concentrated around a finite time interval, especially if its total energy is finite, one may compute the energy spectral density. More commonly used is the power spectral density (or simply power spectrum), which applies to signals existing over all time, or over a time period large enough (especially in relation to the duration of a measurement) that it could as well have been over an infinite time interval. The power spectral density (PSD) then refers to the spectral energy distribution that would be found per unit time, since the total energy of such a signal over all time would generally be infinite. Summation or integration of the spectral components yields the total power (for a physical process) or variance (in a statistical process), identical to what would be obtained by integrating over the time domain, as dictated by Parseval's theorem.

The spectrum of a physical process x(t) often contains essential information about the nature of x. For instance, the pitch and timbre of a musical instrument are immediately determined from a spectral analysis. The color of a light source is determined by the spectrum of the electromagnetic wave's electric field E(t)}E(t) as it fluctuates at an extremely high frequency. Obtaining a spectrum from time series such as these involves the Fourier transform, and generalizations based on Fourier analysis.

In many cases the time domain is not specifically employed in practice, such as when a dispersive prism is used to obtain a spectrum of light in a spectrograph, or when a sound is perceived through its effect on the auditory receptors of the inner ear, each of which is sensitive to a particular frequency. Welch method is a modified segmentation scheme and used to evaluate the average periodogram. Generally the Welch method of the PSD can be describe by the equations below, the power spectral density equation is defined first. Then Welch Power Spectrum that mean average of the periodogram for each interval is expressed. The wavelet transform is emerging as an important processing technique in potential-field methods and has contributed significantly to the processing and inversion of magnetic data. The primary reason is the localization property of the wavelet transform. The concept of the continuous-wavelet transform (CWT) was introduced initially in seismic data processing (Goupillaud et al., 1984), while a form of discrete wavelet transform has long been used in communication theory. These were unified through an explosion of theoretical developments in applied mathematics. Potential-field analyses – magnetic methods in particular – have benefited greatly from these developments.

An incoming EEG data usually comes with a lot of noise and artifacts. So to denoise and reduce the artifacts, the raw data is processed with the Butterworth filter.Once done with this, the power spectral density is used on the denoised signals to extract the rhythm signals such as alpha, beta, theta, gamma and it is then later plotted in a graph. The obtained signals are again processed with the wavelet technique, which extracts the temporal features.

The existing system completely focus on Epilepsy which is Recurrent seizures, which are short events involving one or more parts of the body, describe the condition. Seizures are caused by an excessive synchronised electrical firing of a large number of neurons in the brain. Generalized and localised epileptic seizures are the two forms of epileptic seizures. Electrical firing and synchronised electrical discharges in one or more lobes of the brain are referred to as focal seizures, whereas generalised epileptic seizures affect the whole brain.

The use of 10-second intervals for diverse times makes data analysis both efficient and thorough. The occipital brain has a significant level of inter-ictal activity, indicating that it is the dominant lobe during seizures. Both the pre-interictal and post-interictal areas showed the similar tendency of high values. Interictal lengths, as well as pre and post interictal phases, and the extraction of characteristics from them, have proven to be useful factors in the characterisation of seizures and the knowledge of the prevalent type in the sampled population. The Hjorth parameters (particularly activity) have shown to be useful characteristics for describing EEG.It can be concluded that the Hjorth parameters, showing high significance, can be used for further applications such as classification since they characterize the epileptic EEG signals well. Further analysis with the Hjorth parameters can help identify the lobe that was the source of the seizures, and also help with the prediction of onset of seizure in patients, by understanding the dominant lobe during seizures. There are a ton of diseases related to brain and mental health and all of them should be equally treated to effectively progress in advancing the treatments which can cure the respective illness. But unfortunately though, currently only one particular disease called 'Epilepsy' is being focused or prioritized to. Since this can only limit the use of all the advanced techniques that are being incorporated, including all of the disorders is the main focus of this project. Though this is not easily achievable, we have come up with a solution to do so leaving this existing system to be in a major disadvantage.

II. IMPLEMENTATION

The system is about extraction of the sepctaral and temporal datas of EEG rhythms, which serves as a great help to the medical fraternity. This project generally focuses on all of the mental diseases that are currently existing all over the globe. Additionally, neurosurgeons and neuro researches will be greatly benefitted by it. By extracting and plotting the rhythms of EEG, a person's mental state can be easily identified, which in turn will make the proces easy to predict the illness that is associated with the respective person which is extremely convenient for the mental practitioners.

Basically, denosing and removing the unwanted artifacts from the EEG data is an extremely tedious and a laborious task. And hence by making use of what is served with this project, it has made that process easy for the medical practioners and surgeons since this saves a lot of time and in turn helps in diagnosing faster.Many applications related to stress and other mental behaviours can be built keeping this as a base which can indeed help a lot of people around the world. By knowing their own conditions better, they can adjust their environment and lifestyle according to that which will make their day to day activities a lot easier and inturn having a healthy lifestyle.

Initially, the required data is obtained from the UCI EEG repository and further it is processed by the butterworth filter and later by making use of the power spectral density technique, the derived temporal and spectral data are plotted on a graph.You might simply refer to it as a visual or the entire process and its execution. In this graphic, all functional correspondences present are explained below This graph will be greatly used by the medical practitioners to identify and diagnose the respective disease effectively and also can be used on other related research expense.This diagram is simply a list of all the entities that have been included in the system. The graphic depicts the relationships between them and includes a series of data extraction and processing stages. You might simply refer to it as a visual or the entire process and its execution. In this graphic, all functional correspondences present are explained below.

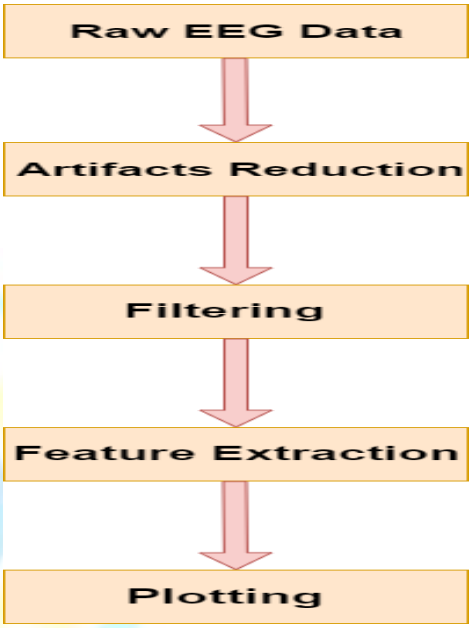

Fig 1: work flow diagram

A. ANACONDA

Anaconda is a Python and R package manager that is available as an open-source project. It is the most often used platform for executing Python and R implementations among data scientists. Because data science has over 300 libraries, having a reliable distribution method for them is essential for every expert in this subject. Anaconda makes package deployment and administration much easier. Furthermore, it includes a number of technologies that use artificial intelligence and machine learning techniques to assist in data collection. Anaconda makes it simple to create, administer, and share Conda environments. Furthermore, Anaconda allows you to launch any desired project with just a few clicks. There are numerous advantages of utilising Anaconda, the following being the most notable: Anaconda is a completely free programme. This implies that you can use it without having to pay for it. Anaconda is a well-known name in the data science community. It is also open-source, which has contributed to its widespread popularity. If you want to work in data science, you'll need to know how to utilise Anaconda for Python, as every recruiter will expect you to have this knowledge. For data science, it's a must-have. It offers over 1500 Python and R data science packages, ensuring that you won't run into any compatibility concerns when working with others.Anaconda makes

package deployment and administration much easier. Furthermore, it includes a number of technologies that use artificial intelligence and machine learning techniques to assist in data collection.

Anaconda makes it simple to create, administer, and share Conda environments. Furthermore, Anaconda allows you to launch any desired project with just a few clicks. There are numerous advantages of utilising Anaconda, Let's say a coworker offers you a project that requires both packages A and B, but you only have package A.You won't be able to complete the job without package B. Anaconda reduces the likelihood of errors occurring.

B. Integrated Development Environment

It's a coding tool which allows us to write, test, and debug your code in an easier way, as they typically offer code completion or code insight by highlighting, resource management, and debugging tools. IDE's provide so many features because of all the features they are extremely useful for development.

IDE enables us to design and manipulate source code. Maintains a smooth Development Cycle Increases efficiency and satisfaction Automatically checks for errors to ensure top quality code. Code completion capabilities improve programming workflow. Deliver top quality software on schedule. Debugger: This tool is used for identifying and remedying errors within source code. Anaconda makes package deployment and administration much easier. Furthermore, it includes a number of technologies that use artificial intelligence and machine learning techniques to assist in data collection. Anaconda makes it simple to create, administer, and share Conda environments. Furthermore, Anaconda allows you to launch any desired project with just a few clicks. There are numerous advantages of utilising Anaconda, This usually tests the various segments of code and identifies the errors before the application is released.

Compiler: This translates the code into a form machine can process, such as binary code. Anaconda makes package deployment and administration much easier. Furthermore, it includes a number of technologies that use artificial intelligence and machine learning techniques to assist in data collection. Anaconda makes it simple to create, administer, and share Conda environments.

Furthermore, Anaconda allows you to launch any desired project with just a few clicks. There are numerous advantages of utilising Anaconda, It is analysed to ensure its accuracy. The compiler then parses and optimizes performance. Code completion: This inserts the common code components. Integrations and plugins: After incorporating all the development tools the workflow and productivity is increased, High level system architechture diagram

Different modules have been used to implement the system. Software is separated into modules, which are individually named and accessible components that are assembled to meet problem requirements.The Feasibility Phase is the initial investigation, or brief study of the problem to determine whether the systems project should be pursued. A feasibility study established the context through which the project addresses the requirements expressed in Business Case and investigates the practicality of a proposed solution. The feasibility study is used to determine if the project should get the go-ahead. If the project is to proceed, the feasibility study will produce a project plan and budget estimates for the future stages of development. Modularity is the single feature of software that enables a programme to be managed rationally.

C. Raw EEG Data:

The Raw EEG Data is driven from the Famous machine leaning repository called UCI repository which in case selection of number channels in the eeg machine is taken into a note where here in our project we have taken the eeg from the two channel eeg device and During an EEG, your healthcare provider typically evaluates about 100 pages, or computer screens, of activity. He or she pays special attention to the basic waveform, but also examines brief bursts of energy and responses to stimuli, such as flashing lights.Evoked potential studies are related procedures that also may be done. These studies measure electrical activity in your brain in response to stimulation of sight, sound, or touch.we have confirmed that which taking the eeg data the patient is absolutly normal and doing his/her regular task.

D. Artifact Reduction and Filtering:

The eeg data drived from the repository has a lot of noise and unwanted artifacts so this module mainly focus on the denoising and artifact reduction. The frequency response of the Butterworth filter is flat in the passband (i.e. a bandpass filter) and roll-offs towards zero in the stopband. The rate of roll-off response depends on the order of the filter. The number of reactive elements used in the filter circuit will decide the order of the filter. The inductor and capacitor are reactive elements used in filters. But in the case of Butterworth filter only capacitors are used. So, the number of capacitors will decide the order of the filter. Here, we will discuss the Butterworth filter with a low pass filter. Similarly, the high pass filter can be designed by just changing the position of resistance and capacitance. So various techniques are used for filtration.in our project we use Butterworth filter which uses the advanced method to denoise the EEG data. Again with low pass filter and high pass filter reducing the frequencies and extracting the proper eeg signal.

E. Feature extraction:

Feature extraction is a process of dimensionality reduction by which an initial set of raw data is reduced to more manageable groups for processing. A characteristic of these large data sets is a large number of variables that require a lot of computing resources to process. Feature extraction is the name for methods that select and /or combine variables into features, effectively reducing the amount of data that must be processed, while still accurately and completely describing the original data set.

After the feature filtering process the eeg data is sent to the feature extraction process which is done by various methods and techniques we use power spectral density method to extract the spectral features and wavelet technique to extract the temporal features.these two method involves a fourier transformation technique and welch method to extract the features in the rhythms of the EEG data.

When visualizing any EEG dataset, the first step usually concerns a visual inspection of single-trial data. With this inspection we can go through all of the recorded epochs in order to evaluate the quality of our dataset. Our goal is to understand.The simplest way to do a visual inspection of an EEG dataset is by using the plot() matplotlib function, which plots epochs as its name indicates. The y axis shows the channel names while the x axis is showing the epoch numbers. Additionally above the plot, we can see the ratio of each event type. Please note that we only use Familiar events in the dataset throughout the tutorials. Single-trial epoch data are usually very noisy. One way of overcoming this drawback is by averaging data over many epoch repetitions, and focusing on average epoch responses, the so-called average Event-Related Potentials, or ERPs. This technique has been widely used in the field of EEG research, as it allows eliminating responses that are irrelevant to a given task. Indeed, average ERPs only contain activity that appears at consistent latencies and electrode locations across repetitions. A typical image of an average ERP response will show 'low' activity during the baseline i.e. before a stimulus occurs.

This is often then followed by large positive or negative deflections of EEG signals during the post-stimulus period, reflecting the average response to an external stimulus. Apart from time-courses of activity, another way to visualize EEG data is as voltage topographies. Topographies display the EEG voltage values at each channel on the scalp. They are similar to a heat map where different voltage ranges are represented with different colors. Topographies allow us to inspect at once the distribution of voltage values on the scalp.

This is particularly advantageous, as they can be informative of all electrodes at once, and not just at single ERP components.The easiest way to plot topographies is through MNE, which has an evoked class function named plot_topomap().This function takes a time range and type of the channels as parameters and it plots. the a topographic map with given data. On the right side of the plot, a color map is provided to undertand the volt ranges that each color represents. Dots on the scalp figures show the location of electrodes. The extracted features from the above module is plotted with the matplotlib python library which creates a GUI to plot the spectral and temporal data for a pictorial representation.

III. RESULTS

All results will be discussed in detail the spectral density with 150Hz sampling rate for input sinusoidal signal of 30Hz frequency. From the results, sampling rate at 50Hz is able to achieve 99.17% accuracy of frequency detection whereas sampling rate at 250Hz obtained 96.24% accuracy of frequency detection. The results show that the accuracy are decreases as the sampling rate increases. This trend is observed because sampling rate will use as the scale during FFT and larger scale to measure the value will decrease the accuracy. Hence, the lowest sampling rate provides the highest accuracy and the accuracy is decreasing with the increasing of sampling rate. shows results for study the effect of input frequency to the accuracy of the algorithm. From the results, lowest input frequency with 10Hz has 94.53% accuracy of frequency detection. The highest input frequency with 50Hz has 98.93% accuracy of frequency detection.

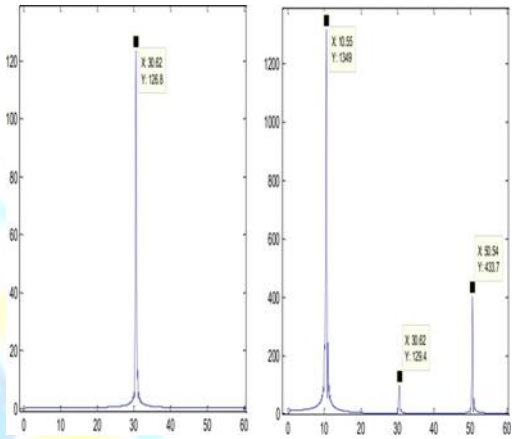

Fig 2: Performance analysis graph 1

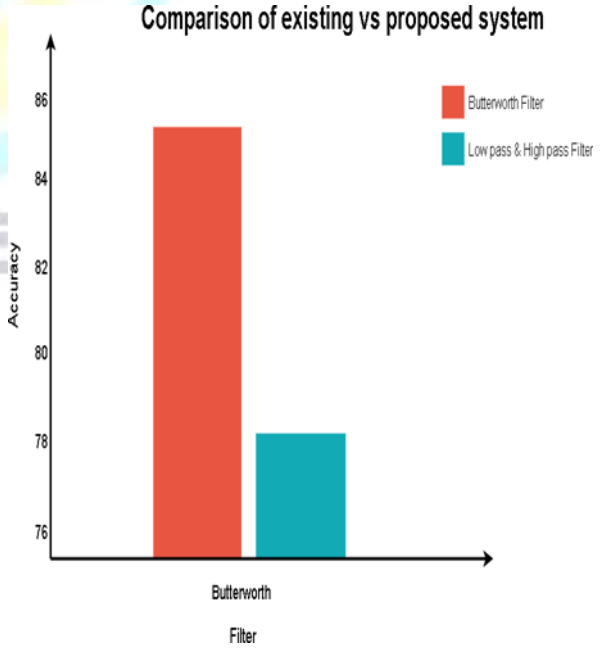

Fig 3: Performance analysis graph 2

The results show that in accuracy is increasing while the input frequency is increasing. Base on the Nyquist rate, the lowest sampling rate must be at least twice of input frequency to avoid aliasing . Hence, concluded from the first and second filter, the sampling rate nearest to twice of input frequency will provide the highest accuracy. the results of

the study the ability of algorithm on complex signal. From the results, it showed that the algorithm was able to detect the complex signals that consist of summation of 10Hz, 30Hz and 50Hz with the frequencies of 10.55Hz, 30.62Hz and 50.54Hz. This results are compared when each signal is detected individually for 10Hz, 30Hz and 50Hz input frequencies are 10.55Hz, 30.62Hz and 50.54Hz respectively. This shows that the algorithm detect the complex signal are same as the signal has been detected individually. Hence, it proves that the algorithm are able to perform on complex signal.

Testing is a set of activities that can be planned in advance and conducted systematically. For this reason a template for software testing, a set of steps into which can place specific test case design techniques and testing methods should be defined for software process. Testing often accounts for more effort than any other software engineering activity. If it is conducted haphazardly, time is wasted, unnecessary effort is expanded, and even worse, errors sneak through undetected. It would therefore seem reasonable to establish a systematic strategy for testing software.

IV. CONCLUSIONS

In brief, the proposed system can come as very effective for the people involved or who work in the medical or healthcare industry since diagnosing diseases can be faster with more accurate data. It can also serve as a medium for more research to be done and can pave more way for advanced solutions. Since this clearly reduces the time it takes to filter the signals obtained from an EEG data, this also is very time saving and effective.

V. FUTURE ENHANCEMENT

Moreover, many applications related to stress and other mental behaviours can be built keeping this as a base which can indeed help a lot of people around the world. By knowing their own conditions better, they can adjust their environment and lifestyle according to that which will make their day to day activities a lot easier and inturn having a healthy lifestyle.

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