Identification of Alzheimer's disease through Feature Extraction using Latent Factor of Multi-Channel EEG

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Abstract

One of the most prevalent and rapidly spreading neurological disorders in the world is Alzheimer's disease. There are several biomarkers available for the evaluation &growth of Alzheimer's disease, and these tools might be seen as crucial for therapeutic applications. EEG signals produce a potent and reasonably priced tool for the diagnosis of many neurological diseases. In this instance, it is necessary to increase the EEG signals' diagnostic precision. A novel approach for utilising EEG signals to diagnose Alzheimer's disease is suggested in this study, which will improve the diagnostic efficacy of the EEG signals and diagnosis. EEG Spectro-temporal Modulation Energy Based aspects, Spectral Features, Coherence Features, and other aspects of EEG Signals are examined in detail.It may be inferred from the characteristics of the EEG signal that were previously mentioned that it can be useful in the diagnosis of dementia and Alzheimer's disease. The main goal of the suggested strategy is to increase the precision of the patient monitoring system, remove variations in the EEG signal, and increase the precision of the procedure.

Keywords: Neurological Disorders, Alzheimer Disease, EEG Signals, Spectral Features, Coherence Features.
DOI Number: 10.48047/nq.2021.19.6.NQ21090 **NeuroQuantology2021;19(6): 218-223**

1. INTRODUCTION

The underlying theory, applications, methods, and implementations of processing or conveying information stored in a variety of physical, symbolic, or abstract representations that are collectively referred to as signals are all included in the enabling technology known as signal processing. It employs formalisations and methods for representation, modeling, analysis, synthesis, finding, recovery, sensing, acquisition, extraction, learning, security, or forensics that are mathematical, statistical, computational, heuristic, as well as linguistic in nature. The purposeful modification of audio signals is known as audio signal processing, and it frequently involves the use of an audio effect or effects unit. Signal processing can take place in either the digital or analogue domains because auditory signals can be electrically represented in either of these two ways. Digital processors work mathematically on the digital representation of the signal, whereas analogue processors work directly on the electrical signal.

The term "analog" refers to something that may be mathematically represented by a set of continuous values. An analogue clock, for instance, has hands that are continually moving on a real clock face, and moving the hands changes the data the clock is displaying. As a result, an analogue signal is a continuous stream of data, in this instance changes in voltage, current, or charge through an electrical circuit (compare with digital signals below). The physical modification of the continuous signal occurs next during analogue signal processing (ASP), which entails modifying the voltage, current, or charge using various electrical devices. In the past, ASP was the only way to modify a signal before the widespread use of digital technologies.

The development of digital signal processing (DSP), a significant undertaking, is ongoing among many engineers. This study focuses on the underlying technology and practical applications of DSP for acoustic signal detection. Active noise control is one of the most well-known implementations for this technology. It employs a microphone to collect ambient noise data, which is then converted into an inverse signal by a DSP processor and broadcast through a secondary speaker. A speech recognition system is another commercial application that enables users to dictate documents and issue voice instructions to boost productivity. The DSP programme must then separate the intended signal from background noise and produce the right output for the input signal. Analog to digital converters, which sample signals in the time domain and transform them to digital form, must be used before analogue acoustic signals may be used in DSP.

The electrical activity of the brain is monitored electro physiologicallythrough electroencephalography (EEG). It monitors voltage variations brought on by ionic current in the brain's neurons and is normally non-invasive. The sort of brain oscillations that may be seen in EEG data is called spectral content, and it is used in diagnostic applications. Epilepsy generates anomalies in EEG data, which are most frequently used to identify the condition. Additionally, it is utilised to identify brain death, encephalopathies, comas, and sleep problems.

Epileptiform and non-epileptiform abnormal activity can be roughly classified as either focal or diffuse, as well as either epileptiform or non-epileptiform. In a very localised region of the brain, focal epileptiform discharges are represented by quick, synchronous potentials in a lot of neurons. Where there is localised injury to the cortex or white matter, there may be focal non-epileptiform aberrant activity over certain regions of the brain. The signs of widespread non-epileptiform aberrant activity include bilateral slowing of the heartbeat or distributed abnormally slow rhythms. The electroencephalogram (EEG) is a recording made from the scalp of the brain's electrical activity. Theta, Delta, and Alpha are the three primary frequencies of human EEG waves.

Delta is the predominant rhythm in newborns up to one year old and in stages 3 and 4 of sleep. It has a frequency of 3 Hz or less. Theta is categorised as "slow" activity and has a frequency range of 3.5 to 7.5 Hz. The posterior areas of the skull on each side are where you'll most often see alpha, which has a frequency between 7.5 and 13 Hz. It is present for the majority of life, particularly after the age of thirteen. When a frequency is 14 Hz or more, activity is considered "fast" or in the beta range. It often has a symmetrical distribution on both sides and is most noticeable from the front. It may be missing or diminished in regions with cortical injury, and it is emphasised by sedative-hypnotic medications. The electrical activity of the brain is monitored electro physiologically through electroencephalography (EEG). It gauges voltage changes brought on by ionic current flowing through the brain's neurons. The sort of brain oscillations that may be seen in EEG data is called spectral content, and it is used in diagnostic applications. The EEG is used to identify brain death, coma, encephalopathies, sleep problems, epilepsy, and other conditions. Evoked potentials (EP) and event-related potentials (ERPs) are two EEG method derivatives. Cognitive science, cognitive psychology, as well as psychophysiological research all make use of these methods.

2. LITERATURE SURVEY

The Alzheimer's disease Neuroimaging Initiative is a multicenter, continuing, longitudinal research that aims to create biomarkers for Alzheimer's disease that can be applied to diagnose and monitor the illness early on. 400 participants alongside initial moderate cognitive impairment (MCI), 200 participants with early Alzheimer's disease, and 200 healthy control participants were planned for the study. The study's main achievements include the creation of standardised techniques for clinical examinations, magnetic resonance imaging, positron emission tomography, along with cerebrospinal fluid biomarkers in a multicenter setting, clarification of the patterns alongside rates of evolution of imaging and CSF biomarker measurements in control subjects, and more.Patients with MCI and AD, increased clinical trial efficiency by identifying those most likely to experience rapid clinical deterioration in the future, confirmation of the AD risk loci CLU, CR1, as well as PICALM, worldwide implications with the creation of schemes such to ADNI in Europe, Asia, and Australia, comprehension of the biology as well as pathobiology of healthy aging, MCI, as well as AD, and the development of infrastructure are all factors that will be considered [1].

The objective of this research seeks to detect people who have Alzheimer's disease from healthy controls using a methodological framework termed multi-modal imaging and multi-level features with multi-classifier (M3). This method comprised the analysis of data from structural MRI as well as resting-state functional MRI, two imaging modalities. Utilizing leave-one-out cross-validation, the method's effectiveness was assessed. Using the M3 technique, classification accuracy was 89.47%, sensitivity was 87.50%, and specificity was 90.91% for the dataset of 16 AD patients and 22 healthy controls. Further investigation showed that the default-mode (medial frontal gyrus, posterior cingulate gyrus, hippocampus, alongside parahippocampal gyrus), occipital (fusiform gyrus, inferior as well as middle occipital gyrus), and subcortical (amygdale and pallidum of lenticular nucleus) zones are primarily engaged among the most discriminating characteristics for classification.The classification output of the M3 approach is encouraging [2].

In contrast to age-matched healthy participants, Alzheimer's disease patients' EEGs are "slower" (i.e., include more low-frequency power) and less complicated, according to medical research. These two occurrences' relationship has not yet been investigated, and it is frequently tacitly believed that they are independent of one another. This research demonstrates the close connection between the two phenomena. Two distinct EEG datasets, one with moderate cognitive impairment patients along with controls and the other with mild Alzheimer's disease (AD) patients and controls, both convey a powerful association among decreasing in speed as well as complexity. The two data sets came from several hospitals, various patients, and various recording methods.The article also looks at the possibility that EEG slowdown and loss of complexity might be early signs of AD. To differentiate MCI and MiAD patients from age-matched control participants, relative power and complexity scores are utilised as characteristics. Classification rates of 83% (MCI) and 98% (MiAD) are being occomplished when two synchrony metrics (synchronisation of stochastic events and Granger causality) are combined. The classification rates are somewhat higher when the compression ratios are included as features compared to just using relative power and synchronisation measurements [3].

This study examines current developments in the use of electroencephalograms (EEG) to detectAD. There have been three main changes in the EEG associated with AD: the EEG slowed down, the EEG signals' complexity was reduced,as well as disturbances in EEG synchronisation. To find these small changes in AD patients' EEGs, a range of advanced computational methods have been presented recently. The study initially discusses techniques for identifying EEG slowness. The paper then discusses several EEG complexity measurements and describes how effective these efforts have been applied to research EEG complexity variations in AD patients.The context of diagnosing AD is therefore taken into account while looking at various EEG synchrony metrics. Additionally, a brief discussion of EEG pre-processing is included. It is required to eliminate artefacts caused by things like head and eye motion or interference from electronic equipment before one can analyse EEG. Pre-processing of EEG has drawn a lot of interest recently. This study describes a number of cutting-edge pre-processing methods, such as blind source separation and various non-linear filtering paradigms. The research also discusses the advantages and disadvantages of computational methods for AD diagnosis based on EEG. Finally, current issues and upcoming difficulties are examined [4].

The neuro-degenerative illness known as Alzheimer's disease includes the most prevalent kind of dementia. It is the most costly illness in contemporary society and is characterised by cognitive, intellectual, and behavioural disruption. As a result, early illness detection is crucial since it enables patients and their families to take preventative actions. EEG is a commonly used diagnostic test for Alzheimer's disease. The EEG signals of AD patients exhibit a number of anomalies. Therefore, it is necessary to create a method for early diagnosis of the disease known as dementia, namely the Mild Cognitive Impairment stage.In recent decades, the role of EEG in the diagnosis and clinical study of Alzheimer's disease has grown in importance. The diagnosis of AD and its early identification in the preclinical stage are now the most crucial tasks. The EEG signal's diagnostic accuracy has to be increased. The concepts for improving the signal's accuracy by utilising various techniques are presented in the study. In simple terms, slowing of the signals, shift of power spectrum to low frequencies, etc. are characteristics of anomalies in the EEG signals. EEG can be used in this way to aid in the early detection of Alzheimer disease [5].

3. PROPOSED SYSTEM

In the next 20 years, the prevalence of neuro-degenerative disorders, including Alzheimer's, is anticipated to more than double. Neurofibrillary tangles, senile plaques, and extensive neuronal cell death in the hippocampal, entorhinal cortex, neocortex, as well as other brain areas are its hallmarks. There are no reliable and legitimate symptoms found in the pre-clinical stage that would permit a very early diagnosis. In the middle level, linguistic challenges including paraphasia and trouble finding the right words increase. Cognitive deficiencies in skills like judgment, abstract or logical thinking, planning, and organising are among those discovered as the disease progresses.One of the variables influencing when Alzheimer's illness first appears is air pollution. In both the Mild AD & MCI stages, early illness identification is crucial since drugs may be started at a young age. Alzheimer's illness has been identification involves the use of several clinical approaches, including genetic testing, physiological indicators, and neuroimaging procedures. One of the most used techniques for conclusively diagnosing dementia is neuroimaging, although it comes with radiation dangers.

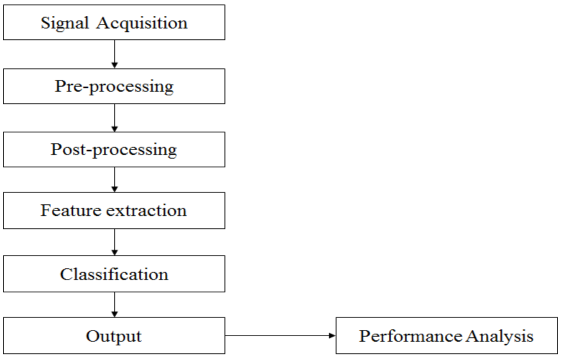

Fig 1: System Architecture

In this study, we propose that default brain variables (also known as latent factors) exist across participants in illness processes, and that decoding latent factor from brain activity aids in the investigation of cognitive impairment. In order to achieve illness detection, according to this report, to extract features of Alzheimer's disease by combining latent variables of EEG with variational auto-encoder. First, power spectrum characteristics are examined, and it is discovered that two groups have distinct dominating frequencies. Further investigation demonstrates that the theta frequency band exhibits obvious discrepancies between the latent factor distribution of Alzheimer's disease and the normal group. Additionally, the transient rotation of the neural state is discovered when the latent components are mapped onto the three-dimensional state space, demonstrating the dynamic properties of the latent factors.Following is a list of the several benefits of the suggested approach:

- Peak signal that can be accurately recovered from an EEG signal, even one that is extremely noisy.
- Our EEG simulator's key benefits include time savings and the elimination of risks while recording the EEG using non-invasive techniques.

Social demands

- The AD is simple to diagnose.
- Because it does not require an external device, it can be detected early in the preclinical stage.
- It is trustworthy to utilise.

The next section provides an explanation of the many phases that are involved in putting the suggested technique into practise:

1. Input Signal

For the purpose of capturing the electrical activity of the brain, electroencephalography (EEG), a method of electrophysiological monitoring, is utilised. It gauges voltage fluctuations caused by ionic current flowing through the brain's neurons. The sort of brain oscillations that may be seen in EEG data is called spectral content, and it is used in diagnostic applications. The most frequent diagnoses made using EEG are those for epilepsy, sleep issues, comas, encephalopathies, even brain death. However, with the development of high-resolution anatomical imaging methods like computed tomography along with magnetic resonance imaging, its application has declined.

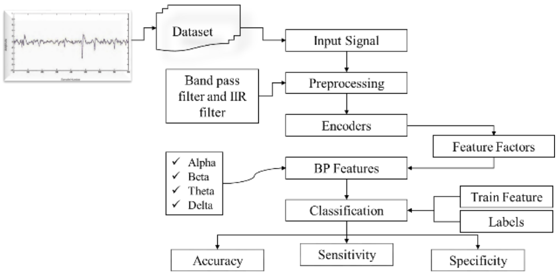

Fig 2: Flow Diagram

2. Preprocessing

Amplification, filtering, and artefact elimination are all part of the pre-processing of the EEG signal. Several methods, like Independent Component Analysis (ICA) along with Blind Source Separation (BSS), are employed to generate an EEG signal that is more improved. Assuming that each subcomponent is statistically independent from the others but non-Gaussian, ICA is a computer technique for decomposing a multivariate signal into additive subcomponents. Blind ICA separation of a mixed signal produces excellent outcomes when the statistical independence condition is true.

3. Feature Extraction

By creating derived values (features) from a starting set of measured data, a feature extraction procedure is carried out. High-level feature extraction is concerned with the mean, standard deviation, and entropy values, whereas low-level feature extraction is focused on the edges. The standard deviation is calculated using power rather than amplitude, whereas the mean value is the average value of a signal. A parametric vector, a discrete spectral density estimate, or a specific digital signal segment can all be used to calculate the entropy value from a finite collection of values.

4. Classification: *(SVM)*

Guided learning models and learning algorithms called Support Vector Machines look at the data utilised in regression and classification research. SVMs are built on the idea of decision planes, which distinguish between a collections of objects with various class memberships. In order to distinguish between different objects inside an image, classification of remotely sensed data is utilised to assign matching levels with regard to groups with homogenous features. SVMs are supervised learning models that analyse data used for regression along with classification analysis. They also include related learning methods.An SVM model is a mapping of the instances as points

eISSN1303-5150

in space with as much space between the examples of the various categories as feasible. The kernel trick allows SVMs to do non-linear classification as along with linear classification via implicitly transforming their inputs into high-dimensional feature spaces.

4. RESULTS

This study suggests a novel way for identifying Alzheimer's disease using EEG signals that improves the reliability of the diagnosis. The suggested technique combines variational auto-encoder with latent EEG variables to achieve illness detection. Investigations into power spectrum features reveal that the dominating frequency of two groups differs. Further investigation demonstrates that the theta frequency band exhibits obvious discrepancies between the latent factor distribution of AD and the normal group. The last step is to determine if the signal is normal or abnormal using the SVM classifier and to identify characteristics throughout the process using wavelet features, as illustrated in the photos below.

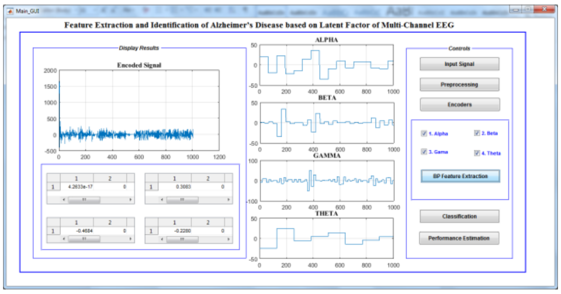

Fig 3: BP Feature Extraction

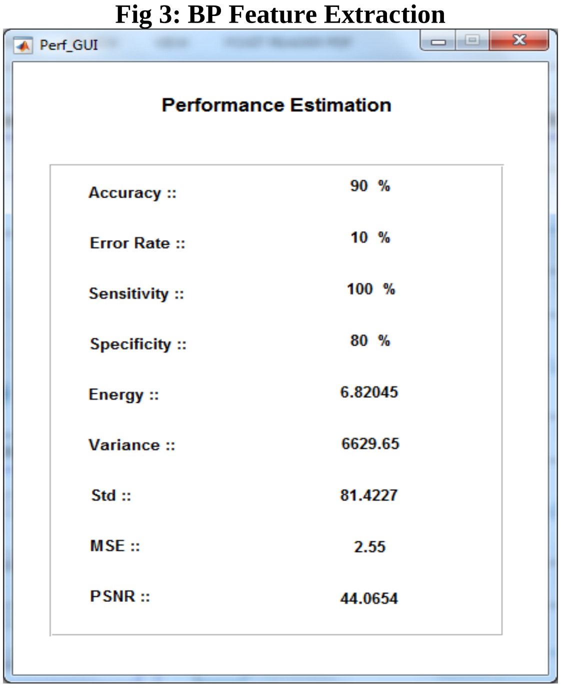

Fig 4: Performance Estimation

5. CONCLUSION

A novel approach for utilising EEG signals to diagnose Alzheimer's disease is suggested in this study, which will improve the diagnostic efficacy of the EEG signals and diagnosis. EEG Spectro-temporal Modulation Energy Based aspects, Spectral Features, Coherence Features, and other aspects of EEG Signals are examined in detail. It may be inferred from the properties of the EEG signal that were previously mentioned that It may be helpful for the diagnosis of dementia as well as Alzheimer's disease. Finally, an SVM classifier is used to determine if a signal is normal or abnormal, and wavelet characteristics are also used to identify features during the process.

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