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CLASSIFYING ELECTROENCEPHALOGRAM (EEG) SIGNALS FOR ACCURATE MENTAL DISORDER ANALYSIS

Shikha Lakra
M.Tech Scholar
Department of Microelectronics and VLSI
University Teaching Department (CSVTU), Bhilai, Chhattisgarh, India.

Dr.Shivangi Chandrakra
Assistant Professor
Department of Microelectronics and VLSI
University Teaching Department (CSVTU), Bhilai, Chhattisgarh, India.

Abstract— **Electroencephalogram (EEG) is a powerful tool for analysis of brain signals. The variation in pattern of EEG signals are useful in computing the mental disorders. In this presented work, the main aim is to study and analyze the techniques available for EEG signal classification. Additionally, contribute a deep learning based technique for accurately predict the mental health. This document discusses the over need of the proposed work, the problem domain and the proposed solution strategy. Additionally, the expected outcome and required tools and techniques have also been discussed.**

Keywords— **Deep Learning, EEG signal classification, Machine learning, Mental health recognition.**

I. INTRODUCTION

The world is rapidly changing and human life style is also changing accordingly. The change in life style and professional pressure may be a reason of developing mental disorders [1]. In addition, the increasing rate of increment of mental disorders are critical public health challenge, because it is a leading global burden of disease. The World Health Organization (WHO) is also concerned on this issue and predicted, mental disorders shall be the first cause of disability [2]. In health care industry, psychoanalysis is still facing two problems: (1) a classification of mental disorders (2) the clinical symptoms are mostly incomplete [3]. Therefore, it is required to develop new ways of diagnosing mental diseases. In recent years Machine Learning (ML), Deep Learning and Artificial Intelligence (AI) are playing a key role in the field of medical diagnosis revolution. These approaches are also help us to advance our understanding and care of mental health. These methods can be use for improving precise diagnosis, developing treatments, and assisting the doctor and patients.

The available automatic recognition of mental states and disorders detection techniques focused on Functional Magnetic Resonance Imaging (fMRI) [4], visual cues [5], and social network analysis [6]. In addition recent years, Electroencephalogram (EEG) analysis based techniques have also been widely adopted. These research efforts are mainly aimed at developing neural networks-based techniques for EEG signals analysis. EEG is an effective tool for capturing the electrical activity of the brain. The analysis of the generated activities is essential for understanding the subject’s emotional states and also various mental disorders. The analysis is based on the concept, where due to the mental disorders, the subject’s body releases cortisol to the brain [7].
The cortisol affects the production of neurons and communication between them. As result, the brain functioning becomes slowing down and also the brain’s electrical activity patterns are also disturbed. The variations of the brain signals from actual flows could help in the diagnosing mental disorders. The development of brain signals analysis methods are challenging because of the unstructured format of signals and high variation. In addition, during the capturing of brain signals the recording can be affected by different types of noise. Therefore, to accurately diagnose the EEG signals the proposed work is aimed to develop a deep learning architecture. This section provide an overview of the proposed and the Next section includes the collection and study of recent literature.

II. LITERATURE SURVEY

The EEG signals contain the potential information to understand the subject’s mental and emotional states. Therefore, the EEG signal analysis has been done in mental health identification and also in emotion recognition. In order to understand the process of automatic EEG signal analysis and classification, a review have been performed. The review includes the recent contributions focused on EEG signal analysis for mental health diagnosis and based on Deep learning techniques. Based on the considered articles in the review, a list of abbreviations have been developed and reported in Table 1. Additionally, the brief work involved in the articles are discussed in this section.

A. **Rafiei et al [8]** focuses on the automated MDD detection using deep neural network. A customized Inception Time model is developed for this task. The channel-selection is conducted to reduce less potential channels. This method achieved 91.67% accuracy with 19 channels and 87.5% after channel reduction. The find shows: (1) Only one minute EEG signal is sufficient for MDD detection, (2) EEG recorded in resting-state is more informative then eyes-open state, and (3) the Inception Time model can improve its efficiency.

Table 1 List of abbreviations

1	AI	artificial intelligence	11	LNR	linear regression
2	BD	Bipolar Disorder	12	LR	logistic regression
3	CAD	computer-aided diagnosis	13	LSTM	long short-term memory
4	CNN	Convolutional Neural Network	14	MDD	Major depressive disorder
5	dDTF	Direct directed transfer function	15	ML	machine learning
6	ECG	Electrocardiogram	16	PCC	Pearson correlation coefficient
7	EEG	Electroencephalogram	17	RFE	recursive feature elimination
8	GPDC	Generalized Partial Directed Coherence	18	RNN	Recurrent Neural Network
9	GRU	Gated Recurrent Unit	19	SBFS	sequential backward feature selection
10	STFT	Short-Time Fourier Transform	20	SVM	support vector machine

B. Zhang et al [9] the spatial–temporal EEG fusion using neural network is proposed. EEG is a time series signal thus RNN with LSTM unit is used for extracting long-term dependence. Next, the temporal EEG data are mapped into a spatial brain functional network, then features were extracted using 2D CNN. The spatial–temporal EEG features are fused to achieve diversity. The results show that the features fusion can improve the detection accuracy with a highest of 96.33%. In addition, they found that theta, alpha, and full frequency band in brain regions of left frontal, left central, right temporal are closely related to MDD detection, especially theta frequency band in left frontal region.

Y. Li et al [10] present a MDD detection framework. They derive highly MDD-correlated features, calculating the ratio of extracted features at frequency bands between β and α. Then, a two-stage feature selection method named PAR is presented with the combination of PCC and RFE. Finally, we employ widely used ML methods of SVM, LR, and LNR for MDD detection. Results show the accuracy and F1 score are up to 0.9895 and 0.9846. The regression determination coefficient R2 is up to 0.9479. Compared with existing detection methods with the best accuracy of 0.9840 and F1 score of 0.97.

C. Greco et al [11] review related to the EEG-based biomarkers for MDD and its subtypes detection. The PRISMA’s tool is used for this task. The papers’ was selected based on titles and abstracts. After screening relevant articles are included in this review. Markers include EEG frequency bands power, EEG asymmetry, ERP components, non-linear and functional connectivity. Results were discussed to the different EEG measures. Findings confirmed the effectiveness of the measures can classify healthy and depressed subjects. The review highlights the link between EEG measures and depressive subtypes and points out some issues to be solved.

H. W. Loh et al [12] proposed a deep learning model based on CNN. First, STFT is applied to the EEG signals to obtain spectrogram images of patients and healthy subjects. These spectrogram images are then fed to the CNN model for detection of MDD patients. The EEG signals were obtained from public database with 34 patients and 30 healthy subjects. The highest classification accuracy, precision, sensitivity, specificity, and F1-score of 99.58%, 99.40%, 99.70%, 99.48%, and 99.55%. This model is highly accurate and validated with diverse MDD database before it can be used in clinical settings. They plan to use developed prototype to detect depression using other physiological signals like ECG and speech signals.

EEG signals offer a signature for MDD and BD. **S. Yasin et al [13]** focus on the literature works adopting neural networks fed by EEG signals. Among those studies, authors discussed a variety of EEG based protocols, biomarkers and public datasets for MDD and BD detection. They also discuss and recommend to improve the reliability of models and for more accurate and more deterministic computational intelligence.

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This review will provide structured and valuable point for the researchers working on depression and bipolar disorders.

Early discovery of mental disorders helps to cure or limit its effect. **A. Saeedi et al [14]** proposed an EEG-based deep learning system to classify MDD patients. First, the relationships among EEG channels in terms of brain connectivity has been extracted. Next, sixteen connectivity methods was used to create an image. These images are applied on five deep learning architectures. These architectures are based on 1D-CNN, 2D CNN and LSTM. This architectures learn patterns in the constructed images. The efficiency of the algorithms is evaluated on resting state EEG data. The experiments show the 1DCNN-LSTM applied on constructed image achieves best results with accuracy of 99.24%.

MDD is diagnosis using questionnaires may not an accurate method. **R. A. Movahed et al [15]** proposes a framework for MDD analysis using different types of EEG features. These features are obtained by different methods like statistical, spectral, wavelet, connectivity, and nonlinear analysis. The SBFS algorithm is used here for feature selection additionally different classifier are used to select the best for the system. This method is validated on a public EEG dataset. The SVM with RBF kernel provides best performance AC of 99%, SE of 98.4%, SP of 99.6%, F1 of 98.9%, and FDR of 0.4% using the.

Table 2 Literature summary

Ref	**Paper type**	**Domain**	**Methods**	**Dataset**
[1]	Implementation	automated detection of MDD using EEG data	Deep learning	19-channel EEG signals
[2]	Implementation	spatial–temporal EEG fusion framework	RNN and LSTM	-
[3]	Implementation	detection of MDD using EEG data	SVM, LR, and LNR for MDD	-
[4]	Review	EEG-based biomarkers for MDD and its subtypes	-	-
[5]	Implementation	MDD detection system developed using deep learning	CNN, spectrogram images, STFT	Data of 34 MDD patients and 30 healthy subjects
[6]	Review	neural networks fed by EEG signals	Neural Network	-
[7]	Implementation	MDD detection system developed using deep learning	1D-CNN, 2D-CNN and LSTM	resting state EEG data 34 MDD patients and 30 healthy subjects
[8]	Implementation	ML framework for MDD diagnosis	SBFS algorithm, SVM with RBF kernel	34 MDD patients and 30 healthy subjects
[9]	Review	Emotion recognition systems	-	-
[10]	Implementation	predicting depression based on spatiotemporal features	CNN and GRU	Public and self-collected EEG dataset

Emotion recognition systems are important for affective computing. There are a lot of ways to build an emotion recognition system. **M. A. Hasnul et al [16]** focuses on emotion recognition research using ECGs as a part of a multimodal approach. Critical observations of data collection, pre-processing, feature extraction, feature selection and dimensionality reduction, classification, and validation are conducted. They highlights the architectures with accuracy of above 90%. The available ECG databases are also reviewed, and analysis is presented. The benefit of emotion recognition systems in healthcare is also reviewed. Finally, a discussion on the future works is suggested and concluded. Findings are beneficial for researchers, and for identifying gaps in the area in improving healthcare.

The accuracy diagnosing Depression may depend on many factors. Thus, finding a way to identify depression conditions is a critical issue. **W. Liu et al [17]**, proposed a depression prediction system based on spatiotemporal features. EEG signals were de-noised to obtain the power spectra. The spatial positions were mapped to the brainpower spectrum. The brain maps were superimposed on a new brain map. Finally, A CNN and GRU were applied to extract the sequential feature. This strategy was validated with a public EEG dataset, achieving an accuracy of 89.63% and an accuracy of 88.56% with the private dataset.

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III. REVIEW SUMMARY

In this paper, most relevant articles that are based on EEG signal analysis using machine learning have been involved for identifying the mental disorder. In these articles out of 10 articles 7 is based on implementation of MDD detection and 3 papers are review articles. In order to perform classification of signals not only the deep learning techniques are used but traditional ML algorithms are also utilized. The SVM, LR and LNR algorithms are traditional algorithms which are used for classification. In addition, the deep learning architecture LSTM is used for extracting long term signal dependence from the EEG signals. Moreover, the CNN architectures are used for extracting deep features as well as classify them more accurately. These facts are also highlighted using the Table 2.
In addition, the results of the methods implemented in literature is also compared using bar graph as given in Figure 1. The X-axis of the diagram shows the methods used for comparison and Y axis shows the percentage accuracy of the model. According to the comparison models [2], [5], [7], and [8] is providing higher accuracy as compared to the other models. These models are able to provide the correct classification up to 99.58%. These methods are tested or validated on the same dataset. The dataset contains 34 patient data and 30 healthy person's data. In addition, the highest classification accuracy is obtained with CNN and spectrogram images. Thus deep learning techniques are more suitable for EEG signal classification. This section is providing the key insights and comparison of the considered methods in this review. The next section, includes the key issues identified and the relevant solution for accurate EEG signal classification and mental disorder detection.

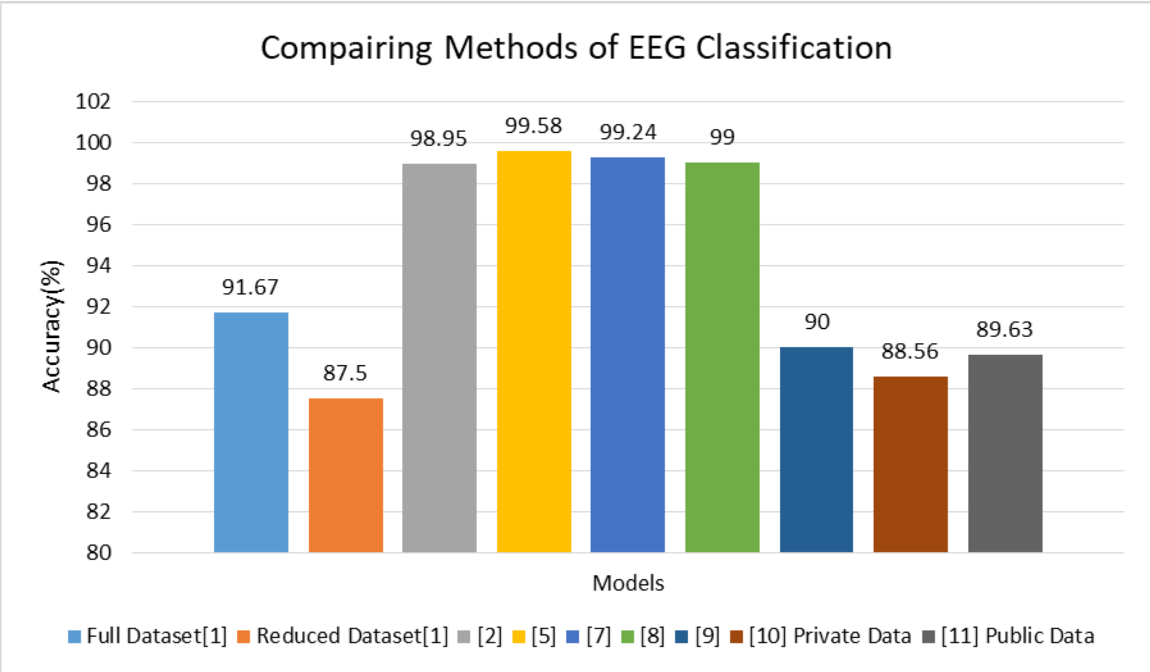

Fig. 1. Comparative Accuracy of EEG classification Techniques

IV. PROPOSED WORK

The clinical and questioner based techniques are not much accurate for mental disorder detection. Therefore, researchers are now these days utilizing EEG signal analysis for diagnosing the mental disorder and its subtypes. The methods that are able to extract most relevant features from EEG signals may provide more accurate analysis. Therefore, the effective EEG signal's feature extraction techniques are helpful in detecting depressive states at early stages to prevent the worsening of the symptoms. Therefore, the proposed work is involving a ML model for effective of EEG-based technique for discriminating between depressed and healthy subjects. The overview of the proposed model for EEG signal classification is demonstrated in figure 2.
The first component of the proposed model is EEG signal database. This database is a historic record of EEG signals for healthy and patient's EEG signals. In this presented work the dataset obtained from Kaggle [18] has been used for performing the experiments. The considered dataset is known as EEG Brainwave Dataset: Feeling Emotions. The data was collected from two people 1 male and 1 female for 3 minutes per state. Three emotions positive, neutral, and negative have been considered. The Muse EEG headband is used to record the EEG signals. Six minutes of resting neutral data is also involved in this dataset. The dataset samples are used with the

preprocessing techniques for optimizing the data quality and reducing the noise from the EEG signals. Next, the preprocessed EEG signals are used with the feature extraction techniques for identifying the key insights form the raw signals. In traditional machine learning based data analysis the separate techniques of feature selection was used. But, in deep learning techniques the neural network extract the features self from the input data and then the extracted features are learned. These features are known as deep features. Sometimes, for extracting the deep features the pre-trained networks are also used. In this presented work the deep learning techniques are proposed to utilize in designing the EEG signal processing technique. Therefore, the preprocessed data is further split into two parts i.e. training and validation set. The training part of data is total of 80% of the entire samples additionally the 20% of samples are used as validation set. The training samples are used with the proposed deep learning architecture, which is configured in our future studies and the validation of the proposed models is proposed to perform. During the validation of the model, the metal health of the subject has been predicted and performance in terms of precision, recall, f-score and accuracy. This section is providing the overview of the proposed EEG signal classification model. The next section is providing conclusion of this paper.

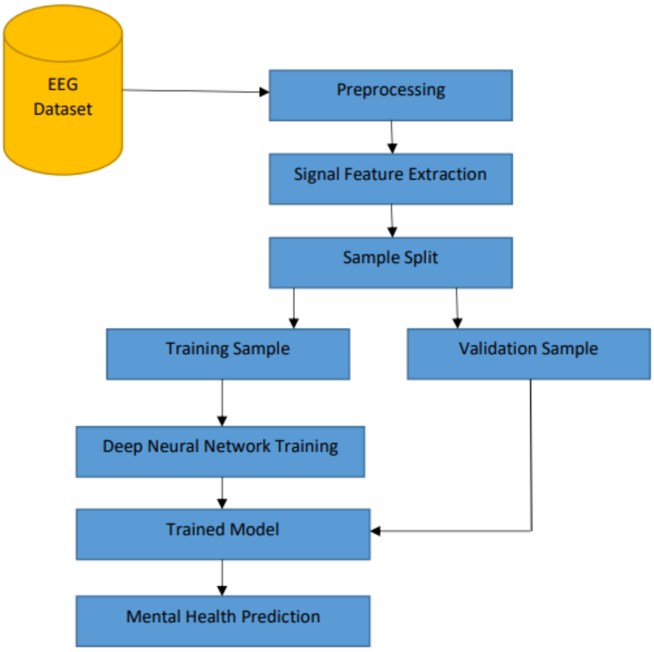

Fig. 2 Proposed EEG signal classification technique

V. CONCLUSION

The EEG is a popular and proven technique for recording the brain activity. The analysis of EEG signals provide very useful insights about mental health, emotion state, mental disorders, etc. Therefore, the study and automatic analysis of EEG signal is very useful for medical and health industry. In this paper, a review of recently developed deep learning techniques has been performed for analyzing and classifying the EEG signals. A total of 10 research paper has been analyzed among 7 are based on implementation and 3 are based on review. These paper is analyzed first and key abbreviations have been collected and studied. Next, a brief overview of these articles have been performed. Further, the summary of the collected literature has been described using table and comparison of performance is given in terms of bar graph. The bar graphs are indicating some techniques are available which can provide the accuracy up to 99%. Further based on the experiences gain from the literature survey a machine learning techniques has been presented and the details about the components used in this ML model explained. In near future, this model is implemented using the python technology and hosted in Google Colab infrastructure. After successful implementation of the proposed model for EEG signal classification system, the following outcomes are expected.

1. A deep learning architecture for accurate classification of EEG signal classification
2. A model for automatic mental disorder detection
3. Study of EEG signal Deep feature extraction techniques

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