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# Machine Learning and EEG in Diagnosing Depression: A Survey

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***Abstract—*** Early diagnosis of depression is considered as critical since this issue can become severe and at its worst, can lead to person's self-harm and also early diagnosis helps in preventing depression rather than treating it. Aim of this paper is to review the mainstreaming of Machine Learning tools in health informatics and focusing on diagnosis of depression based on the data obtained from electroencephalographic (EEG) recordings.

***Keywords- Machine Learning; EEG; Depression; Diagnosis***

## I. INTRODUCTION

Mental disorders in India are one of the major causes of non-fatal diseases. In 2017, about 197.3 million people had mental disorders in India. It comprises depressive conditions of 45.7 million and anxiety disorders of 44.9 million. According to the survey of Global Burden of Disease Study during 1990–2017, there is a significant correlation among the occurrence of depressive disorders and the death rate for suicides. The mental disorder contribution to India's overall DALYs rose from 2.5 percent in 1990 to 4.7 percent in 2017. Depressive disorders added most to overall mental disorders DALYs in 2017 as shown in Figure 1 [1].

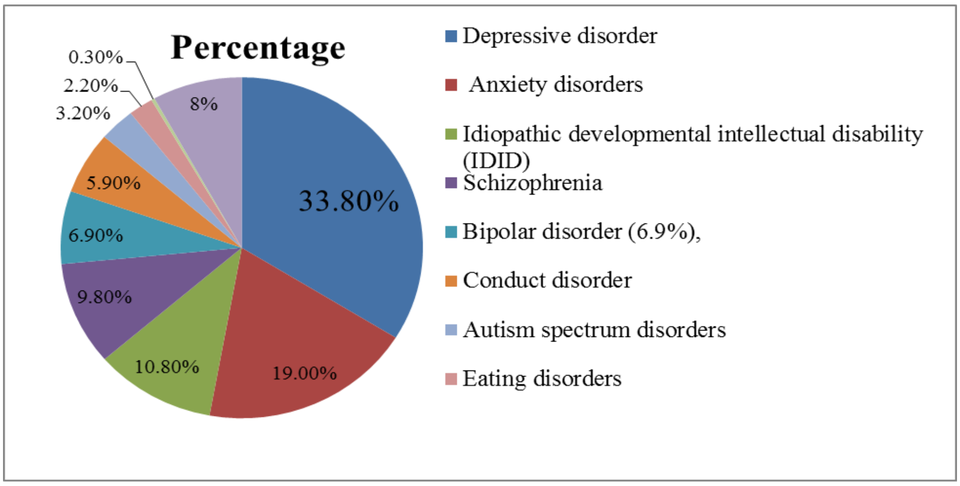


FIGURE: 1: CONTRIBUTION TO DALYS WITH VARIOUS MENTAL DISORDERS IN 2017.

Depression is characterized as a low mood state, missing confidence or enjoyment, guilt feeling or low self-worth, disturbed sleep or appetite, low energy and poor concentration. This issue may become recurring and create serious deficiencies in a person's ability to take care of his/her day-to-day activities. Depression at its worst, can lead to suicide. This tragic death is linked to the loss of about 850 000 lives each year across the globe [2].

Reports on depression have shown that half of patients with depression have not been identified and the majority of patients continue to be undiagnosed over several visits to a primary care physician [3].

Early screenig and early intervensions are needed to prevent the emergence of severe depression, instead of getting treatment for it. Depression is the most aviodable disorder according to the Institute of Medicine (IoM) committee on the preventiom of mental disorder. Thus it is important to recognize and intervene early. Hence early intervention could aviod unnecessary MDD related suffering and chronic illness [4].

Artificial Intelligence (AI) and Machine learning (ML) systems have accomplished (super) human performance in several tasks that were previously considered computationally unachievable. Due to increase in data available and major hardware advancements combined with new optimization algorithms, developments in the field were made [5] [6]. Data mining and machine learning approaches have been progressively used in data analysis in a variety of fields, from medicine to finance, education and energy applications. Machine learning methods enable relevant additional information to be deduced from data extracted through data mining. This valuable and important information helps companies to formulate their strategic plans on a legitimate basis and gain massive time and resource benefits [7].

The classification of psychiatric disorders by incorporating neuroimaging techniques and applications to artificial intelligence is becoming a leading research priority. The application of feature selection (FS) and classification approaches realize the value of biological biomarkers and lead to the clinical and neurologic disorder treatment process [8].

## II. MACHINE LEARNING IN HEALTH INFORMATICS

ML is highly useful in medical information technology, where the majority of problems involve handling ambiguity. Thomas Bayes (1701–1761) laid the theoretical basis for the probabilistic ML. Probabilistic inference has strongly influenced artificial intelligence and statistical learning and the inverse probability enables unknowns to be inferred, data learned and predicted. The use of ML approaches in biomedicine and health will lead to even more evidence-based decision making and personalized medicine approach [9].

There is a vast pool of data collected from daily patient care in many hospitals beyond the conventional recording of vital sign. This big data dilemma typically involves that only limited subsets of data are used for health care monitoring; while machine learning based health informatics technology provide the ability to inform clinical care by fusing Electronic Health Records (EHR) information [10].

Machine learning techniques in screening and analysis and estimation of future events were deployed in research framework as listed in Table I [11].

TABLE I: APPLICATION OF ML IN ANALYSIS AND TREATMENT.

| Investigation and Classification | Estimation and Prediction |
|---|---|
| ***Analysis of Waveform:*** | |
| **Obstetrics:** Intrapartum observation | Cardiovascular risk estimation |
| **Neurology :** Mobile gait monitoring | Breast cancer recovery estimation |
| ***Image analysis:*** | |
| **Pathology :** Lymph node metastases identification in breast cancer | Estimation of colorectal cancer results |
| **Dermatology:** Benign and malignant tumors detection.<br>Fungal infection detection, Skin cancer classification | Survival prediction of non- small cell lung cancer |
| **Ophthalmology :** Diabetic retinopathy classification,.<br>Macular degeneration classification | Hospitalization forecast owing to heart failure |
| **Cardiology :** Acute coronary syndrome diagnosis.<br>Heart attack condition identification | Health treatment usage prediction. |
| **Radiology:** Mammography. Pneumonia identification from chest x-ray | Sepsis diagnosis in intensive care unit, emergency room and on the hospital floor. |
| ***Analysis of electronic health record:*** | Key line estimation of related diseases and morality. |

| | |
|---|---|
| **Inpatient treatment prediction :** Sepsis detection in emergency room, Determining the symptoms of breast cancer Identification in event of a heart attack, Patient phenotype recognition through ICU data review. | Treatment results prediction in social distress |

## III. MACHINE LEARNING AND EEG SIGNAL IN DIAGNOSING DEPRESSION

Despite the complexity of mental health along with the present state of engineering, it is pretty unlikely that one program or machine learning paradigm will be able to include a method that would be effective in all of these circumstances. Favoring concrete use case growth, driven by an awareness of a particular disorder, would likely lead to more successful efforts. To develop methods for realistic usage of mental health treatment needs a thorough knowledge of clinical disorder, the present mental healthcare system, and medical ethics. Hence in order to develop secure, reliable and practical mental health solutions, strong collaboration with domain experts and clinicians would inevitably be needed [12].

Depression is a dynamic therapeutic condition that may provide physicians with difficulties for both accurate diagnosis and successful prompt care. Such problems have triggered the introduction of various machine learning techniques to help improve this condition treatment. These approaches use clinical and physiological observations obtained from Neuro-imaging to build models capable of identifying depressed patients v/s non-depressed patients and forecasting clinical outcomes. [13].

Electroencephalogram (EEG) is a relatively noninvasive diagnostic device that gives information on the physiological and psychological status of the brain and helps to understand its dynamic complexities. EEG impulses are highly nonlinear and non-stationary, with considerable variation in their amplitude from person to person. It is also an essential scientific diagnostic tool for severe neurological disorders [14].

Behshad Hosseinifard et.al used EEG signal obtained from 45 un medicated depressed subjects and 45 controls of different age group in eye closed condition as tool and extracted linear feature such EEG band power and nonlinear feature such as DFA (Detrended Fluctuation analysis), higuchi, correlation dimension and maximum lyapunov exponent and used KNN (K Nearest Neighbors) , LDA (Linear Discriminant Analysis) and LR (Linear Regression) classifiers for classifications and they found good classification accuracy from linear features and LR classifier [15].

U Rajendra Acharya et.al tested a model using EEG signal obtained from left and right half of the brain of 15 control and 15 subjects of age group between 20 to 50 in both eye opened and closed condition for screening of depression using CNN (Convolutional Neural Network) approach, a kind of deep neural network machine learning technique with a conclusion that the EEG signals from the right hemisphere are more distinctive in depression than the EEG signals obtained from the left hemisphere [16].

Hanshu Cai et.al tested the performance of different ML techniques such as Support Vector Machine, K-Nearest Neighbor, Classification Trees, and Artificial Neural Network in diagnosing the depression on the psychiatric data collected by 3 electrode EEG acquisition system at Fp1, Fp2, and Fpz electrode sites of 92 subjects and 121 controls and appreciated KNN accuracy [17].

Yousef Mohammadi et.al proposed a fuzzy function based on a neural network model by analyzing the 19 channel EEG signal obtained from 60 depressed subjects under closed eye condition. Nonlinear features such as fuzzy entropy (FuzzyEn), Katz fractal dimension (KFD) and fuzzy fractal dimension (FFD) are extracted from EEG signal and fuzzy function based on neural network (FFNN) and support vector machine (SVM) classifier are incorporated to discriminate depressed subjects and demonstrated prominent advantage of FFNN over SVM [18].

Shamla Mantri et.al conducted an experiment on EEG data obtained from 8 surface electrodes of 13 control and 12 depressive subjects with the aid of Fast Fourier Transform (FFT) and Support Vector Machine (SVM) and suggested linear method of EEG analysis for depression identification [19].

Manish Sharma et.al proposed an Automated Diagnosis of Depression system using bandwidth-duration localized (BDL) three-channel orthogonal wavelet filter bank (TCOWFB) and EEG signal for the detection of depression. The analysis carried on EEG signal obtained from bipolar channels FP2-T4 (right half) and FP1-T3 (left half) of the brain of 15 subjects and 15 controls. Least square support vector machine (LS-SVM) technique is used for classification [20].

S.Dhananjay Kumar et.al proposed LSTM (Long-short term memory) deep learning model for predicting the trends of depressive levels for the next few instants by analyzing the bipolar channels FP2-T4 (right half) and FP1-T3 (left half) EEG signals of 30 subjects with eyes open and closed states and found less Root Mean Square Error (RMSE) in LSTM compared to CNN-LSTM and ConvLSTM [21].

## IV. SUMMARY AND CONCLUSION

Depression screening is critical as of other physical illness and disorders. Diagnosing of depression is the first step towards getting support. The most difficult task for psychiatrists is to assess suicide risk in patients suffering from depression. In particular psychiatrists are facing a challenge in organizing and extracting the relevant information from the clinical data.

Machine learning is an exciting field with the ability to recognize patterns in data that cannot be identified by humans either visually or through conventional analytical techniques. Table II outlines the different Machine Learning methods on EEG data to diagnose the depression

TABLE II: SUMMARY.

| Author | Data Acquisition | Number of Samples | Machine Learning Techniques | Observations |
|---|---|---|---|---|
| Behshad Hosseinifard et.al [13] | EEG data from 19 surface electrode in rest state ( eye closed) | Subject: 45 Control: 45 | KNN, LDA, LR | LR exhibits 90% accuracy in classification. |
| U Rajendra Acharya et.al [15] | EEG data from bipolar channels in eye opened and closed condition | Subject: 15 Control: 15 | CNN | CNN exhibits 93.5% accuracy in classification |
| Hanshu Cai et.al [16] | EEG data from 3 electrode by applying outside stimulus. | Subject: 92 Control: 121 | SVM, KNN Classification Trees, ANN | Among KNN exhibits 76.98 % accuracy in classification |
| Yousef Mohammadi et.al [17] | EEG data from 19 channel electrode in eye closed state. | Subject: 60 | FFNN, SVM | FFNN exhibits 90 % accuracy in classification |
| Shamla Mantri et [18] | EEG data from8 surface electrode | Subject: 13 Control: 12 | FFT,SVM | SVM and FFT exhibits 84.00% accuracy in classification. |
| Manish Sharma et.al [19] | EEG data from bipolar channels. | Subject: 15 Control: 15 | BDL, TCOWFB, LS-SVM | BDL TCOWFB exhibits 99% accuracy in classification. |
| S.Dhananjay Kumar et.al [20] | EEG data from bipolar channels in eye opened and closed condition | Subject: 30 | LSTM | Found less RMSE value in LSTM |

From the review it can be conclude that there is a vast scope in exploring different machine learning based diagnosing techniques that could incorporate all of the obtained clinical data about a subject in a more quantitative way so that it may helpful to the psychiatric professionals to diagnose the high risk patients and to provide preventive care.

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