International Journal of Modern Developments in Engineering and Science
Volume 1, Issue 9, September 2022
https://www.ijmdes.com | ISSN (Online): 2583-3138

Prediction of Human Emotions by Neural Oscillations

Payal Mahajan[1*], Anjali Gautam[2], P. C. Lisna[3]
[1]Student, School of Advanced Sciences, VIT-AP University, Amaravati, India
[2]Assistant Professor, JK Lakshmipat University, Jaipur, India
[3]Assistant Professor, School of Advanced Sciences, VIT-AP University, Amaravati, India

***Abstract*: Brainwave, better known as neural oscillation is generally a neural oscillation or an electric impulse which is repetitive, often referred to as a rhythmic activity formed due to the interaction between various neurons in the CNS (Central Nervous System). All the neurons sync with the help of pacemaker cells or through the ability of the neurons to quickly sync up which is also referred to as entrainment. Brainwaves can be read using EEG method. Electroencephalography, or EEG, is a method used to measure neural oscillations within the brain. In this method, certain electrodes are placed on the patient's scalp to note the data regarding electrical functioning of neurons in cerebral cortex. EEG identifies the impulses or waves created during the time of a billion neurons being active all together and it also notes the signals from specific places around each electrode. It basically provides a diagram or a graph of electrical activity in the brain represented as waves having different frequency, shape and amplitude. EEG is particularly used to measure brain activity during a particular event like losing a competition, accomplishing something or even feeling sleepy. These types of brain activities are called event-related potential. In this paper we will be predicting emotional sentiments using various machine learning algorithms. We have performed statistical extraction of brainwaves to create a larger dataset that is then reduced to a much smaller dataset by feature selection method for experimentation. In general, we have focused on three sentiments – Positive, negative and neutral. Algorithms like–Logistic Regression (with/without PCA-Principal Component Analysis), Support Vector Machine (SVM), Random Forest, XG Boost have been used and then their predictions are used to get to a conclusion.**

***Keywords*: Neural Oscillation, EEG, Logistic Regression, SVM, Random Forest, XG Boost, PCA.**

1. Introduction

In the whole world, there are different people trying to work on something and make it better for which deep knowledge and better accuracy are the two main keys. There are people – students, teachers, scientists or doctors trying to study EEG waves and understand the way humans behave with regard to the situations provided to them. Using these keys, we have tried to build a model which will predict the emotional state of a person with respect to a particular situation.

EEG waves are oscillation waves and that are used by many researchers to get to a conclusion. In the proposed work, we have used three sets of emotions namely – positive, negative and neutral. We have used a dataset and applied certain machine learning algorithms. The algorithms used in this paper are Logistic Regression, XGBoost, Random Forest, Support Vector Machine Classifier, Artificial Neural Network and calculated their accuracies and wall time at the end to compare them and find a conclusion.

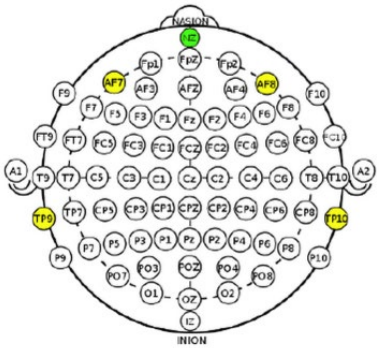

Fig. 1. EEG sensors headband

This table can used for emotions classification in a human-

Table 1
Emotional classification

Emotional Category	Emotions
A	The feeling of humiliation (Negative)
B	The feeling of disgust (Negative)
C	The feeling of fear (Negative)
D	Feeling happy (Positive)
E	Feeling distressed (Negative)
F	The feeling of surprise (Negative) – Lacking dopamine
G	Feeling anger or rude (Negative)
H	Feeling excited about something (Positive)

They corresponded to a scene which people were shown to mark their emotion and brain wave movement on it. For instance –

Table 2
Example movies and emotions

Movies	Emotions
Desh Drohi	Humiliation, Anger, Shame – Negative
Banjrangi Bhaijaan	Interest, Excitement, Happy – Positive
Rang De Basanti	Anger, Excitement – Neutral
The Haunted House	Scared, Shock – Negative

*Corresponding author: pmahajan70@gmail.com

Just like the above examples, people were shown scenes from various movies, MUSE headband (it is a wearable EEG band used for brain sensing) was used with a resolution of four (TP9, AF7, AF8, TP10) electrodes (these are used to detect the flow of electrons in the brain) and the readings for positive, negative and neutral emotions were recorded and the data was converted into time series data and stored. It was then reduced to smaller datasets by feature selection processes which are Bayes Network, Info Gain etc.

2. Related Work

A lot of people have researched and experimented about EEG data and got conclusions. Some of them are,

(Jordan and Aniko, 2019, UK). The authors used both single and ensemble machine learning methods on a given set of data which had three emotional classes – positive, negative and neutral. They used high performing data mining strategy along with facial EMG signals to classify and get up to 97.89% accuracy. They also used OneRule classification method to show the AF7 electrode's mental state classification. The best single method was neural network (deep neural network in specific) with 94.89% accuracy but Random Forest outperformed it by 2.99% which was 97.89%. Their approaches were OneR, Decision Trees, Naïve Bayes, Support vector Machine, Sequential Minimal Optimisation, Linear regression, Multilayer Perceptron. But the best outcome came from Random Forest method with the Infogain dataset having 97.89% accuracy. (*Jordan and Diego, 2019, UK*). The authors here used EEG statistical features and Artificial Neural Networks to classify EEG data. They performed Multilayer Perceptron (MLP) and Long Short-Term Memory (LSTM). They also applied adaptive boosting method to both methods and then used to find emotional state, attention state and the number of subjects one was thinking of. Adaptive Boosted LSTM shows 84.44%, 97.06%, and 9.94% of respective accuracies on the attention state, emotional state, and number datasets which is better as compared to Adaptive Boosted MLP. Their approaches were Multilayer Perceptron (ANN) and Long Short-Term Memory (LSTM) along with adaboosting them. The outcome came out to be 1) AdaBoosted LSTM - 84.44% and 97.06% accuracy and AdaBoosted Multilayer Perceptron - 79.7% and 96.23 accuracy. (*Vaishali and Rajesh, 2020)* The authors in this paper have used Modified Differential Entropy method (MD-DE) to extract features from EEG dataset. They have done EEG analysis on their own created dataset called IDEA which was done on 14 different people. They used Bidirectional Long Short-Term Memory (BiLSTM) and MLP to classify the emotional states. They applied these methods on openly available SEED and DEAP datasets too. The y established that MD-DE along with BiLSTM gave the best results. Their approaches were BiLSTM and MLP and the outcome - MD-De (feature extraction) + BiLSTM -88.57% accuracy. (*Taki and Faisal, November 2020, Imperial Open*). The authors in this paper have used PCA for feature extraction and then performed machine learning models on the significant dataset. Their aim was to classify the emotional states into three categories – Positive, Neutral and Negative. After performing various single classification methods, they came to a conclusion that XGBoost algorithm gave the best accuracy with a less time complexity. Their approaches were Linear Support Vector machine, Random Forest, Long Short-Term Memory (LSTM), Logistic Regression, and Extreme Gradient Boosted (XGBoost) classifier, Artificial Neural Network, and the outcome was PCA + XG Boost which gave 99.44% accuracy.

3. Proposed Work and Methodologies

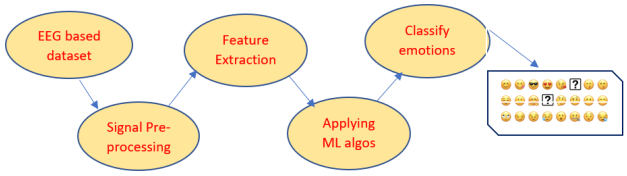

Fig. 2. Process to classify the dataset

Fig. 2 shows the whole process of what steps are taken to classify the dataset and find a conclusion diagrammatically.

There are various machine learning algorithms and processes used in this model. The stepwise procedure we performed were,

1) Data Collection: Data can be collected from Kaggle and accessed through, https://www.kaggle.com/datasets/birdy654/eeg-brainwave-dataset-feeling-emotions?select=emotions.csv
2) Understanding the data dimensions and its attributes.

Table 3
Comparison papers along with their authors, journals and results

S. No.	Paper Title	Authors	Publish Year and Journal	Accuracy/ Conclusion
1	Mental Emotional Sentiment Classification with an EEG-based Brain-machine Interface	Jordan J. Bird, Aniko Ekart, Christopher D. Buckingham, Diego R. Faria	April 2019 Conference: The International Conference on Digital Image & Signal Processing At: Oxford University, UK	Deep Neural Network 94.9%
2	A Deep Evolutionary Approach to Bioinspired Classifier Optimisation for Brain-Machine Interaction	Jordan J. Bird, Diego R. Faria, Luis J. Manso, A. Ekart, Christopher D.B.	August 2019 Conference: The International Conference on Digital Image & Signal Processing At: Oxford University, UK	1) AdaBoosted LSTM - 84.44% and 97.06% 2) AdaBoosted Multilayer Perceptron - 79.7% and 96.23%
3	IDEA: Intellect database for emotion analysis using EEG signal	Vaishali M. Joshi, Rajesh B. Ghongade	October 2020 Journal of King Saud University - Computer and Information Sciences	MD-De (feature extraction) + BiLSTM -88.57%
4	Electroencephalogram (EEG) brainwave signal-based emotion recognition using extreme gradient boosting algorithm	Taki Hasan Rafi, Faisal Farhan, Md. Ziaul Hoque, Mohd Farhan	November 2020 Imperial Open	PCA + XG Boost - 99.44%

3) Understanding and graphing the emotional sentiments each member had.

Fig. 3. 3 Classes of emotions in dataset- Positive, Negative, Neutral

4) Training the model and applying ML Algorithms on the dataset to get a clear vision. The models performed in the paper are,
   a) Random Forest Classifier – It is a machine learning algorithm which is an ensemble classifier following bagging and tree approach. It contains many decision trees containing result of different subsets of the dataset and then averages it and forms a conclusive result. The algorithm used here is,
      1. You are given a training set and you have to select k random data points.
      2. Building subsets or number of decision trees according to the chosen data points.
      3. Define the number of decision trees you want to build as n.
      4. Repeating step 1 and 2.
      5. Find accuracies of each selected decision tree and whichever wins will give them with new data points.

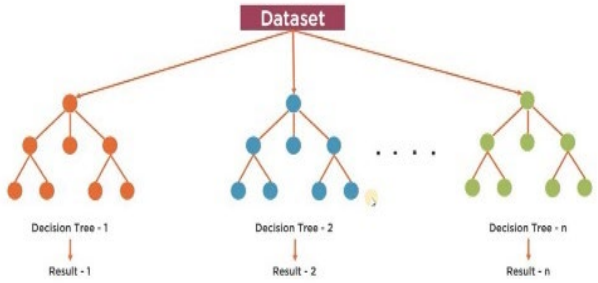

Fig. 4. Random Forest

   b) Logistic Regression Classifier – It is nothing but a supervised machine learning algorithm which is very simple to understand. LR is used to predict the probability of dependent variable whose nature can be only two classes. It is used for classification problems.

We have used PCA (Principal Component Analysis) to reduce number of required variables where all co-linear variables get clubbed together. The assumptions made for logistic regression are-

A 1-The predicted outcomes should be binary (which can mean it is binary logistic regression).

A 2- The independent variable which influence the outcome must be independent of each other too.

A 3- Independent variables can be linearly related to the odd factors.

A 4- Take large sample sizes to apply logistic regression.

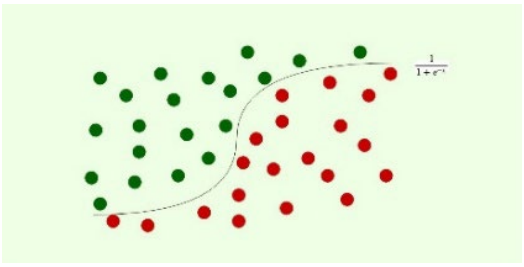

Fig. 5. Logistic Regression

In Logistic regression, we have used PCA. Steps to perform PCA,

- Step 1: Get the dataset and divide into training and testing dataset.
- Step 2: We will represent our data into a structure like matrix where rows are data items and columns are dimensions of dataset.
- Step 3: Now we will standardise our data like selecting high variance over low variance. Then we will divide each point with the standard deviation of its column and form a new matrix M.
- Step 4: Calculating the total variance and transposing the final matrix and multiplying it my M. The final matrix will be the covariance of M.
- Step 5: Finding Eigen values and Eigen vectors of M matrix.
- Step 6: We sorted the eigen values in decreasing order. The final matrix is lets say called R.
- Step 7: We will now multiply both formed new matrices and calculate new features which are all independent of each other.
- Step 8: We will now remove all un important features.

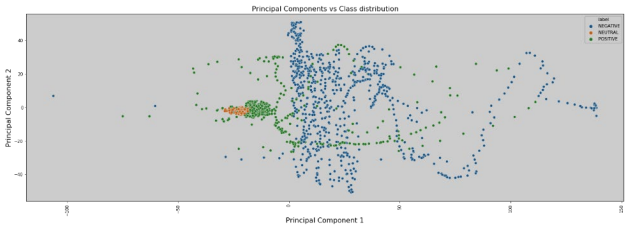

Fig. 6. Principal component analysis of the dataset

   c) Artificial Neural Network Classifier- It is a classification technique which contains a connection of input and output layer network where each connection has weight. The ANN algorithm works as,

- Step 1: We will find information to the input layer. We will transfer the information to the hidden layers

present in the network.

- Step 2: The inner connection between both the input layer and hidden layer adds weight to each input randomly at the starting point and then the bias is added to each neuron.
- Step 3: The weighted sum is a combination of the weights and bias of each neuron.
- Step 4: Its then passed through an activation function which has the power of feature extracting and then output is calculated. It's called Forward Propagation.
- Step 5: The final step is to calculate the error by comparing output with original given output. After error calculation, model weight is finally updated.

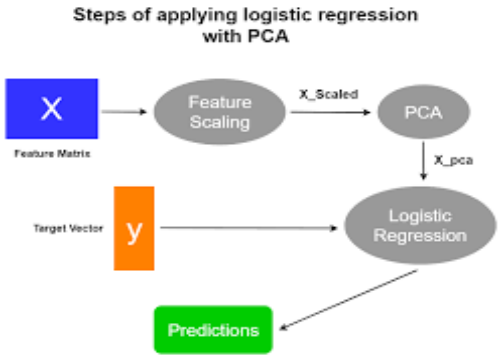

Fig. 7. Logistic Regression with PCA

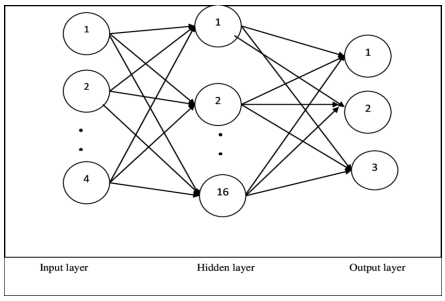

Fig. 8. ANN classifier

d) Support Vector Machine Classifier- It is a classification technique used to transform data and find and optimal boundary between all possible outputs. The important terms in SVM includes,

- Support Vectors – These are the datapoints are very close to the hyper plane.
- Hyperplane – It is nothing but a decision plane which helps in dividing a set of points/objects in diverse classes.
- Margin – It is the gap between any two lines, which can be calculated by the perpendicular distance of lines and support vector.
- Goal of doing SVM – We perform it to divide data points into two different classes by finding a hyperplane.

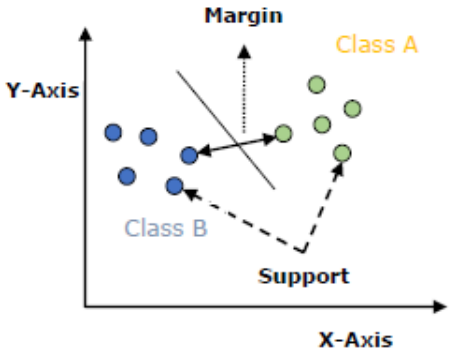

Fig. 9. SVM

e) XGBoost – It is a gradient boosting decision tree which is scalable and used for regression and classification problems for ranking purposes. It automatically reduces the feature set. Features of XG boost include,

- Regularized Learning – It helps us to escape over fitting by smoothing the final weights.
- Gradient Tree Boosting – Here we train the model by using the additive manner.
- Column Subsampling and Shrinkage – These two are the other techniques to avoid over-fitting in a given sample.

Fig. 10. XGBoost

5) Finding accuracies of all the algorithms and finding a conclusion based on the received percentage and wall time it requires.

4. Experiments and Results

We have used 7 different machine learning algorithms and compared them with the found accuracies and wall time to confer how fast we can predict emotional sentiments using brainwave readings.

Accuracies of any given model are the percentages of the correct predictions for the test data. It can be used to determine which model is the best by looking at the various patterns formed in training data or input.

Wall time is the total time taken for any specific programme to be executed and successfully completed. It includes both CPU time and System time.

The following graph and table are made from the observations gathered during experimenting.

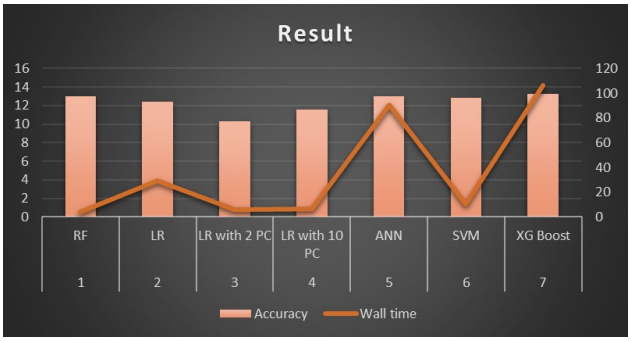

Fig. 11. Result

Table 4
Algorithms used and their results

S.No	Machine Learning Algorithm	Accuracy	Wall Time
1	Random Forest Classifier	97.79%	5.01 s
2	Logistic Regression Classifier	93.19%	3 min 9 s
3	Logistic Regression Classifier with 2 PCs	77.52%	7.87 s
4	Logistic Regression Classifier with 10 PCS	86.58%	8.89 s
5	ANN Classifier	97.65%	12 min 11 s
6	Support Vector Machine (SVM)	96.43%	1 min 36 s
7	XGBoost	99.43%	14 min 14 s

5. Conclusion

From the result table, we can conclude that according to the accuracies, XGBoost is the best fit algorithm with an accuracy of 99.43% and according to the wall time, Random Forest Classifier takes the least time to complete the task i.e., 5.01 seconds.

This paper explored single methods of classification algorithms on a particular dataset and found a way to represent what a person might feel at that time. The methods we used showed us that an EEG headband machine can be effectively used to know one's emotional state. If we know the emotional states, we can know how to improve mental health systems, human to human interaction and overall assessment of the mental situation of a person.

Declaration

All the authors of this paper declare the they don't have any personal or financial interests in the making of this paper. The paper is not made under any beneficial circumstances.

Acknowledgement

This research paper would not have met it's ends without the help of my professors. Dr. Anjali Gautam, thanks for helping me out through the whole process. Dr. Lisna, thanks for your valuable suggestions and recommendations. This research is highly indebted to both of you. The authors would also like to show their gratitude for the availability of IEEE latex files which were very helpful in the making of this research paper.

References

[1] J. J. Bird, A. Ekart, C. D. Buckingham, D. R. Faria, "Mental Emotional Sentiment Classification with an EEG-based Brain-machine Interface", The International Conference on Digital Image & Signal Processing, Oxford University, UK, April 2019.

[2] M. A. Lujan, M. V. Jimeno, J. M. Sotos, J. J. Ricarto, A. L. Borja, "A Survey on EEG Signal Processing Techniques and Machine Learning: Applications to the Neurofeedback of Autobiographical Memory Deficits in Schizophrenia", Electronics 2021, 10(23), 3037, December 2021.

[3] V. M. Joshi, R. B. Ghongade, "IDEA: Intellect database for emotion analysis using EEG signal", Journal of King Saud University - Computer and Information Sciences 34(7), October 2020.

[4] J. J. Bird, D. R. Faria, L. J. Manso, P. P S Ayrosa, A. Ekart, "A study on CNN image classification of EEG signals represented in 2D and 3D", J Neural Eng 2021 Feb 25;18(2).

[5] M. M. Moazzami, "EEG signal processing in brain–computer interface", Michigan State University, 2012.

[6] M. A. Bell, K. Cuevas, "Using EEG to Study Cognitive Development: Issues and Practices", PMC 2013 Jul 10.

[7] N. Yildirim, A. Varol, "A research on estimation of emotion using EEG signals and brain computer interfaces", International Conference on Computer Science and Engineering (UBMK), October 2017.

[8] S. D. Puthankattil, P. Joseph, U R. Acharya, C. M. Lim, "EEG signal analysis: a survey", Journal of Medical Systems 34(2), April 2010.

[9] L. T. Trujillo, C. T. Stanfield, R. D. Vela, "The Effect of Electroencephalogram (EEG) Reference Choice on Information-Theoretic Measures of the Complexity and Integration of EEG Signals", Front. Neurosci., Sec. Brain Imaging Methods, 25 July 2017.

[10] P. Ma, Q. Gao, "EEG Signal and Feature Interaction Modeling-Based Eye Behavior Prediction Research", Computational and Mathematical Methods in Medicine, Vol 20, May 2020.

[11] I. P., F. B. B., "A Detailed Analysis of EEG Signal Processing in E-healthcare Applications and Challenges", International Journal of Innovative Research in Science Engineering and Technology 10(1):635, January 2021.

[12] C. T. lin, C. S. Huang, W. Y. Yung, A. K. Singh, C. H. Chuang, Y. K. Wang, "Real-Time EEG Signal Enhancement Using Canonical Correlation Analysis and Gaussian Mixture Clustering", Hindawi, Journal of Healthcare and Engineering, vol. 2018, January 2018.

[13] K. Varbu, N. Muhammad, Y. Muhammad, "Past, Present, and Future of EEG-Based BCI Applications", Sensors 2022, 22, 3331.

[14] S. Gupta, J. K. Bhatti, "Pre-processing, Feature Extraction and Classification of EEG signals for Brain Computer Interface", Journal of Emerging Technologies and Innovative Research", Volume 4 Issue 5 May-2017.

[15] K. P. Thomas, N. Robinson, K. G. Smitha, A. P. Vinod, "EEG-based Discriminative Features During Hand Movement Execution and Imagination", 15th International Conference on Control, Automation, Robotics and Vision (ICARCV), November 2018.