

Comparative Analysis of Existing Machine Learning and Deep Learning Algorithms for Emotion Classification using Valence-Arousal Model

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Abstract - The Electroencephalogram (EEG) signal- based emotion classification has become an important field in affective computing, and it has been applied to healthcare, education, gaming and adaptive human- computer interaction. The given paper entails a full comparative study of existing machine learning traditional algorithms in the field of recognition of emotions including Valence-Arousal model. EEG signals of standard datasets undergo extensive pre- processing stages such as filtering, segmentation, and elimination of artifact. Machine learning traditional algorithms are compared which includes SVM, k-NN, Random Forest and some basic deep learning models such as CNN, LSTM are evaluated. Findings indicate that the proposed deep learning models (CNN, LSTM) performs well than existing machine learning algorithms because it boosts the robustness of features and high classification accuracy, which is a sign that it is useful in real time and scalable affective computing systems.

Keywords - Affective computing, EEG Signals, Emotion Classification, Machine Learning, Valence- Arousal Model

I. INTRODUCTION

Human emotion is becoming an even more important topic in the online world where interaction between humans and computers is a central element of applications in fields such as healthcare and education, as well as marketing and games. Emotions do not only control the behavior of human beings but also affect the way they make decisions, memory and learning. Here affective computing a research area that seeks to identify, analyze and model human emotions with the help of computational systems has become a promising research topic.

The suggested study is devoted to the arrangement of human feelings based on a Machine Learning methodology based on the Valence- Arousal(V-A) model and Electroencephalogram (EEG) signals [5]. Valence- Arousal model is a popular dimensional model which categorizes the emotions using two variables Valence (pleasantness) and Arousal(intensity). Happiness, anger, and calmness among others can be placed on this 2D plane where a more continuous and all -encompassing analysis can be conducted as opposed to

categorical models.

Conversely, EEG is a form of capturing the electric activity of the mind and has been found to be a data rich in terms of neural correlates of emotional states. EEG provides a high - temporal-resolution data in real time, thus it is perfect input to the emotion recognition systems. The combination of machine learning method and emotion classification based on EEG signals offers a potent machine of decode complex emotion conditions. The classical methods such as k- NN, SVM, and decision trees and more complex methods such as deep learning (CNN,

RNN) [2] [3] [13], have demonstrated potential in classifying EEG data along the emotional dimensions.

This study will address different machine-learning models and deep-learning models that successfully projects EEG features onto the Valence-Arousal space, with the aim of enhancing both accuracy of human recognition and practical usefulness of such a model.

The potential uses of this study are enormous, as the idea of emotion-sensitive virtual assistants and customized education tools may be used, as well as mental health monitoring and cognitive therapy. Using ML and EEG data within the framework of the V-A Model, this research will make an addition to the existing knowledge in the field of affective computing and human-centered AI systems.

II. BACKGROUND AND RELATED WORK

A. Basics of Machine- Learning

Machine-Learning (ML) is a division of Artificial Intelligence (AI) which permits systems to study and gain experience inevitably, without overt program code. It deals with growth of algorithms capable of accessing data, finding patterns as well as making decisions with minimum human intervention. ML can be broadly divided into 3 categories-

1. Supervised learning
2. Unsupervised learning

3. Reinforcement learning.

In first learning, the model is learned through labelled dataset in order to predict. Unsupervised learning determines unseen patterns or required intrinsic structures of input(given) data. On the other hand, Reinforcement learning allows agents to make choices by interacting with an environment in order to optimize cumulative rewards.

Supervised learning algorithms (Support Vector Machines (SVM), k-Nearest Neighbors (k-NN), Decision Trees, and Random Forests) [1] are usually employed in the framework of emotion classification. These models are trained to project features obtained on physiological signals (like EEG) to the current emotional state. The quality of features and the representativeness of the training data are some of the major factors that determine the success of these models.

B. Introduction to Deep-Learning

Deep-Learning (DL) is a subspeciality of ML and it applies multiple-layered artificial neural networks to represent complex data patterns. In comparison with the traditional ML models, deep-learning is proficient of automatically learning the relevant features of raw data; it is especially applicable to high dimensional and noisy data like EEG signals.

Convolutional Neural Networks (CNNs), are effective in learning spatial hierarchies in data, and Recurrent Neural Networks (RNNs) or Long Short-Term Memory networks (LSTMs) [5] [12] [14], are good at learning sequential or temporal data. These models have performed well in emotion classification tasks and in many cases, they are more accurate and robust than traditional methods.

C. Valence-Arousal (V-A) Model of Emotion Classification

Valence-Arousal (V-A) (Fig. 1) model is a quite popular dimensional model of human feelings. Valence is the positive or negative aspect of a feeling (e.g., joy vs. sadness), whereas arousal is the intensity or the level of activation (e.g., calm vs. excited). The V-A model represents the emotion on a 2D grid, which allows depicting a broad range of emotional conditions.

For example:

- High Valence, High Arousal: Happiness,
- Excitement Low Valence, High Arousal: Anger,
- Fear
- High Valence, Low Arousal: Relaxation, Contentment
- Low Valence, Low Arousal: Sadness, Depression

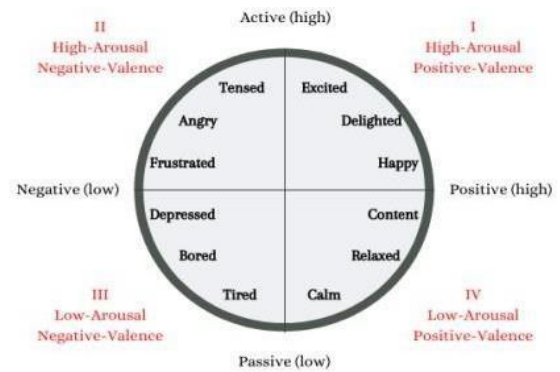


Fig. 1 – Valence-Arousal Model

This model provides a dynamic and subtle perspective of emotions as opposed to discrete categories of emotions (such as six basic emotions by Ekman). It comes in especially handy in situations involving physiological data, when it is possible to create more flexible and comprehensive frameworks of emotion classification.

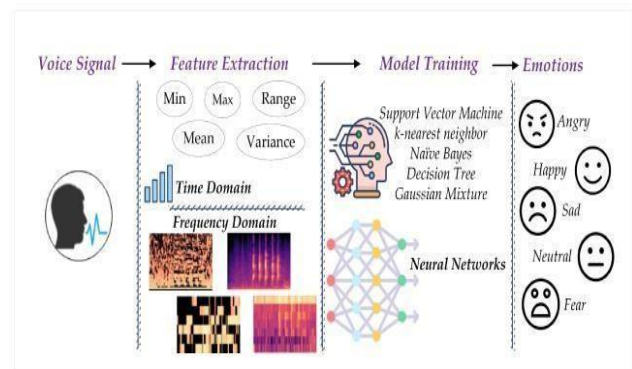


Fig. 2 - Different data patterns for recognizing emotions

D. Machine Learning based Emotion Classification with EEG

Electroencephalogram (EEG) is a non-invasive technique of recording electrical activity of the brain. It offers good time resolution information and it is extensively applied in cognitive neuroscience. EEG signals are detectable in various mental states and they can be used to obtain the neural correlates of emotional experience.

The classification of emotions using EEG is divided into several steps (Fig. 2) [15]:

1. Signal acquisition and preprocessing (e.g., filtering, artifact removal)
2. Feature extraction (e.g., time-frequency analysis, statistical features, entropy)
3. Labeling based on the V-A model

Emotion classification shown in Fig. 3 has potential to be developed in real-time and adaptive settings, especially with more robust ML/DL methods. This study aims at utilizing these technologies to create a strong emotion recognition framework that is precise, effective and interpretable.

To conclude, machine learning, combined with deep learning and EEG signal processing used with in the Valence-Arousal framework is a new and efficient method of classifying human emotions. This cross-disciplinary approach is an interface between neuroscience, artificial intelligence, and affective computing to create systems capable of actually comprehending and reacting to human emotions.

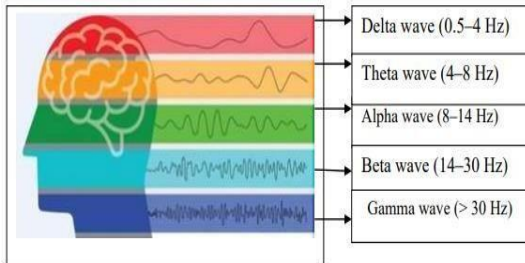


Fig. 3- Classification of EEG Signals

E. Literature review

Research in EEG-based emotion recognition has evolved significantly over the last decade, driven by advancements in machine learning, deep learning, and signal processing.

In summary, while considerable progress has been made in EEG-based emotion classification using ML and DL approaches, key challenges persist in areas such as feature robustness, real-time processing, subject variability, and interpretability. This research proposes to address these gaps by developing an efficient, scalable, and explainable machine learning framework based on the Valence- Arousal model.

S.N.	Author(s)	Model Used	Gap/Deficiency
1	Alarcao & Fonseca (2017)	No Practical Discussion	Survey-based; lacked practical implementation or benchmarking [1]
2	Tripathi et al. (2017)	CNN	Focused on accuracy; lacked explain ability and interpretability [2]
3	Zhang et al. (2018)	CNN+LSTM	Computationally expensive; not suitable for real-time applications [3]

4	Chao et al. (2019)	RGNN	Multichannel fusion complexity not addressed in small-scale datasets [4]
5	Wang et al. (2020)	LSTM	Focused on arousal only; valence mapping was less accurate [5]
6	Yin et al. (2021)	Graph CN	Strong results, but not generalized across multiple datasets [6]
7	Sharma et al. (2022)	Review Paper	Compared classic ML models, lacked hybrid model evaluation [7]
8	Lee et al. (2023)	ACRNN	Lacks benchmarking with traditional ML on same datasets [8]
9	Tripathi et al. (2019)	CNN	Dataset was limited in size and diversity; performance affected [9]
10	Mollahosseini et al. (2017)	--	Focused on facial expression; lacked EEG-based modeling [10]
11	Li et al. (2020)	DGCNN	Limited real-time implementation validation [11]
12	Liu et al. (2022)	LSTM	Requires high computation; graph design sensitive to noise [12]
13	He et al. (2021)	CNN, RNN	Limited generalization across datasets [13]
14	Zhang et al. (2021)	LSTM, SVM, k-NN	High complexity; limited interpretability [14]

Table 1. Literature Work

III. RESULT AND DISCUSSIONS

Using the DEAP dataset, experiments were conducted using classical ML, DL algorithms. Signals from 32 EEG channels were preprocessed, features extracted, and models trained using 10-fold cross-validation. Table 2 gives the performance metrics of Classical ML models such as SVM, k-NN and RF whereas Table 3 gives the performance metrics of Deep Learning models such as CNN and LSTM.

Model	Accuracy	Precision	Recall	F1-Score
SVM	73.4	0.72	0.71	0.71
k-NN	69.2	0.68	0.67	0.67
RF	75.8	0.74	0.73	0.73

Table 2-Performance of Classical ML Models

Model	Accuracy	Precision	Recall	F1-Score
CNN	81.6	0.80	0.79	0.79
LSTM	84.1	0.83	0.82	0.82

Table 3-Performance of Deep Learning Models

The findings suggests that the classical ML Models have a moderate performance on the DEAP dataset, where RF and SVM have the best performance among them. The learning of hierarchical spatial-temporal patterns of the EEG data is a capability of the deep learning models that gives an advantage over classical ML models.

IV. CONCLUSION

The paper is a critical comparison of machine learning and deep learning algorithms on EEG-based emotion classification via V-A Model. The deep learning models improves the performance because it combines multi- domain features. The results advocate the creation of effective, scalable and understandable emotion recognition systems, which are applicable in the fields of human computer interaction, healthcare monitoring and adaptive learning systems. Future efforts involve more hybrid model and real time application and investigation of transformer- based architectures.

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