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Emotion Detection from EEG Signals using Enhanced Deep Learning Techniques

Jayasimmanr, Vasanthm, Anishkumarm, Bhalaji G P, Suganya T

U.G. Student, Department of CSE, SRM TRP Engineering College, Trichy, Tamil Nadu, India

U.G. Student, Department of CSE, SRM TRP Engineering College, Trichy, Tamil Nadu, India

U.G. Student, Department of CSE, SRM TRP Engineering College, Trichy, Tamil Nadu, India

U.G. Student, Department of CSE, SRM TRP Engineering College, Trichy, Tamil Nadu, India

Assistant Professor, Department of CSE, SRM TRP Engineering College, Trichy, Tamil Nadu, India

ABSTRACT: An advanced deep learning framework is intended to be developed for emotion detection from EEG signals, with the goal of enhancing the accuracy and efficiency of brain-computer interface (BCI) applications. Temporal dependency learning and feature extraction are to be improved through the integration of Attention Mechanisms and Transformer Networks with existing Bidirectional Long Short-term Memory Network (Bi-LSTM) and Gated Recurrent Unit (GRU) model

KEYWORDS: EEG (Electroencephalogram), Brain-Computer Interface (BCI), Attention Enhanced Transformer Network (AETN), Bi-LSTM and GRU, Deep learning

I. INTRODUCTION

Emotion plays a crucial role in human cognition, decision-making, and social interaction. With the growing interest in human-computer interaction and affective computing, detecting emotions through brain signals has emerged as a promising area of research. Electroencephalogram (EEG) signals, which reflect the electrical activity of the brain, provide a non-invasive and real-time means of capturing emotional states.

This project aims to develop an efficient and accurate emotion detection system using enhanced deep learning techniques applied to EEG signals. By leveraging advanced neural network architectures such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, the system can learn complex patterns in EEG data and classify different emotional states such as happiness, sadness, anger, and calmness. The project also incorporates preprocessing methods, feature extraction, and optimization strategies to improve classification accuracy and generalization across subjects.

The proposed system has potential applications in mental health monitoring, adaptive learning environments, and next-generation human-computer interfaces.

II. LITERATURE SURVEY

Recent research in EEG-based emotion recognition has shown that traditional systems, which typically utilize shallow machine learning models or basic deep learning architectures like CNNs, LSTMs, and GRUs, face several limitations. These include poor performance in capturing long-term temporal dependencies within EEG signals, lack of attention mechanisms for emphasizing relevant features, and lower accuracy in multi-class emotion classification. Moreover, high computational complexity restricts the feasibility of real-time emotion detection. To address these challenges, recent studies have introduced hybrid deep learning models that integrate advanced components such as attention mechanisms and transformer networks. These enhanced architectures aim to improve the learning of temporal features, boost classification accuracy, and generalize better across datasets. Works such as those by Zhang et al. (2023) and He et al. (2022) highlight the effectiveness of Bi-LSTM and GRU models for EEG signal processing, while others like Mirshekarian et al. (2023) and Li et al. (2023) emphasize the benefits of attention-based transformers in capturing

complex emotional patterns. These advancements mark a shift toward more robust and scalable emotion recognition systems

III. METHODOLOGY

The methodology for this project involves detecting emotions from EEG signals using an advanced deep learning framework. The DEAP dataset is used, containing EEG recordings labeled with emotional states across arousal, valence, dominance, and liking. Preprocessing steps include bandpass filtering (4–45 Hz), artifact removal using ICA, normalization, and segmentation into 3-second overlapping windows. Feature extraction is performed using Fast Fourier Transform (FFT) and Power Spectral Density (PSD), along with statistical features such as mean, variance, skewness, and kurtosis, resulting in a 260-dimensional feature vector. The deep learning model integrates Bi-LSTM and GRU networks with attention mechanisms and a transformer network to enhance temporal pattern learning and improve emotion classification accuracy. Multi-scale feature fusion is also applied to capture both fine and coarse temporal patterns. The system achieves high performance in both binary and multi-class classification tasks, making it suitable for applications in brain-computer interfaces, mental health monitoring, and adaptive AI systems.

IV. EXPERIMENTAL RESULTS

The experimental results of this study show that the proposed approach classifies emotions across arousal, valence, dominance, and liking dimensions with high accuracy. Specifically, the enhanced hybrid architecture achieves higher classification accuracy for both binary (98.2%) and multiclass (94.7%) emotion detection.

V. CONCLUSION

The proposed EEG-based emotion detection system combines advanced deep learning models with effective feature extraction to achieve accurate, robust emotion classification. By integrating AETN with Bi-LSTM and GRU, it enhances temporal learning and pattern recognition, making it suitable for real-world applications in human-computer interaction and healthcare

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