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A Multimodal Systematic Review of Stress Detection in University Students Based on Machine Learning and Physiological Measures

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Abstract— The discovery of stress among university students has come to be a common area of study, particularly due to its long-term implications on cognition and mental health. In this present comprehensive review, we adopt a systematic approach to describe the recent trends in a variety of methods employed for detecting stress. The methods employed are machine learning (ML) and deep learning (DL) methods and physiological parameters as secondary markers of stress. We present the most prominent findings, recognize the existing limitations, and specify the areas of research that need further investigation, based on the information from 20 recent studies in the area. In addition, the review also identifies key limitations in the existing body of literature, most importantly, the requirement for the development of personalized models, integration of real-time monitoring functions, and fusion of heterogeneous data sources, which would be preferable for improving our understanding and regulation of stress.

Keywords— Sentiment Analysis, Stress Detection, Machine Learning, Deep Learning, Physiological Data, Academic Stress, AI-Based Stress Management

I. Introduction

Stress is a regular phenomenon in the life of a student, particularly in university life, where workload and academic pressure have a strong influence on the mental health of an individual [19] [6]. Academic stress has serious psychological and physiological effects on cognitive functions, concentration, and academic performance [10] [17]. With the advent of artificial intelligence, ML and DL models have been suggested to identify stress in students from physiological, behavioural, and textual information [7].

Sentiment analysis can be used to detect stress by analyzing the emotional tone and language used in text, speech, or social media posts [15] [9].

Machine learning-based stress detection exists in two general categories: self-reported survey-based and physiological signal-based. While self-reported data is biased and subjective, physiological signal-based stress detection techniques like electroencephalogram (EEG), photoplethysmogram (PPG), and galvanic skin response (GSR) provide objective data [8] [11]. Different studies have tried hybrid approaches using a combination of a few physiological and behavioural markers for better accuracy [13] [14]. This paper is a comprehensive review of existing stress detection models, their effectiveness, disadvantages, and areas for future work [16] [18].

II. Related Work

The people world is engaged in social media. The discuss various topics and post various opinion. This research

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explains the homophily effect in social media perception analysis [21]. Social media use is a common place in our society. The people express their opinion in social media. There are various methods of analysis on sentiments or opinions. There are various methods for sentiment analysis on social media posts [22]. There are various methods available for sentiment analysis. This study proposed a new method using Genetic algorithm [23]. This study proposed a hybrid method for sentiment analysis. The performance of the suggested model is better than another similar model [24]. This paper discusses the firely algorithm and its usage on sentiment analysis [25]. This paper presented a model based on Explainable artificial intelligence. This model indicates the higher confidence compared to other similar model [26].

Survey of literature provides comparative evaluation of various research studies on machine learning-based stress detection models. The comparison is classified based on research aim, gaps covered, outcomes, limitations, and future implications. Systematic comparison of the studies enables the most efficient methods and their limitations to be identified (Refer to Table 1 & Figure 2 in the Figures & Table Section).

III. Methodology

The research process entails a number of steps, with efficient stress detection using AI algorithms:

- ***a. Data Collection****:* There are various sources of data used to offer overall stress detection. Physiological data includes EEG, PPG, GSR, and HRV, as well as behavioural data such as facial expression, tone of voice, and keystroke behaviour. Sentiment analysis textual data from self-reporting and social media messaging is also used to gauge the intensity of mental stress [20].
- ***b. Data Preprocessing:*** Preprocessing includes noise elimination from physiological data, normalization, and feature extraction to give meaningful data to the model. Irrelevant features or redundant features are removed to refine the training.
- ***c. Feature Extraction:*** For physiological data, EEG features like Alpha, Beta, and Gamma wave patterns are extracted. Heart rate variability is extracted from PPG data, and text sentiment analysis is performed using NLP models to identify signs of stress in written answers.
- ***d. Model Selection and Training:*** Several machine learning algorithms like Support Vector Machines (SVM), Random Forest (RF), and K-Nearest Neighbours (KNN) are used. Supportive deep learning methods like Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and transformer models are also used. Models using these various sources of data have been observed to show improved accuracy in stress detection [12].
- ***e. Evaluation Metrics:*** Performance of the model is evaluated using accuracy, precision, recall, F1-score, and ROC-AUC. These measures help determine the validity of each method in identifying levels of stress in students.

IV. Results and Discussion

Results show that models based on deep learning perform better than conventional machine learning methods in detecting stress. The hybrid CNN-LSTM model achieves the best performance as it can detect both temporal and spatial patterns of physiological signals. The following table shows comparative model performance (Refer to Table 2 in the Figures & Table Section).

V. Conclusion and Future Scope

This extensive review firmly brings into sharp focus and emphasizes the vast advancements made in the field of AI-

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based stress detection, and the advantages and limitations related to the various methodologies being utilized. Stress detection has taken a quantum leap forward with the use of sophisticated machine learning algorithms, but a number of issues related to privacy, computational efficiency, and the nature of real-time processing remain and need to be addressed with caution. The results suggest that hybrid models, which use both physiological and behavioural inputs quite effectively, are likely to provide the most beneficial and desirable results in the context of stress detection.

There is a requirement to think about possible uses of federated learning architectures, which can effectively offer individual privacy as well as data analysis. In addition to this, the integration of wearable devices into this system will enable real-time monitoring of stress levels, thereby enabling real-time measurement of stress. Apart from this, the creation of stress management systems based on artificial intelligence specific to every user's requirement and environment is crucial. In addition to this, the success of cross-cultural cross-validation of divergent data sets will increase overall usability of models for implementation by a large population demographic towards the identification of stress.

VI. Figures And Tables

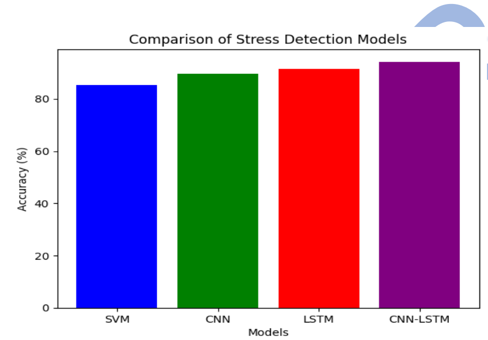

Figure 1. Comparison of stress detection models

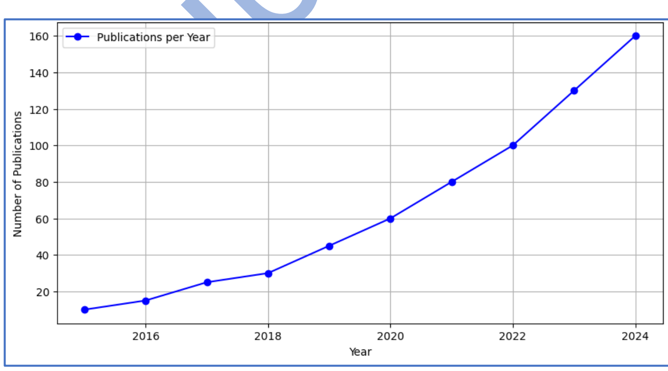

Figure 2. Trend of Stress Detection Research in the Last 10 Years

Table 1. Literature Survey Table

Authors	**Research Objective**	**Problem/Gaps Addressed**	**Findings & Conclusion**	**Limitations & Weaknesses**	**Future Research Suggestions**
Ahuja & Banga (2019) [1]	Machine learning-based stress detection	Limited dataset size	SVM achieved high accuracy but struggled with real-time implementation	Small sample size, limited physiological data	Collecting larger, diverse datasets with real-time analysis
Li et al. (2025) [2]	Deep learning on emotional signals	Lack of real-time stress monitoring	Improved performance in deep learning models	Hardware requirements are expensive	Deploying real-time models for stress monitoring

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Fernandez et al. (2024) [3]	EEG-based stress detection	Subjectivity in self-reported stress data	Effective real-time stress detection using EEG	High computational complexity	Optimization of feature extraction methods
Liu et al. (2024) [4]	Systematic review of academic stress detection	Lack of standardized datasets	Comprehensive comparison of models	Variability in datasets limits comparability	Creation of standard datasets for benchmarking
Ramachandra et al. (2024) [5]	Deep learning model calibration	Need for user-specific data calibration	Improved stress detection with personalized models	Data privacy concerns	Federated learning techniques for privacy-preserving AI models

Table 2. Comparison table of different models

Model	Accuracy (%)	Precision	Recall	F1-Score
SVM	85.2	0.81	0.83	0.82
CNN	89.6	0.87	0.88	0.87
LSTM	91.4	0.90	0.91	0.91
CNN-LSTM	94.2	0.93	0.94	0.93

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