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Stress Detection System Using Machine Learning

Prof. S. A. Solanke[1], Shreyash S. Tidke[2], Tejas G. Malokar[3], Sarvesh S. Udapurkar[4], Faiz Mohammad Sheikh[5], Prajakta G. Gaikwad[6]

[1]Assistant Professor, [2, 3, 4, 5, 6]Student at P R Pote Patil College of Engineering and Management, Amravati

Abstract: Stress is a pervasive aspect of modern life, posing significant health risks if left unmanaged. Early detection of stress is crucial for preventing adverse health outcomes and promoting well-being. This paper presents a novel approach to stress monitoring and management using machine learning (ML) techniques and wearable physiological sensors. By analyzing multimodal datasets, including electrocardiogram (ECG) signals and other physiological parameters, our proposed model aims to accurately detect stress levels in individuals. Leveraging low-cost wearable sensors and IoT technology, our system provides real-time feedback and alerts individuals to their stress levels, enabling proactive intervention to mitigate health risks. Through a comprehensive review of existing stress detection approaches and integration of ML algorithms, our study contributes to the development of more efficient and effective stress monitoring systems. This research holds promise for improving health outcomes and enhancing quality of life in individuals facing stress-related challenges.

Keywords: Stress Monitoring, Machine Learning, Wearable Sensors, Physiological Signals, Health Management

I. INTRODUCTION

In today's fast-paced world, stress has become a pervasive issue affecting individuals' physical and mental well-being. Stress not only impacts daily life but also poses significant risks to long-term health, including heart disease, cancer, and weakened immune systems. Recognizing the importance of stress management, various approaches have been explored to detect and monitor stress levels effectively. One such approach is the development of the Remote Stress Detector, an IoT device designed to assess an individual's stress level based on their heartbeat reading. Stress often manifests as an increase in heart rate, akin to the physiological response observed during a heart attack. Leveraging this correlation, the Remote Stress Detector collects heart rate data locally and transmits it to a server for analysis. Computation is performed on the server, which then predicts whether the individual is experiencing stress, generating a chart of the data for individual review.

Utilizing Node MCU as the development board and micro-python for programming, the Remote Stress Detector employs a pulse sensor to measure heart rate accurately. By mapping stress levels to heartbeat data, the device can provide valuable insights into an individual's emotional state, whether they are nervous, apprehensive, or engaged in physical activity. Such remote monitoring capabilities hold significant promise for applications in medical industries, facilitating patient care and management, particularly for individuals with heart disease. Despite the growing recognition of stress's impact on health, quantifying and detecting stress remains a challenge. Existing datasets are limited in size and scope, hindering the development of robust machine learning algorithms for stress detection. However, the Remote Stress Detector offers a solution by enabling the collection of reliable data from diverse individuals, thereby enhancing the accuracy and effectiveness of stress detection methods.

Moreover, the device's ability to monitor heart rate during exercise holds implications for fitness enthusiasts, ensuring that individuals engage in physical activity safely and effectively. By incorporating machine learning techniques and leveraging comprehensive datasets, the Remote Stress Detector represents a significant advancement in stress monitoring technology, offering potential benefits for health management and well-being.

II. RELATED WORKS

In recent years, stress detection has garnered significant attention, with various approaches being explored across different domains. These approaches vary based on the factors considered and the methodologies employed for stress detection. One common area of focus is the utilization of wearable sensors and IoT devices for continuous monitoring of individuals' stress levels. Philip Schmidt et al. introduced the WESAD dataset, which has been instrumental in wearable affect and stress detection research. They collected physiological data from 15 individuals using wearable devices such as RespiBAN Professional and Empatica E4, recording parameters like three-axis acceleration, electrocardiogram (ECG), blood volume pulse, body temperature, respiration, electromyogram, and electrodermal activity. Their study evaluated five machine learning algorithms for stress detection, achieving promising classification accuracies.

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Similarly, Jacqueline Wijsman et al. focused on measuring physiological signals using wearable sensors to detect mental stress. Their study involved recording ECG, skin conductance, respiration, and electromyogram data from participants, extracting features for analysis. They employed various classifiers to distinguish between stress and non-stress conditions, achieving notable accuracy rates. Additionally, Saskia Koldijk et al. developed automatic classifiers to investigate the relationship between working conditions and mental stress-related conditions using sensor data. Their study incorporated body postures, facial expressions, computer logging, and physiological signals such as ECG and skin conductance. By subgrouping users and training specialized models, they demonstrated the effectiveness of their approach in differentiating stressor and non-stressor working conditions, highlighting the importance of considering contextual factors in stress detection.

Overall, these studies underscore the significance of wearable sensors and IoT devices in monitoring stress levels and advancing stress detection research. By leveraging machine learning algorithms and diverse physiological signals, researchers aim to develop more robust and reliable stress detection systems, offering potential applications in healthcare, workplace safety, and personal well-being.

TABLE I
PREVIOUS RELATED RESEARCH WORKS

Ref	Title	Dataset	Result
[4]	Stress Detection with Machine Learning and Deep Learning using Multimodal Physiological Data	Public dataset WESAD dataset	Achieved accuracy 84.32% and 95.21% using RF, DT, AdaBoost, KNN, LDA, SVM and DL
[4]	Stress Detection through Speech Analysis using Machine Learning	Public Dataset Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS) dataset	CNN- Achieved accuracy 94.26%-94.3%
[4]	Introducing WESAD, a Multimodal Dataset for Wearable Stress and Affect Detection	Public dataset WESAD dataset	Accuracy of 80% (three class) and 93% (two class) was achieved using RF, DT, AdaBoost, KNN, LDA, and SVM
[4]	A Machine Learning Approach for Stress Detection using a Wireless Physical Activity Tracker	Private Dataset Collected own dataset using FITBIT device and analysis using ANOVA	AIC- 782.8842 (Logit model) AIC- 781.6256 (Probit model) AIC-786.8999 (Complementary Log-Log model) *lower AIC, the better of model
[4]	Machine Learning and IoT for prediction and detection of stress	Private Dataset Collected own dataset and classified using Python	LR-66% SVM-68%
[4]	Machine Learningbased signal processing using physiological signals for stress detection.	Private Dataset Collected own dataset based on heart rate, EMG, GSR hand and foot data, respiration and classified using WEKA	KNN classifier- Achieved accuracy 92.06% SVM- Achieved accuracy 96.82%
[4]	Stress detection using wearable physiological sensors	Private Dataset Collected own dataset from BNPPGED	SVM- Achieved accuracy 82%
[4]	Emotion Recognition Based on Multichannel Physiological Signals with Comprehensive Nonlinear Processing	Private Dataset Collected own dataset based on the ECG,GSR,EMG	KPCA reduce the features and GBDT for classifier- Achieved accuracy 93.42%

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[4]	Emotion Recognition by Heart Rate Variability	Public Dataset MAHNOB dataset	SVM- Achieved accuracy 48.5%
[4]	Classification of Physiological Signals for Emotions Recognition using IOT	Private Dataset-SAID Dataset Collected own dataset using ECG and GSR SAID Dataset	ANN- Achieved Mean accuracy 75.8% and standard deviation of accuracy 11.38%

III. LITERATURE REVIEW

The literature review on stress monitoring and management systems using machine learning (ML) encompasses a broad spectrum of research efforts aimed at understanding and addressing stress-related issues through technological interventions. These endeavors primarily focus on leveraging various physiological signals, wearable sensors, and ML algorithms to detect and manage stress effectively.

Researchers have recognized stress as a pervasive concern affecting individuals' physical and mental well-being, necessitating proactive strategies for its identification and mitigation. Stress manifests through diverse physiological responses, including alterations in heart rate, electrodermal activity, respiration, and body temperature, among others.

To address this challenge, studies have explored the use of wearable devices equipped with sensors capable of capturing these physiological signals in real-time. For instance, the WESAD dataset introduced by Philip Schmidt et al. serves as a valuable resource for researchers, offering comprehensive physiological data collected from individuals under various stress conditions. Similarly, Jacqueline Wijsman et al. and Saskia Koldijk et al. have conducted studies utilizing wearable sensors to measure physiological responses and classify stress levels accurately.

Machine learning techniques play a crucial role in analyzing the vast amounts of data generated by these sensors and deriving meaningful insights.

Researchers have employed a range of ML algorithms, including Support Vector Machines (SVM), Decision Trees, Random Forests, and Deep Learning Neural Networks, to develop predictive models for stress detection. These models leverage features extracted from physiological signals to classify individuals into different stress categories with high accuracy.

Furthermore, the integration of Internet of Things (IoT) technologies has facilitated remote monitoring and management of stress. Remote Stress Detector devices, as discussed in one of the papers, utilize IoT connectivity to transmit physiological data to centralized servers for analysis and decision-making. This enables real-time monitoring of individuals' stress levels and timely interventions when necessary.

Overall, the literature review underscores the interdisciplinary nature of stress monitoring and management research, which combines insights from psychology, physiology, engineering, and computer science.

By leveraging advancements in wearable technology, ML algorithms, and IoT connectivity, researchers aim to develop robust and user-friendly systems for stress detection and intervention, ultimately enhancing individuals' health and well-being in today's fast-paced world.

IV. METHODOLOGY

A. *Dataset and Features Extraction*

The study utilizes the WESAD dataset, a multimodal dataset containing motion data and physiological features of 15 subjects. Data is collected using both chest-worn (RespiBAN Professional) and wrist-worn (Empatica E4) devices during various study protocols. Features are extracted from different modalities, including accelerometer, ECG, BVP, EDA, EMG, RESP, and TEMP signals. Statistical features such as mean, standard deviation, minimum, maximum, and peak frequency are computed for each modality.

B. *Preprocessing and Classification Algorithms*

Six machine learning algorithms (Random Forest, Decision Tree, AdaBoost, k-Nearest Neighbour, Linear Discriminant Analysis, and Kernel Support Vector Machine) and a deep learning artificial neural network (ANN) are employed for classification. The dataset is preprocessed using Principal Component Analysis (PCA) and Quantile Transformer for normalization. Two types of classifications, three-class and binary classification, are performed. Decision Tree and Random Forest classifiers are tuned with parameters for optimal performance. A simple neural network model is constructed for both classification tasks.

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C. Performance Evaluation

The evaluation metric used is accuracy, calculated using confusion matrices. Sensitivity analysis is also performed to assess the true positive rate of stress detection. The leave-one-subject-out (LOSO) cross-validation procedure is adopted to evaluate the models' generalization performance. The final accuracy is reported as the mean of all testing accuracies across different subjects in LOSO cross-validation, ensuring subject independence.

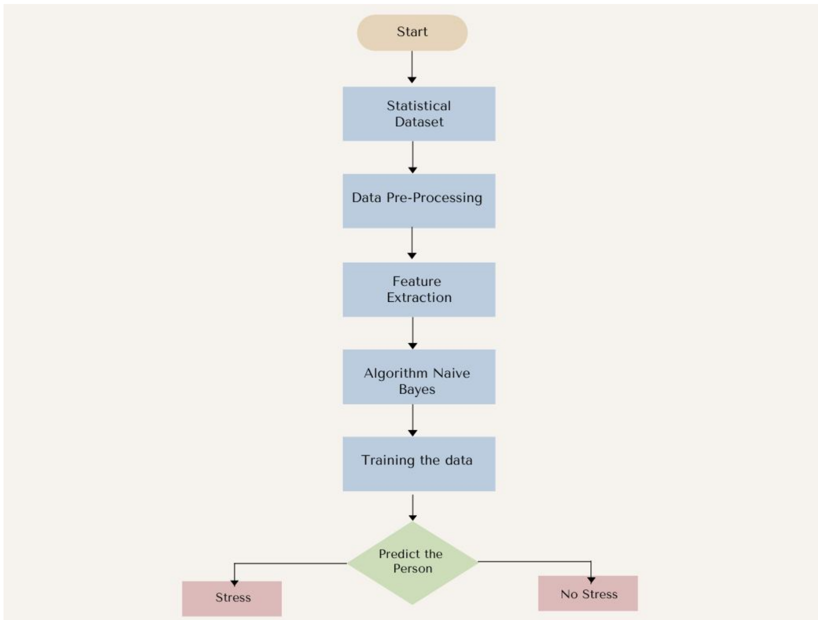

Fig. 1. Schematic flow diagram of Stress Detection Methodology

V. RESULTS AND DISCUSSION

The proposed stress detection system utilizes a Tree Optimised Cubic SVM model, which outperforms other models in terms of accuracy. The model achieves an accuracy of 96.3%, indicating its efficacy in stress detection. The confusion matrix (Fig. 7) illustrates the classification performance of the Tree Optimised Cubic SVM model, demonstrating its ability to accurately classify individuals into stressed and non-stressed categories. Furthermore, the optimization process for the SVM model involves minimizing the objective function value, which is depicted in Fig. 8. As the objective function value decreases, the model's optimization improves, leading to enhanced classification accuracy. The estimated objective function value and function evaluation time provide insights into the efficiency of the optimization process, with lower values indicating better performance.

Comparing the performance of different SVM kernels, the Tree Optimised Cubic SVM model stands out with the highest accuracy across all kernel types, as shown in Table II. This underscores the effectiveness of combining decision tree and SVM algorithms for stress detection. The model's superior accuracy, coupled with improvements in sensitivity and elapsed time, highlights its potential for accurate and efficient stress detection. Overall, the proposed system presents a robust approach to stress detection, leveraging machine learning techniques to analyze heart rate variability data. By achieving high accuracy levels, the system demonstrates its utility in real-world applications, including healthcare monitoring and stress management. Future research may explore the integration of additional physiological modalities and refinement of the classification algorithms to further enhance the system's performance and applicability.

VI. FUTURE SCOPE

Future research in stress detection should focus on integrating multiple modalities, including physiological data, facial cues, and audio/video recordings, to provide a comprehensive understanding of stress levels. Exploring novel features derived from advanced signal processing techniques could enhance detection accuracy. Personalized stress detection models, tailored to individual characteristics and contexts, could improve relevance and effectiveness. Real-time monitoring with wearable sensors and intervention capabilities holds promise for early detection and management. Longitudinal studies are essential to validate the reliability and generalizability of detection algorithms across diverse populations. Addressing ethical and privacy concerns surrounding data collection and usage is crucial for responsible deployment. By pursuing these avenues, researchers can advance stress detection technology to better support mental health and well-being.

VII. CONCLUSION

The culmination of the four studies underscores the growing significance of stress detection and the evolving methodologies employed to address this critical issue. Each paper contributes unique insights into the realm of stress detection, offering distinct approaches and methodologies to enhance accuracy and efficacy. In the first study, the focus lies on leveraging machine learning and deep learning techniques to detect stress using physiological data from the WESAD dataset. The proposed model achieves commendable accuracy rates of 84.32% and 95.21% in three-class and binary classification tasks, respectively. However, the study acknowledges the need for caution due to the limited number of subjects and suggests avenues for future research, including the integration of self-reports and additional modalities.

The second study explores the use of wearable sensors and machine learning algorithms for stress detection, highlighting the effectiveness of features extracted from heart rate variability and skin conductance. The findings emphasize the potential of low-cost sensors and machine learning algorithms like Support Vector Machine, Random Forest, and K-Nearest Neighbor in accurately predicting stress levels. However, challenges such as computation time and reliance on costly commercial devices are noted. In the third study, the researchers introduce a novel model utilizing Tree Optimised Cubic SVM, surpassing the performance of existing models in stress detection. The heightened accuracy of the proposed model underscores its potential for facilitating timely interventions to mitigate health risks associated with stress.

Finally, the fourth study explores the use of classifiers like Logistic Regression and SVM, demonstrating significant improvements over other algorithms like VF-15 and Naive Bayes. The adoption of SVM yields a notable increase in accuracy, showcasing its effectiveness in stress detection.

Collectively, these studies underscore the importance of early stress detection and intervention, offering valuable insights into novel methodologies and approaches to enhance accuracy and efficacy. Moving forward, integrating these findings and exploring interdisciplinary collaborations could pave the way for more robust and reliable stress detection systems, ultimately contributing to improved health outcomes and quality of life.

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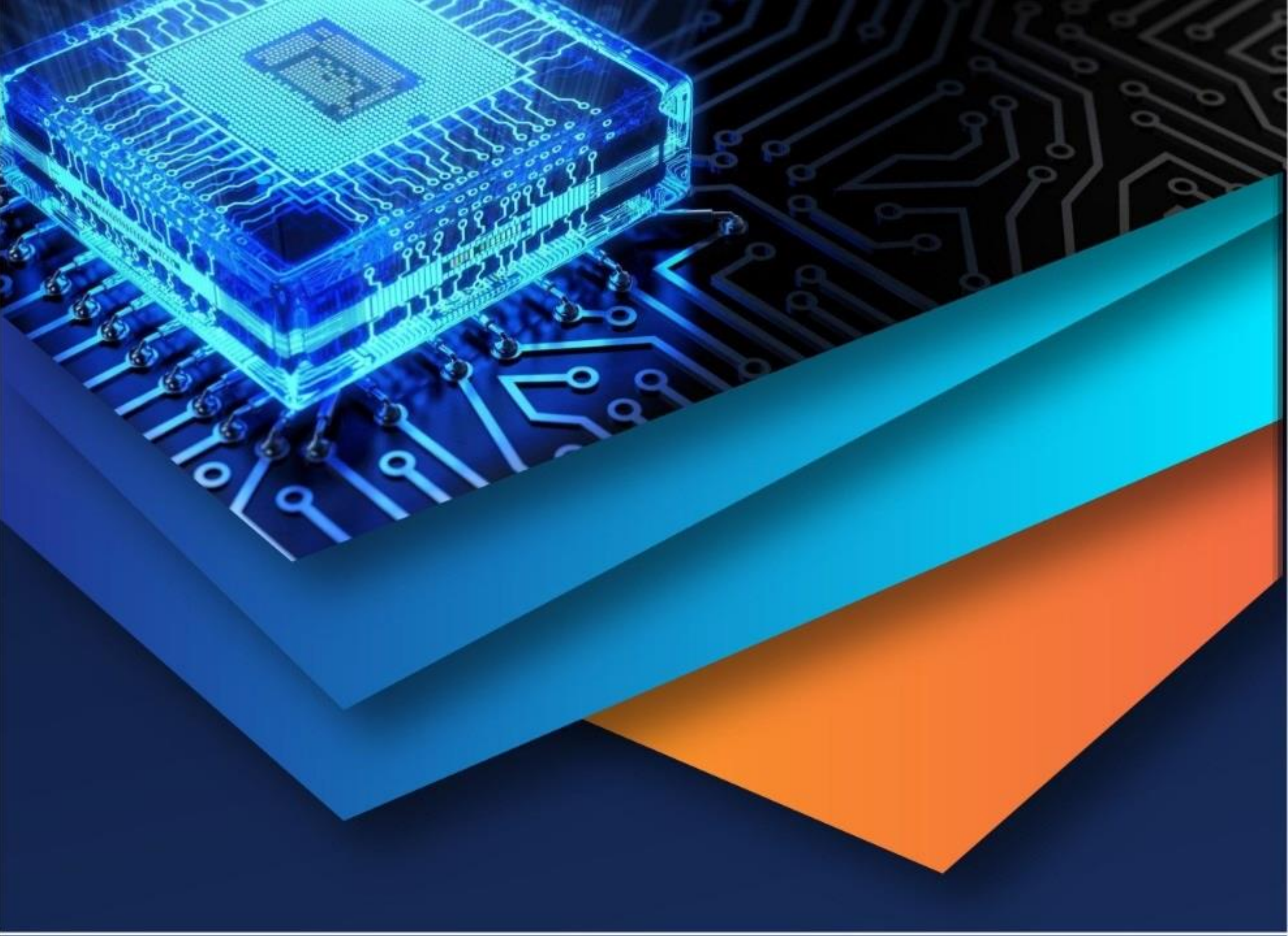

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