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STRESS DETECTION CLASSIFICATION USING WEARABLE DEVICES USING GRADIENT BOOSTING ALGORITHM

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Abstract: Mental stress in academic environments adversely impacts students' well-being and academic performance. Through the exploration of wearable devices, particularly the utilization of IBI-derived HRV and electrodermal activity (EDA), the research demonstrates the potential for real-time stress de tection and monitoring. The findings underscore the effec tiveness of wearable technology in identifying stress among students, offering opportunities for timely interventions to alleviate its negative effects. Moreover, this paper has delved into the efficacy of stress reduction techniques, specifically the impact of listening to meditation audio. The results in dicate that suchpractices canbevaluable tools for stress reduction, providingstudentswithaccessiblemeanstoman age their stress levels. By incorporating a hybrid feature selectionapproachwithmachine learning classifiers, fine tuned through Bayesian optimization has illustrated theef fectiveness of the proposed classification models. This hybrid features election method improved the classification accuracy by 2.61% for two-level stress classification and by 1.86% for three-level stress classification compared to existing models with out hybrid feature selection. This suggests incorporating HRV and EDA signals in wearable devices can enhance stress prediction accuracy. In the future, researchers can focus on further refining the utilization of HRV and EDA signals, which can contribute to developing more advanced and accurate wearable stress monitoring systems, there by improving the over all effectiveness of stress managemen tinterventions.

Key word : Academic environment, Explainable AI, Feature Selection, Machine Learning, Mental stress, Wearable Device

I. Introduction

This work utilizes wearable devices for real-time stress detection and investigates the effectiveness of meditation audio in reducing stress levels after academic exposure. Physiological data, including Interbeat Interval (IBI)-derived Heart RateVariability (HRV), BloodVolume Pulse (BVP), and electrodermal activity (EDA), are collected during the Montreal Imaging Stress Task (MIST). The stress classification methodology employs an integrated approach using Genetic Algorithm and Mutual Information to reduce feature set redundancy. It further uses Bayesian optimization to fine-tune machine learning hyperparameters. The results indicate that the combination of EDA, BVP, and HRV achieves the highest classification accuracy of 98.28% and 97.02% using the Gradient Boosting (GB) algorithm for 2-level and 3-level stress classification. In contrast, EDA and HRV alone achieve a comparable accuracy of 97.07% and 95.23% for 2-level and 3-level stress classification, respectively. Furthermore, the SHAP Explainable AI (XAI) analysis confirms that HRV and EDA are the most significant features for stress classification. The study also finds evidence that listening to meditation audio reduces stress levels. These findings highlight the potential of wearable technology combined with machine learning for real-time stress monitoring and management in academic environments.

1.1 Hardware Requirements

- **Wearable Devices:** wearables should have the following sensors for physiological data collection Heart Rate Sensor, Skin Type equation here.Conductance Sensor, Temperature Sensor , Microphone
- **IoT Devices:** Sensors installed from wearable Devices, Temperature Sensor, Accelerometer

2. Related work

The related work in stress detection using wearable devices and machine learning has been extensively studied, focusing on physiological signals such as heart rate variability (HRV), electrodermal activity (EDA), blood volume pulse (BVP), and skin temperature. Several researchers have employed machine learning techniques, including Support Vector Machines (SVM), Random Forest (RF), and Deep Neural Networks (DNN), to classify stress levels. Traditional models such as logistic regression and K-Nearest Neighbors (KNN) have also been used, but they often struggle with feature selection and real-time processing. Recent studies have integrated optimization techniques like Genetic Algorithms and Bayesian optimization to enhance model performance. Gradient Boosting methods, including XGBoost and LightGBM, have emerged as superior algorithms due to their ability to handle high-dimensional physiological data efficiently. Furthermore, Explainable AI (XAI) techniques such as SHAP analysis have been utilized to identify the most influential features in stress classification, primarily HRV and EDA. Studies have also explored the impact of meditation audio on stress reduction, showing promising results in real-world applications. The integration of wearable biosensors with machine learning models provides a practical approach to real-time stress monitoring, making it highly relevant for academic, clinical, and workplace environments.

3. RESEARCH METHODOLOGY

The research methodology for stress detection classification using wearable devices with the Gradient Boosting Algorithm involves a systematic approach comprising data collection, preprocessing, feature extraction, model training, and evaluation. Data is gathered from wearable sensors such as smartwatches and fitness bands, measuring physiological signals like heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA), skin temperature, and respiration rate. The collected data is then preprocessed to remove noise and normalize values for consistency. Relevant features are extracted and selected to improve model performance. The Gradient Boosting Algorithm, a machine learning technique that builds an ensemble of weak decision trees, is applied to classify stress levels. The model is trained using labeled datasets, validated using cross-validation techniques, and evaluated based on metrics such as accuracy, precision, recall, and F1-score. This methodology ensures a robust and reliable stress classification system, enabling real-time stress monitoring and early intervention for mental well-being.

3.1 Population and Sample

In stress detection classification using wearable devices with the Gradient Boosting Algorithm, the population refers to all individuals who could potentially be studied for stress detection, including students, working professionals, athletes, and individuals with stress-related conditions. These individuals regularly use wearable devices such as smartwatches and fitness trackers that monitor physiological signals like heart rate, skin temperature, and electrodermal activity. The sample is a carefully selected subset of this population, chosen based on specific criteria to ensure accurate and meaningful results. A representative sample typically includes participants from different age groups, genders, and professional backgrounds, ensuring diversity in stress response patterns. The sample size is determined based on statistical techniques to ensure reliability and generalizability. Proper sampling methods, such as random sampling or stratified sampling, help minimize bias and improve the performance of the Gradient Boosting model in classifying stress levels. A well-defined population and sample contribute to the effectiveness of the study in developing accurate and practical stress detection systems.

3.2 Data and Sources of Data

In stress detection classification using wearable devices with the Gradient Boosting Algorithm, the data consists of physiological and behavioral signals collected from wearable sensors. These signals include heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA), skin temperature, respiration rate, and movement patterns, which serve as key indicators of stress levels. The source of data comes from multiple channels, including publicly available datasets such as WESAD (Wearable Stress and Affect Detection) and the PhysioNet Stress Recognition Database, real-time data collected from wearable devices like smartwatches (Apple Watch, Fitbit, Garmin), and experimental studies where participants are monitored under controlled stress-inducing and relaxation conditions. Additionally, self-reported stress assessments using tools like the Perceived Stress Scale (PSS) are often used to validate physiological data. By integrating diverse data sources, the study ensures a comprehensive dataset for training the Gradient Boosting model, improving its accuracy and effectiveness in classifying stress levels for real-time applications in healthcare and well-being.

3.3 Theoretical framework

The theoretical framework for stress detection classification using wearable devices with the Gradient Boosting Algorithm is based on the integration of physiological stress response, wearable sensor technology, and machine learning principles. Stress triggers changes in the autonomic nervous system (ANS), leading to variations in heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA), skin temperature, and respiration rate, all of which can be monitored using wearable devices. These physiological signals serve as input data for stress classification. The Gradient Boosting Algorithm, a powerful machine learning technique, is used to analyze these signals by combining multiple weak decision trees to enhance classification accuracy. The framework involves key steps such as data collection from wearable sensors, preprocessing to remove noise, feature extraction to identify stress-related patterns, and model training to classify stress levels. By continuously improving prediction performance, this approach provides an accurate and efficient method for real-time stress detection, enabling practical applications in mental health monitoring, workplace well-being, and personalized stress management

3.4 Statistical tools and econometric models

In stress detection classification using wearable devices with the Gradient Boosting Algorithm, various statistical tools and economic models are used to ensure accurate analysis and real-world applicability. Statistical tools such as descriptive statistics (mean, standard deviation, variance) help in understanding the distribution of physiological data like heart rate (HR), heart rate variability (HRV), and electrodermal activity (EDA). Inferential statistics, including ANOVA (Analysis of Variance), t-tests, and correlation analysis, are applied to examine relationships between stress indicators and classification accuracy. Machine learning evaluation metrics such as accuracy, precision, recall, F1-score, and ROC-AUC (Receiver Operating Characteristic - Area Under the Curve) assess the model's performance.

From an economic perspective, stress detection using wearable devices can be analyzed through cost-benefit models and decision-making frameworks. The cost-effectiveness model evaluates the economic viability of implementing stress monitoring solutions in workplaces and healthcare systems by comparing the costs of wearable technology with the potential benefits, such as improved employee productivity and reduced healthcare expenses. Additionally, behavioral economic models, such as the Health Belief Model (HBM) and Utility Theory, help assess how individuals perceive

3.4.1 Descriptive Statistics

In stress detection classification using wearable devices with the Gradient Boosting Algorithm, descriptive statistics play a crucial role in analyzing physiological data and understanding stress patterns. Descriptive statistics summarize the collected data from wearable sensors, including heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA), skin temperature, and respiration rate. Measures such as mean, median, and mode help identify the central tendency of these physiological signals, while standard deviation and variance provide insights into data dispersion and variability across different stress levels. Additionally, skewness and kurtosis assess the distribution shape of the data, helping determine whether it follows a normal pattern. Frequency distributions and histograms can visualize stress level variations among participants. These statistical measures are essential in preprocessing and feature selection, ensuring that the Gradient Boosting Algorithm is trained on well-structured and meaningful data, ultimately improving its accuracy in classifying stress levels.

3.4.2 Modules

The stress detection classification system using wearable devices with the Gradient Boosting Algorithm is structured into several key modules, each playing a crucial role in data collection, processing, and classification. The first module, Data Acquisition, involves collecting physiological signals such as **Heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA**), **skin temperature, and respiration rate** from **wearable sensors like smartwatches and fitness bands. The Data Preprocessing module cleans and normalizes the collected data by removing noise and handling missing values to ensure consistency. The Feature Extraction and Selection module identifies the most relevant physiological indicators contributing to stress classification**, optimizing the input for the machine learning model. The Gradient Boosting Model Training module applies the Gradient Boosting Algorithm to train the system using labeled stress data, refining weak decision trees into a strong predictive model. Finally, the Stress Classification and Visualization module categorizes stress levels (low, moderate, or high) and presents real-time feedback through dashboards or mobile applications, enabling users to monitor and manage stress effectively. These interconnected modules ensure an efficient, accurate, and scalable system for real-time stress detection and mental well-being applications.

3.4.3 Software and Hardware requirements

The hardware requirements for stress detection classification using wearable devices with the Gradient Boosting Algorithm include a processor of Intel i3 or higher with a speed of 2.9 GHz, a minimum of 4 GB RAM, and at least 160 GB of hard disk storage. The software requirements involve a system running on Windows 7 Ultimate as the operating system, with Python as the primary coding language. The backend development relies on Django-ORM, while the frontend design is created using HTML, CSS, and JavaScript. Data management is handled using MySQL (WAMP Server). Additionally, functional requirements outline the essential components of the system, including input data processing, output generation, data storage, and computational tasks, ensuring efficient stress classification and real-time analysis.

3.4.4 Equation

In stress detection classification using wearable devices with the Gradient Boosting Algorithm, mathematical equations play a crucial role in model training and prediction. The core of Gradient Boosting lies in optimizing a loss function by iteratively adding weak learners (decision trees) to minimize errors. The predicted outcome at each stage is updated using the previous model and a new weak learner scaled by a learning rate :

F_m(x) = F_{m-1}(x) + \eta h_m(x)

The loss function measures the difference between actual stress levels and predicted values . Gradient Boosting minimizes this loss by computing the negative gradient as the pseudo-residual:

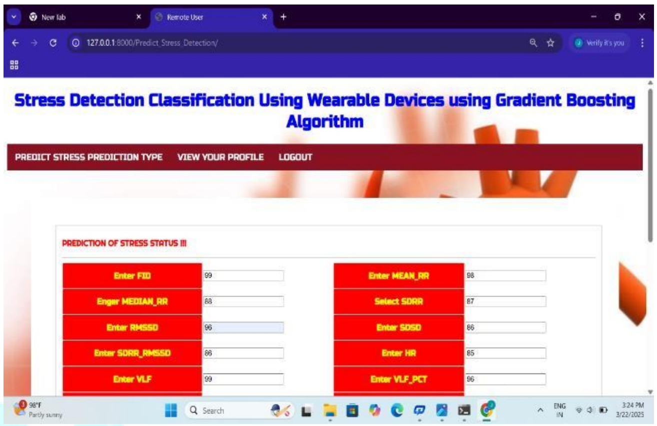
g_m = -\frac{\partial L(y, F_{m-1}(x))}{\partial F_{m-1}(x)}

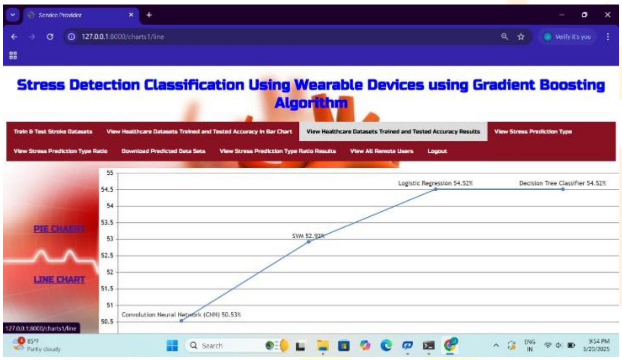
Each weak learner is then trained to fit , and the optimal weight for the new tree is computed as:

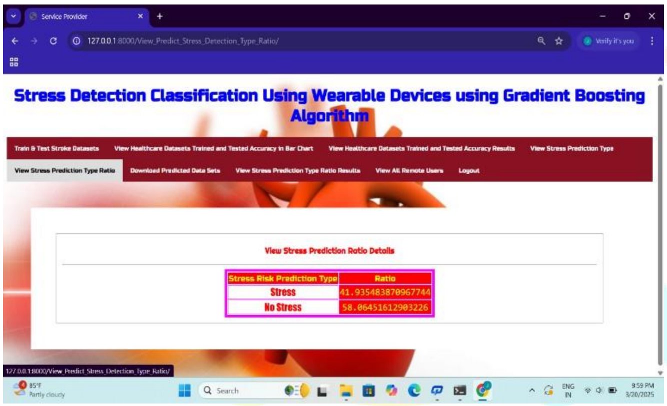
\gamma_m = \arg\min_{\gamma} \sum_{i=1}^{n} L(y_i, F_{m-1}(x_i) + \gamma h_m(x_i))

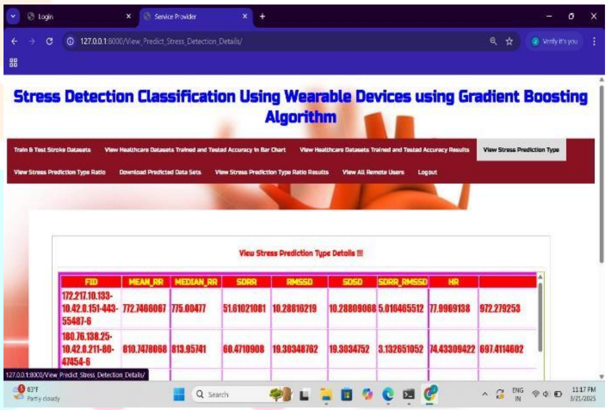
By iteratively refining

4. Output Screens









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