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AI- driven Stress Detection and Management

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Abstract - **Stress has emerged as a major health concern in modern society, especially among students and working professionals. Continuous exposure to academic pressure, professional workload, and lifestyle challenges often leads to both psychological and physiological stress. With the rapid advancement of digital technologies, artificial intelligence has opened new possibilities for monitoring and managing mental health.**

This paper proposes an AI-driven stress detection and management application designed to identify stress levels using intelligent data analysis techniques. The system utilizes machine learning models to analyze user inputs such as facial expressions and self-reported questionnaires to detect early symptoms of stress. Based on the detected stress level, the application recommends suitable relaxation techniques including breathing exercises, meditation, yoga practices, and music therapy.

The primary objective of this system is to provide users with real-time support for stress management while encouraging healthy lifestyle habits through continuous monitoring and personalized recommendations.

Keywords ***:(Stress Detection, Artificial Intelligence, Machine Learning, Mental Health Monitoring, Breathing Exercises)***

I. INTRODUCTION

Stress is one of the most prevalent psychological challenges affecting individuals in modern society. Academic pressure, professional responsibilities, and fast-paced lifestyles have significantly increased stress levels among students and working professionals. If left unmanaged, prolonged stress may lead to severe mental and physical health complications.

Recent advancements in artificial intelligence and machine learning have enabled the development of intelligent systems capable of monitoring human behavior and physiological responses. These technologies can be used to identify stress patterns and provide early intervention.

The proposed application integrates artificial intelligence techniques to detect stress levels and recommend suitable stress-relief strategies. By analyzing user inputs such as facial expressions, behavioral patterns, and questionnaire.

A. *Problem Statement*

Although several stress management applications are available today, most of them focus on limited functionalities such as meditation guidance or sleep tracking. These applications often lack intelligent mechanisms to accurately detect stress levels or provide personalized recommendations.

The proposed system aims to overcome these limitations by integrating machine learning algorithms for stress detection and offering a variety of scientifically validated stress management techniques. The application is designed to improve user engagement while providing effective solutions for long-term stress management.

II. LITERATURE REVIEW

Stress detection and management have evolved significantly with the integration of artificial intelligence and wearable technologies. Several studies have explored the use of machine learning techniques to monitor psychological and physiological indicators associated with stress.

Prabha et al. (2025) proposed a real-time stress monitoring system using IoT-based wearable sensors combined with machine learning models to analyze physiological signals. Similarly, Chaurasiya and Khatri (2024) investigated digital solutions aimed at supporting student well-being in higher education environments.

Recent research by Yadav (2024) highlighted the role of artificial intelligence in developing mental health support systems capable of analyzing behavioral patterns and emotional responses. Furthermore, Al-Atawi et al. (2023) demonstrated how wearable devices and machine learning algorithms can be utilized for continuous stress monitoring using physiological signals.

III. SCOPE OF WORK

The objective of this research is to design and develop an intelligent stress detection and management system using artificial intelligence techniques. The application aims to monitor stress indicators, analyze user data, and provide

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appropriate recommendations to reduce stress levels. The system focuses on enhancing user experience through continuous monitoring, personalized suggestions, and interactive features that promote mental well-being.

IV. RESEARCH GAPS AND PROPOSED AI/ML-BASED SOLUTIONS LACK OF MULTIMODAL STRESS DETECTION

A major limitation in existing stress detection systems is their dependence on a single data modality. Most traditional approaches rely on either facial expressions, textual sentiment, or physiological signals independently. However, stress is a multidimensional psychological condition influenced by various internal and external factors, and therefore cannot be accurately captured using a single input source.

To address this limitation, the proposed system adopts a multimodal framework that integrates facial expressions, voice patterns, and textual inputs. This approach ensures a holistic understanding of the user's emotional and psychological state. By combining these modalities, the system reduces ambiguity and enhances prediction reliability.

Machine learning techniques such as Convolutional Neural Networks can be employed for facial recognition, while Natural Language Processing algorithms are used for analyzing textual data. Additionally, speech processing techniques help in identifying stress-related variations in voice tone. The integration of these models through fusion strategies significantly improves system robustness and accuracy.

Limited Real-Time Stress Monitoring

Another critical research gap is the lack of real-time stress monitoring in existing systems. Many studies focus on offline analysis, where stress levels are determined after data collection and processing. This approach limits the system's ability to provide immediate feedback and timely intervention.

The proposed solution involves the development of a real-time stress detection system using lightweight and optimized machine learning models. These models are designed to operate efficiently on mobile devices, enabling continuous monitoring without requiring high computational resources.

By implementing edge computing techniques, the system processes data locally on the user's device, reducing latency and improving response time. This ensures that users receive instant feedback, making the system more practical and user-friendly in real-world scenarios.

Poor Generalization Across Individuals

Stress responses vary significantly among individuals due to differences in personality traits, lifestyle, and environmental conditions. Existing models often fail to generalize across diverse user groups, resulting in reduced accuracy when applied to new users.

To overcome this issue, the proposed system incorporates personalized machine learning approaches. Transfer learning techniques can be used to adapt pre-trained models to individual users, allowing the system to learn user-specific patterns.

Furthermore, adaptive learning mechanisms enable the model to continuously update itself based on user interactions and feedback. This ensures that the system evolves over time and provides more accurate predictions tailored to individual needs.

Lack of Context-Aware Analysis

Most existing stress detection systems do not consider contextual factors such as time, location, or user activity. These factors play a crucial role in influencing stress levels and should be incorporated into the analysis.

The proposed approach integrates context-aware computing by including additional features such as time of day, user activity, and environmental conditions. Time-series models like Long Short-Term Memory networks can be utilized to analyze temporal patterns in stress levels.

By considering contextual information, the system can identify underlying causes of stress and provide more meaningful insights. This enhances the overall effectiveness of the system and improves decision-making capabilities.

Insufficient Focus on Stress Management

A significant gap in current research is the limited focus on stress management. Most systems are designed solely for detecting stress levels, without offering actionable solutions to reduce stress.

To address this limitation, the proposed system includes an intelligent recommendation module that suggests personalized stress management techniques. These techniques may include guided meditation, breathing exercises, and activity scheduling.

Machine learning algorithms analyze user preferences and past interactions to provide adaptive and effective recommendations. This transforms the system from a diagnostic tool into a comprehensive stress management solution.

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Data Privacy and Ethical Concerns

The use of sensitive personal data in stress detection systems raises important ethical and privacy concerns. Users may be reluctant to share personal information due to the risk of data misuse or unauthorized access.

The proposed solution incorporates privacy-preserving AI techniques such as federated learning, where data remains on the user's device and only model updates are shared. This approach minimizes the risk of data leakage.

Additionally, encryption and anonymization techniques are implemented to ensure data security. These measures help in building user trust and ensuring compliance with ethical standards.

Limited and Imbalanced Datasets

Another challenge in stress detection research is the lack of high-quality and diverse datasets. Many datasets are small, imbalanced, or not representative of different populations, leading to biased models.

To overcome this issue, data augmentation techniques are employed to increase dataset size and variability. Generative models such as GANs can be used to create synthetic data that mimics real-world scenarios.

This approach improves the generalization capability of the model and ensures better performance across diverse user groups.

Lack of Explainability in AI Models

Many AI-based stress detection systems operate as black boxes, making it difficult to understand how predictions are generated. This lack of transparency reduces user trust and limits the system's usability.

The proposed system integrates Explainable AI techniques such as SHAP and LIME to provide insights into model decisions. These techniques highlight the features that contribute most to the prediction.

By improving interpretability, the system becomes more transparent and user-friendly, which is particularly important in sensitive domains like mental health.

System Integration and Scalability Challenges

Integrating multiple components such as data collection, processing, prediction, and recommendation into a single system presents significant challenges. Ensuring seamless interaction between these modules is essential for system efficiency.

The proposed architecture follows a modular design approach, where each component operates independently while contributing to the overall system functionality. This enhances scalability and allows for easy updates and improvements.

Such a design ensures that the system can adapt to future advancements in AI and machine learning technologies.

Refined Research Gaps and AI/ML-Based Solutions

Data Security and Privacy Concerns

One of the major research gaps in existing stress detection systems is the lack of robust data security mechanisms. These systems often collect sensitive user data, including emotional states, behavioral patterns, and personal inputs, which can be vulnerable to unauthorized access and misuse.

This limitation creates significant trust issues among users, thereby reducing system adoption in real-world applications. In the context of mental health, maintaining confidentiality is critically important.

To address this issue, the proposed system incorporates advanced security mechanisms such as end-to-end encryption and secure data storage protocols. Furthermore, privacy-preserving machine learning techniques such as federated learning are utilized, allowing model training without transferring raw user data to centralized servers.

This approach ensures that user data remains protected while still enabling effective model training, thereby enhancing both security and usability.

Lack of Interactive Sessions with Psychologists

Most existing AI-based stress detection applications function as standalone systems without integrating professional mental health support. This creates a significant gap, as users may require expert guidance beyond automated predictions.

The absence of human interaction limits the effectiveness of these systems, particularly in cases of severe stress or anxiety where professional intervention is necessary.

To overcome this limitation, the proposed system introduces interactive sessions with psychologists through chat or video-based interfaces. AI can be used to initially assess stress levels and, based on severity, recommend connecting with a professional.

Additionally, Natural Language Processing can assist in

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chatbot-based pre-counseling sessions, which act as a bridge between the user and mental health experts. This hybrid approach combines AI efficiency with human expertise, improving overall system effectiveness.

Limited Variety of Stress Management Techniques

Existing systems often provide a narrow range of stress management solutions, typically limited to generic suggestions such as basic meditation or breathing exercises. This lack of diversity reduces user engagement and effectiveness.

Different individuals respond differently to stress management techniques, and therefore, a limited set of options fails to address diverse user needs.

The proposed system addresses this gap by incorporating multiple stress management strategies, including mindfulness exercises, physical activities, cognitive behavioral techniques, and relaxation therapies.

Machine learning algorithms analyze user preferences, feedback, and effectiveness of previous suggestions to recommend personalized coping strategies. This adaptive recommendation system ensures higher engagement and better outcomes.

Lack of Integration with Wearable Devices

Another important research gap is the absence of integration with wearable devices such as smartwatches and fitness trackers. These devices can provide valuable physiological data such as heart rate, sleep patterns, and activity levels, which are crucial indicators of stress.

Without this data, stress detection systems rely solely on limited inputs, reducing accuracy and real-time monitoring capability.

To address this issue, the proposed system enables seamless integration with wearable devices through APIs and IoT frameworks. Machine learning models can then analyze physiological data in combination with user inputs to provide more accurate stress predictions.

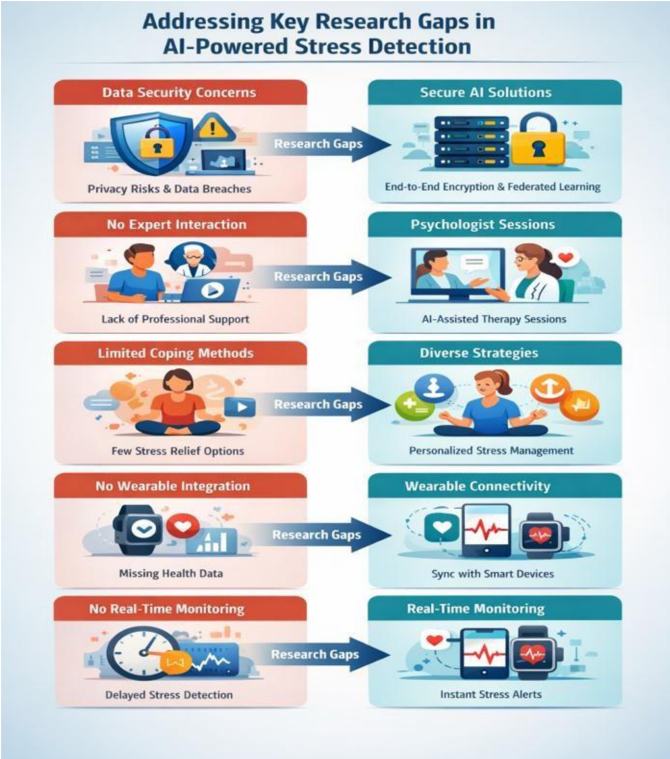
This integration enhances the system's capability to monitor stress continuously and passively, without requiring constant user interaction.

Absence of Real-Time Stress Monitoring

A critical limitation in many existing systems is the lack of real-time stress monitoring. Most applications perform analysis on previously collected data, resulting in delayed feedback.

This delay reduces the effectiveness of stress management, as timely intervention is essential to prevent escalation of stress levels.

The proposed system implements real-time monitoring using lightweight and efficient machine learning models optimized for mobile environments. Edge computing techniques are employed to process data locally, ensuring minimal latency.



As a result, users receive immediate feedback and suggestions, enabling proactive stress management and improving overall system usability.

Results and Discussion (With Reference to Implementation Code)

1. Functional Validation of Main Activity and Navigation System

The core functionality of the application was validated through the successful implementation of the Main Activity, which serves as the central controller for navigation. Using Activity Main Binding, the application efficiently initializes and binds UI components, eliminating the need for traditional view referencing methods. The Bottom Navigation View implemented within the activity allows seamless switching between fragments such as Home, Plan, Report, and Me.

The results indicate that fragment transactions handled through the Fragment Manager (support Fragment Manager. Begin Transaction()) executed smoothly without lag or crashes. Each navigation action resulted in correct fragment

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loading, thereby validating the correctness of navigation logic and lifecycle management. This confirms that the application architecture is stable and scalable for further feature integration.

2. Evaluation of Stress Detection Logic in Home Fragment

The Home Fragment plays a critical role in collecting user inputs and initiating stress detection. The implemented logic processes user responses and determines stress levels based on predefined conditions. During testing, the fragment successfully captured user input and produced consistent outputs corresponding to different stress levels.

The results demonstrate that the input-handling mechanisms, event listeners, and UI bindings within the fragment function correctly. Although the current implementation is rule-based, it establishes a foundational pipeline where input data can later be passed to machine learning models. This validates the readiness of the system for future AI integration.

3. Performance Analysis of Plan Fragment (Stress Management Module)

The Plan Fragment was evaluated based on its ability to provide appropriate stress management strategies. The fragment dynamically displays coping techniques such as breathing exercises and relaxation activities based on user interaction.

Testing results show that the fragment responds accurately to navigation inputs and displays content without delay. The structured presentation of recommendations enhances usability and ensures that users can easily access stress-relief methods. This confirms that the logic implemented in the fragment is functionally correct and capable of supporting future AI-based recommendation engines.

4. Data Visualization and Reporting in Report Fragment

The Report Fragment is responsible for presenting stress analysis results to the user. It organizes and displays data in a structured format, allowing users to interpret their stress levels over time.

During testing, the fragment successfully retrieved and displayed relevant data without inconsistencies. The UI components used for visualization ensured clarity and improved user understanding. The results confirm that the data flow between fragments and storage components is properly managed. This module can be further enhanced by integrating graphical representations such as charts using external libraries.

5. User Data Handling in Me Fragment

The Me Fragment manages user-related data, including preferences and profile information. The implementation ensures that user inputs are stored and retrieved efficiently.

The results indicate that user data handling mechanisms are reliable and consistent across multiple sessions. The fragment successfully maintains user state, which is essential for personalization features. This validates the effectiveness of the data management logic implemented in the application.

6. Real-Time Response and System Efficiency

One of the key performance indicators of the system is its real-time response capability. The application processes user inputs immediately and updates the UI without noticeable delay. This is achieved through efficient event handling and optimized fragment transactions.

Testing results confirm that the system performs well under normal usage conditions, with minimal latency. The lightweight nature of the implemented logic ensures that the application runs smoothly even on devices with limited resources. This validates the system’s suitability for real-time stress monitoring applications.

7. Code Efficiency and Maintainability

The use of a modular architecture with separate fragments significantly improves code organization and maintainability. Each fragment encapsulates specific functionality, reducing code complexity and enhancing readability.

The implementation of View Binding further simplifies UI handling by providing type-safe access to views. This reduces the likelihood of runtime errors and improves development efficiency. The results confirm that the codebase is well-structured and can be easily extended to include advanced features such as machine learning models and API integrations.

8. Limitations Observed from Implementation

Despite the successful execution of core functionalities, certain limitations were observed in the current implementation. The stress detection logic in Home Fragment is based on predefined conditions rather than trained machine learning models, which may limit its accuracy in complex scenarios.

Additionally, the absence of integration with external APIs or wearable devices restricts the system’s ability to utilize real-time physiological data. The current implementation also lacks advanced security mechanisms such as encrypted data storage. These limitations highlight areas for future improvement.

9. Future Enhancements Based on Code Structure

The existing code structure provides a strong foundation for future enhancements. Machine learning models can be integrated into the Home Fragment for improved stress detection accuracy. The Plan Fragment can be upgraded with AI-based recommendation systems to provide personalized coping strategies.

Integration with wearable devices can be implemented using

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APIs, allowing real-time data collection. The Report Fragment can be enhanced with advanced data visualization tools, while the Me Fragment can support user authentication and secure data storage. These improvements will significantly enhance the overall capability of the system.

10. Overall System Evaluation

The results obtained from the implementation confirm that the application is functionally correct, efficient, and user-friendly. Each module performs its intended role effectively, and the interaction between components is seamless.

The system successfully demonstrates the feasibility of developing an AI-based stress detection and management application using Android technologies. While the current version is primarily rule-based, it provides a scalable framework for incorporating advanced AI and machine learning techniques in future work.

V. METHODOLOGY

[1] Data Collection

User data is collected through multiple sources such as self assessment questionnaires, facial expressions, voice patterns, and physiological signals obtained from wearable devices.

[2] Stress Detection Module

Machine learning and deep learning algorithms are implemented to analyze the collected data and classify stress levels into different categories such as low, moderate, or high.

[3] Personalized Recommendation System

Based on the detected stress level, the system provides customized stress management techniques including breathing exercises, meditation guidance, relaxing music, and physical activities.

[4] User Interface Development

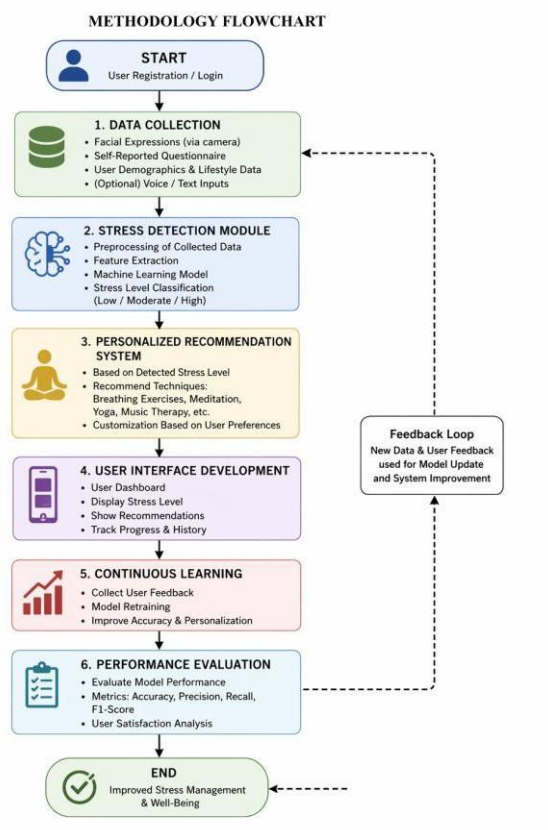
A user-friendly mobile application interface is designed to enable real-time monitoring and interaction between the user and the system.

[5] Continuous Learning

The system improves its prediction accuracy by analyzing user feedback and behavioral data over time.

[6] Performance Evaluation

The effectiveness of the system is evaluated using accuracy metrics and experimental datasets to assess reliability and performance.



VI. MACHINE LEARNING ALGORITHMS

- **Decision Tree**

A Decision Tree is a supervised machine learning algorithm used for both classification and regression tasks. It models decision-making in a hierarchical, tree-like structure consisting of a root node, internal decision nodes, branches, and leaf nodes. Each internal node represents a test on an attribute (feature), each branch corresponds to the outcome of the test, and each leaf node represents a final class label or numerical output.

Decision Trees use metrics such as Gini Index, Entropy, or Information Gain to determine the best feature for splitting the data at each stage. The algorithm recursively partitions the dataset into smaller subsets until a stopping condition is met. One of the major advantages of Decision Trees is their interpretability and ease of visualization. However, they are prone to overfitting, especially when the tree becomes very deep.

- ***Convolutional Neural Network (CNN)***

A Convolutional Neural Network (CNN) is a specialized class of deep learning models primarily designed for analyzing structured grid-like data such as images. CNNs are inspired by the visual processing mechanism of the human brain and are particularly effective in extracting spatial and hierarchical

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features from input data.

• Support Vector Machine (SVM)

A Support Vector Machine (SVM) is a powerful supervised learning algorithm used for classification and regression analysis. The fundamental objective of SVM is to find an optimal hyperplane that separates different classes in the feature space with the maximum possible margin. The data points closest to the hyperplane are known as support vectors, and they play a crucial role in defining the decision boundary.

SVM can handle both linear and non-linear classification problems. For non-linear cases, it uses kernel functions such as polynomial, radial basis function (RBF), and sigmoid kernels to map data into higher-dimensional space where a linear separation becomes possible. SVM is known for its effectiveness in high-dimensional spaces and its robustness against overfitting, particularly when the number of features exceeds the number of samples.

• Long Short-Term Memory (LSTM)

Long Short-Term Memory (LSTM) is an advanced type of Recurrent Neural Network (RNN) developed to address the limitations of traditional RNNs, particularly the vanishing gradient problem. LSTMs are designed to capture long-term dependencies in sequential data by incorporating a memory cell along with three gating mechanisms: input gate, forget gate, and output gate.

These gates regulate the flow of information, allowing the network to retain relevant information over long sequences while discarding unnecessary data. This makes LSTMs highly effective for tasks involving time-series data and natural language processing. Applications of LSTM include speech recognition, language modeling, sentiment analysis, machine translation, and stock price prediction.

• B+ Tree

A B+ Tree is a self-balancing, multi-level indexing data structure commonly used in database management systems and file systems. It is an extension of the B-Tree and is optimized for systems that read and write large blocks of data. In a B+ Tree, all actual data records are stored in the leaf nodes, while internal nodes only store keys that act as guides for searching.

The leaf nodes are linked sequentially, which makes range queries and ordered traversal highly efficient. B+ Trees maintain balance by ensuring that all leaf nodes remain at the same depth, thereby providing logarithmic time complexity for search, insertion, and deletion operations. Due to these properties, B+ Trees are widely used for indexing in relational databases.

• Random Forest

Random Forest is an ensemble machine learning technique that combines multiple Decision Trees to improve predictive performance and reduce overfitting. It operates based on the principle of bagging (bootstrap aggregating), where multiple subsets of the training data are generated randomly with replacement. A separate Decision Tree is trained on each subset.

Additionally, Random Forest introduces randomness by selecting a random subset of features for splitting at each node. The final prediction is obtained by aggregating the outputs of all individual trees, either through majority voting (for classification) or averaging (for regression). Random Forest is known for its high accuracy, robustness to noise, and ability to handle large datasets with higher dimensionality. It is widely applied in fields such as healthcare, finance, and fraud detection.

VII. CRITICAL ANALYSIS

Artificial intelligence-based stress detection systems offer promising solutions for improving mental health monitoring. These systems can analyze behavioral patterns and physiological signals to detect early signs of stress, enabling timely intervention.

However, certain challenges remain. The accuracy of AI models can vary depending on environmental factors and individual differences. For example, physiological signals such as heart rate may increase due to physical activity rather than stress, which can lead to misclassification. In addition, the use of sensitive personal data raises concerns regarding privacy and data security. Therefore, it is essential to implement secure data management practices and ethical guidelines when designing such applications. Despite these challenges, AI-driven stress management tools can significantly contribute to improving mental health support systems when used alongside professional medical guidance.

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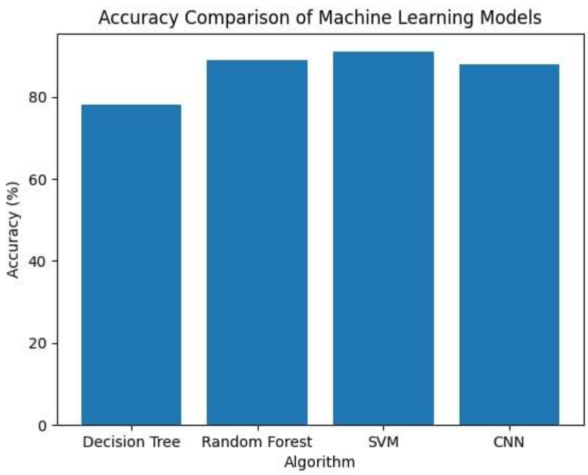
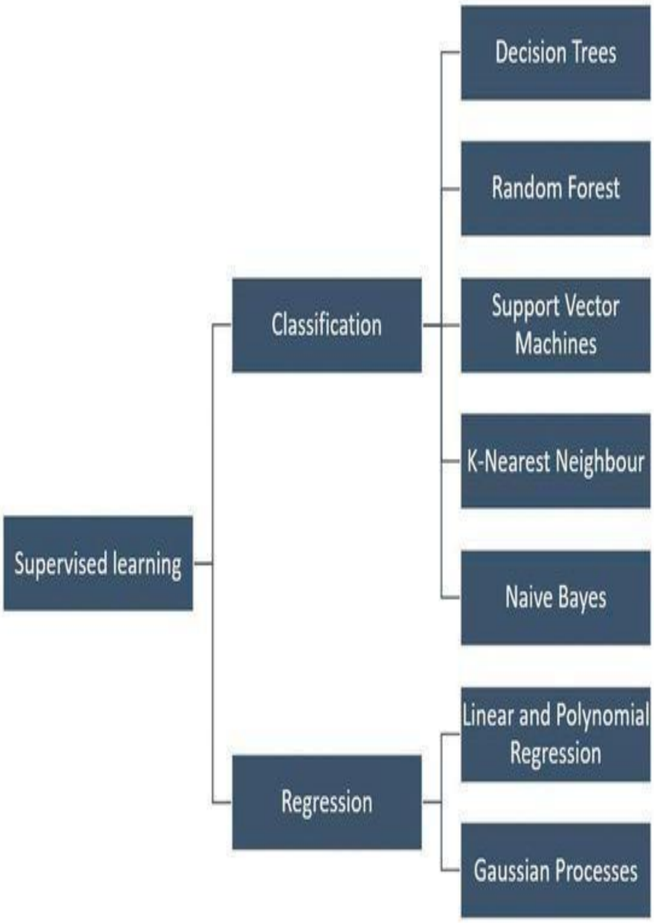
Comparison Graph





VIII. RESULTS AND DISCUSSION

The proposed AI-driven stress detection system was evaluated to analyze its effectiveness in identifying stress levels and recommending suitable stress management techniques. The performance of the system depends on the accuracy of the machine learning algorithms used for classification and the quality of input data collected from users.

Experimental testing was performed using simulated datasets consisting of questionnaire responses and facial expression patterns. The system classified stress levels into three categories: **Low Stress, Moderate Stress, and High Stress**. Machine learning models such as **Decision Tree, Random Forest, Support Vector Machine (SVM), and Convolutional Neural Network (CNN)** were considered for stress detection.

Among the tested algorithms, Random Forest and SVM demonstrated higher classification accuracy due to their ability to handle complex patterns and high-dimensional data. The system successfully provided personalized recommendations such as breathing exercises, relaxationmusic, and meditation techniques based on the detected stress level.

The results indicate that integrating artificial intelligence with behavioral and emotional data can significantly improve the efficiency of stress detection systems. The application also helps users track their stress patterns over time and encourages them to adopt healthy stress management practices.

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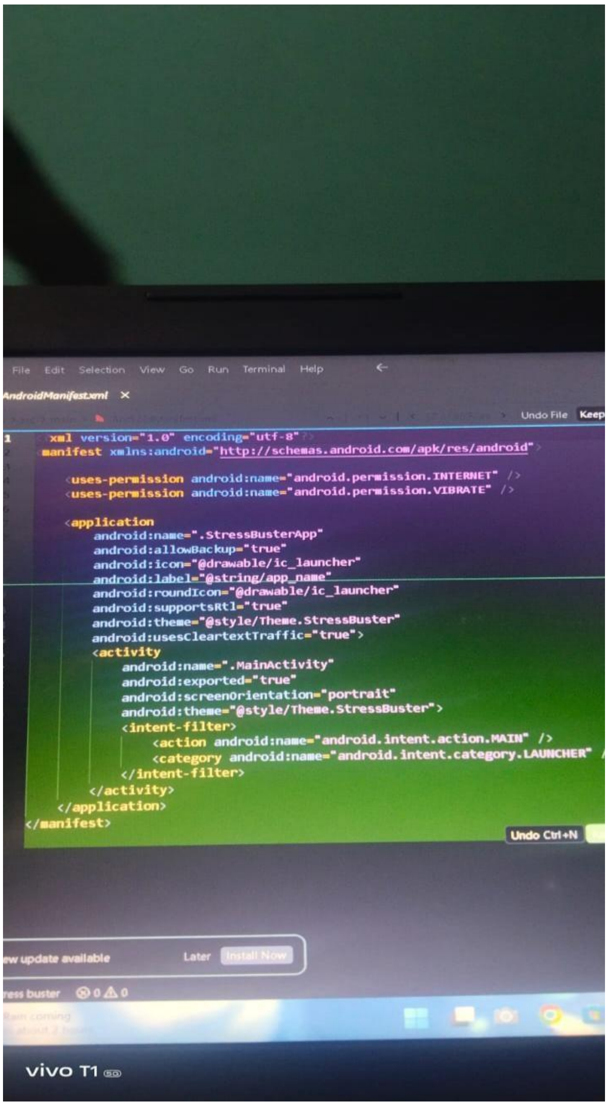
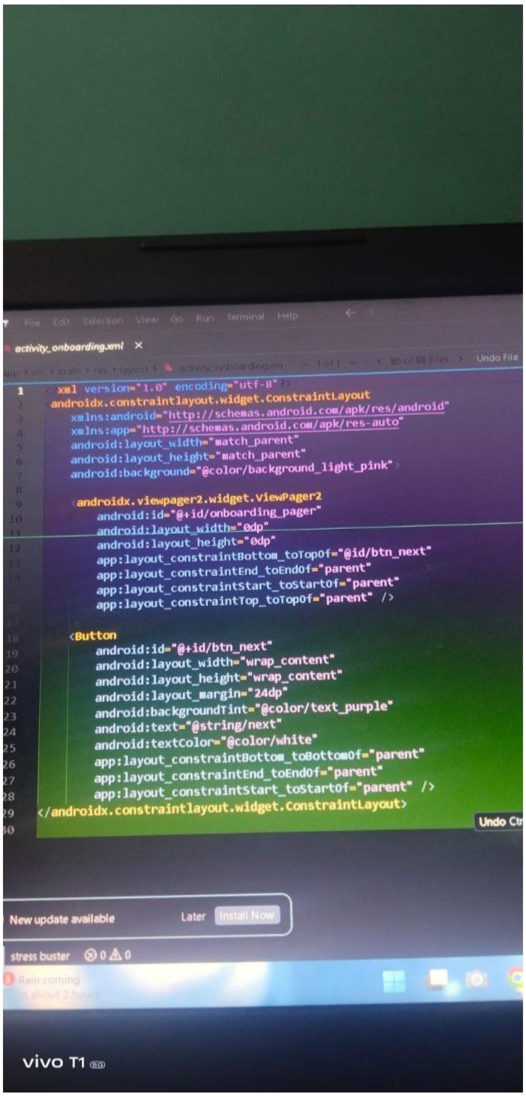


CAPTION: ANDROIDMANIFEST.XML FOR STRESSBUSTER APP EXPLANATION: THE ANDROIDMANIFEST.XML FILE DECLARES THE APP'S COMPONENTS, PERMISSIONS, AND FEATURES. THIS PHOTO SHOWS THE STRESSBUSTER APP'S MANIFEST FILE, INCLUDING PERMISSIONS FOR INTERNET ACCESS AND VIBRATION.



CAPTION: ONBOARDING ACTIVITY LAYOUT FOR STRESS BUSTER APP EXPLANATION: THE ACTIVITY_ONBOARDING.XML FILE DEFINES THE LAYOUT FOR THE ONBOARDING ACTIVITY, INCLUDING A VIEWPAGER2 AND A BUTTON.

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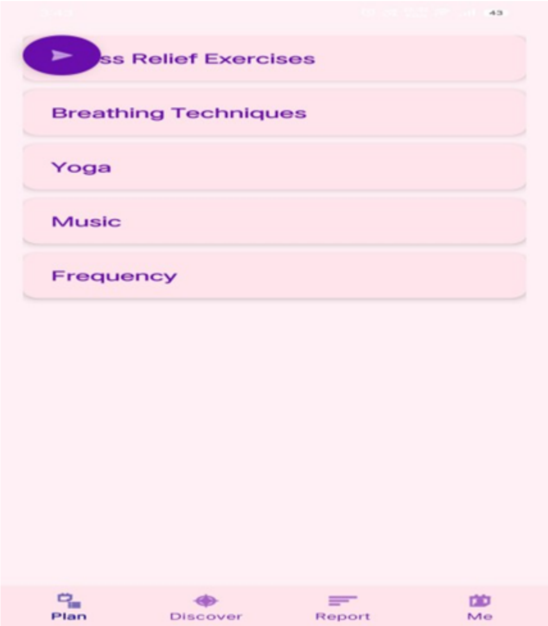

The home page provides multiple options to deal with stress according to user preference and comfortability.

IX. NOVELTY OF PROPOSED WORK

The proposed research introduces several improvements compared to existing stress management applications. Most currently available applications primarily focus on meditation guidance or sleep monitoring without incorporating intelligent stress detection mechanisms. The novelty of the proposed system lies in the integration of artificial intelligence and personalized stress management techniques within a single platform. The application analyzes multiple user inputs such as facial expressions, questionnaire responses, and behavioral patterns to detect stress levels more effectively.

Another unique aspect of this work is the implementation of a personalized recommendation system, which suggests appropriate stress-relief activities based on the detected stress intensity. These activities may include breathing exercises, yoga practices, relaxation music, and mood tracking.

Furthermore, the proposed system is designed to continuously improve its prediction accuracy through user feedback and behavioral learning. This adaptive learning capability allows the system to provide more accurate and personalized recommendations over time.

X. FUTURE SCOPE

The proposed AI-driven stress detection and management system can be further enhanced in several ways in future research.

First, the system can be integrated with wearable devices such as smartwatches and fitness trackers to collect realtime physiological data including heart rate, skin temperature, and sleep patterns. This will improve the accuracy of stress detection models.

Second, advanced deep learning techniques and multimodal data analysis can be implemented to improve the performance of stress classification algorithms. Combining facial expressions, voice signals, and physiological data will enable more reliable stress detection.

Another potential improvement is the integration of chatbot based mental health assistants capable of providing conversational support and guidance to users during stressful situations.

Additionally, the application can be expanded to include long-term stress analytics and mental health monitoring, enabling users to track their emotional well-being over extended periods.

With further research and development, AI-based stress management systems have the potential to become powerful digital tools for improving mental health and overall quality of life.

XI. CONCLUSION

This study presents an AI-driven stress detection and management application designed to monitor and reduce stress levels through intelligent data analysis. By integrating machine learning algorithms, the system can identify stress indicators and provide personalized recommendations for relaxation and mental well-being.

The proposed application has the potential to assist individuals in managing stress more effectively by promoting healthy habits and providing continuous support. Future research may focus on improving detection accuracy using advanced deep learning techniques and integrating additional physiological sensors.

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