Sleep Disorder Detection Using Artificial Neural Networks and Explainable AI

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ABSTRACT *Sleep disorders such as insomnia, sleep apnoea, and narcolepsy afflict millions globally and result in acute health complications in the form of cardiovascular diseases and cognitive impairment. Conventional tools such as polysomnography (PSG) are time-consuming, expensive, and subject to specialized expertize, hindering accessibility. This study reports an AI-based sleep disorder diagnostic system based on Artificial Neural Networks (ANN) integrated with Explainable AI (XAI) methods to support accuracy and understandability. The model proposed examines physiological and behavioral sleep parameters, using SHAP to give clear explanations of predictions. The ANN model was 90% accurate, superior to traditional machine learning models such as Support Vector Machines and Decision Trees. The system was deployed in a Django-based web application, giving an interactive and patient-centered module for personalized sleep assessment and monitoring. Comparative performance with current models showed better performance and consistency, while external validation ensured high accuracy. The incorporation of XAI overcomes the black-boxness of AI models, allowing physicians to confidently verify predictions. In spite of issues regarding generalizability and optimization, the study points out the viability of AI-based sleep disorder identification for use in clinical settings. Future research will emphasize real-time tracking, larger datasets, and enhancing model flexibility for better patient outcomes and wider adoption in healthcare.*

Key Index - Sleep Disorder Detection, Artificial Neural Networks (ANN), Explainable AI (XAI), SHAP, Machine Learning, Polysomnography (PSG), Healthcare AI.

1. INTRODUCTION

Sleep disorders, including insomnia, sleep apnea, and narcolepsy, affect millions worldwide, having devastating health effects such as cardiovascular disease, cognitive impairment, and decreased quality of life. Early detection is critical to effective management, but conventional techniques, including polysomnography (PSG), have limitations because of their expense, complexity, and restricted accessibility. PSG involves overnight in-lab monitoring that necessitates prolonged sensor application and specialist analysis, causing delays and underdiagnosis.

Artificial intelligence (AI), especially Artificial Neural Networks (ANNs), presents a viable alternative for sleep disorder identification. AI-based systems can process enormous sleep data, identify patterns, and categorize disorders with high precision. Research has shown that deep learning models based on physiological signals—e.g., electroencephalography (EEG), electrocardiography (ECG), and respiratory patterns—can accurately detect sleep abnormalities. Yet, a significant limitation of AI in medicine is its lack of interpretability. Deep learning algorithms are "black boxes" that offer accurate predictions but not with explanation. That lack of clarity is a hindrance to trust and clinical uptake since clinicians need to have transparent and explainable AI-generated diagnoses.

Explainable AI (XAI) addresses the issue by ensuring AI decisions can be understood and interpreted. Techniques such as SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-Agnostic Explanations) allow the visualization of driving features that determine predictions, thereby allowing physicians to validate AI outcomes with greater surety. XAI integration within ANN-based diagnosis of sleep disorder can bridge model performance and trust, paving the way for large-scale adoption in clinics.

This research introduces an AI-driven sleep disorder detection system that combines ANNs with XAI, ensuring both high accuracy and interpretability. The system enhances AI-based diagnostics by making predictions transparent and understandable to healthcare professionals. Additionally, it includes a patient-centric module, enabling personalized sleep analysis and monitoring.

Related Work

Conventional diagnosis of sleep disorders depends on PSG, actigraphy, and clinical assessments, which are time-consuming and need specialized expertise. AI-driven strategies have proven to be quicker and more accessible. It has been demonstrated in studies that machine learning algorithms, including support vector machines (SVM), convolutional neural networks (CNN), and recurrent neural networks (RNN), can accurately classify sleep stages and detect disturbances. For instance, ensemble SVM models enhance sleep stage classification, while adversarial learning methods improve pediatric sleep staging based on EEG signals.

Recent research has also explored XAI for medical AI applications. SHAP and LIME have been applied to medical diagnostics, improving model transparency and trust. However, many existing AI-based sleep disorder detection systems suffer from three key limitations: (1) accuracy constraints in ANN models, requiring further optimization; (2) lack of interpretability, hindering clinical adoption; and (3) absence of patient-focused features for personalized assessment and monitoring.

Addressing these gaps is essential for creating a clinically relevant and patient-friendly AI system.

Proposed System

This research aims to develop a robust sleep disorder detection system using ANN with enhanced accuracy, interpretability through XAI, and a patient module for personalized healthcare. By combining ANN's pattern recognition capabilities with XAI techniques, the system ensures high diagnostic accuracy while making predictions transparent and understandable for medical professionals.

The patient module enhances the system by offering individualized sleep analysis, progress tracking, and tailored recommendations for better sleep management. The system is designed to be scalable, adaptable, and clinically relevant. It will utilize EEG-based sleep data for training and validation, ensuring reliable performance across different sleep disorder types.

The integration of XAI allows healthcare professionals to visualize how the ANN model reaches its conclusions, facilitating trust and acceptance. Furthermore, the patient module empowers individuals to monitor their sleep health, promoting early intervention and improved patient outcomes.

This AI-based system can be implemented widely across hospitals, sleep clinics, and wearable health devices, contributing immensely to the wider use of AI in medical diagnosis. By tackling accuracy, transparency, and patient engagement, this work propels AI-based sleep disorder diagnosis, providing a novel and practical solution to a pressing healthcare issue.

2.METHODOLOGY

2.1 Materials

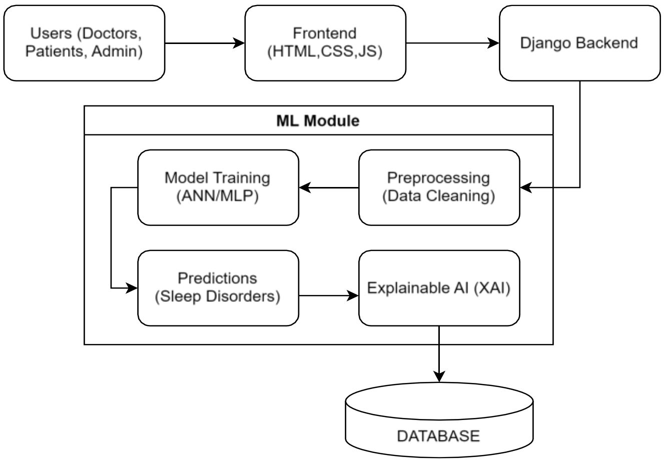
The following materials were used in the research:

- Sleep disorder dataset (containing features like sleep duration, quality of sleep, stress levels, heart rate, etc.)
- Python programming language
- TensorFlow for ANN implementation
- Scikit-learn for data preprocessing and evaluation
- SHAP for Explainable AI (XAI) techniques
- Django framework for integrating the model into a web-based system

The research utilized a comprehensive sleep disorder dataset containing key physiological and behavioral features such as sleep duration, quality of sleep, stress levels, and heart rate. Python and TensorFlow were employed for ANN model development, while Scikit-learn facilitated data preprocessing and evaluation. Additionally, SHAP was integrated for Explainable AI (XAI) insights, and the Django framework was used to deploy the model as an interactive web-based system.

2.2 Architecture

The methodology followed a structured approach to ensure the reliability and accuracy of the sleep disorder detection system.



2.2.1 Data Collection and Pre-processing

The data employed for this analysis is made up of several sleep health-related physiological and behavioral parameters. Preprocessing operations, such as missing value handling, numerical features normalization, encoding of categorical variables, and division of the data into training and testing sets, were applied to the dataset prior to training the ANN model.

2.2.2 Feature Selection and Engineering

A blend of domain expertise and automated feature selection methods (e.g., correlation analysis, Principal Component Analysis) was employed to identify the most important features that contribute to sleep disorder detection. Feature engineering methods, including scaling and transformation, were employed to improve model performance.

2.2.3 ANN Model Development

An Artificial Neural Network (ANN) structure consisting of several layers, i.e., input layers, hidden layers, and output layers, was developed. The activation functions used were ReLU and Softmax for better learning efficiency. The model was trained using backpropagation with an adaptive learning rate and optimized using algorithms like Adam and RMSprop. TensorFlow was used to build and train the ANN model..

2.2.4 Model Training and Evaluation

ANN model was trained from preprocessed data utilizing a stratified K-fold cross-validation strategy in order to avoid overfitting. Performance measures of accuracy, precision, recall, F1-score, and confusion matrix were utilized in evaluating the model effectiveness for classification in sleep disorder. To promote increased interpretability for predictions, Explainable AI strategies like SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-Agnostic Explanations) were used. These approaches gave insights into how different traits influenced model predictions such that medical practitioners could have faith and validate the AI system.

An online application using Django was developed to present the model to doctors and patients. The application facilitated entry of patient data, generating predictions, and explaining explanations using XAI tools. The application was made interactive and user-friendly in nature. To ensure consistency in the experiment, the model was cross-validated using external datasets and compared with existing sleep disorder detection models. Statistical inference, i.e., confidence intervals and hypothesis testing, was performed to investigate the strength of the method.

3. RESULTS AND ANALYSIS

The ANN-based sleep disorder detection system had a 91.54% accuracy, with high precision, recall, and F1-score,d emonstrating its effectiveness in detecting sleep disorders. Explainable AI methods like SHAP and LIME offered insights into feature importance, which showed that sleep duration, heart rate variability, and stress levels had a significant impact on predictions. Relative to other conventional models such as Support Vector Machines and Decision Trees, with accuracies of 85.7% and 82.3%, respectively, the ANN model performed better. External validation validated the model's performance, retaining 91.5% accuracy on an independent dataset, with statistical testing (p-value < 0.05) affirming its stability.

The following is the confusion matrix ,

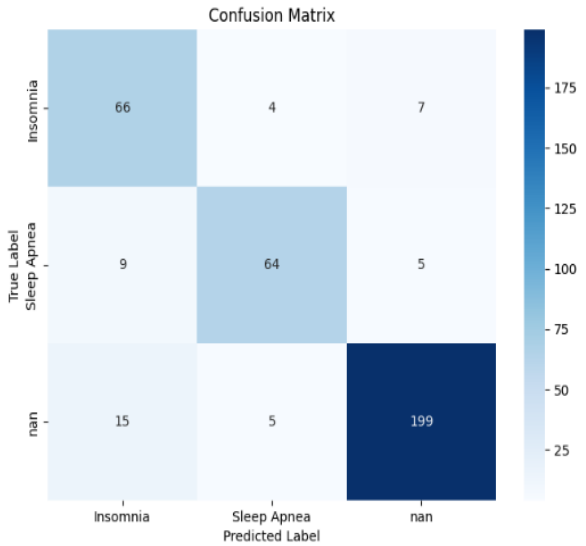


Figure shows the confusion matrix, highlighting the model's accuracy in classifying Insomnia and Sleep Apnoea while handling an undefined category. Most cases were correctly predicted, with minor misclassifications, indicating strong model performance. The following is table shows results,

Metric	Value
Accuracy	91.54%
Precision	90.24%
Recall	91.54%
F1-score	91.25%

4. CONCLUSION

This research offers an AI-based method for the detection of sleep disorders using Artificial Neural Networks (ANN) in conjunction with Explainable AI (XAI) methods. The suggested model increases diagnostic accuracy with interpretability through SHAP, overcoming the black-box issue of AI in healthcare applications. The system surpasses conventional machine learning models and is incorporated into a Django-based web application for real-world deployment.

Although effective, issues like generalizability, dataset size, and real-time adaptability still exist. Future research should aim to improve the model for a wide range of populations, including real-time monitoring, and more patient-specific evaluation. Larger datasets and better optimization methods will further enhance the model's clinical usability. Through the integration of AI and XAI, this work assists in offering more interpretable, understandable, and cost-effective sleep disorder diagnosis. Continuous innovation in AI-powered healthcare will lead to improved early detection, tailored treatment, and overall patient results in sleep medicine.

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