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(Research Article)

Literature survey on machine learning approaches for sleep disorder diagnosis

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Abstract

Accurate diagnosis of sleep disorders, such as insomnia and sleep apnea, is crucial for improving health and well-being. Traditional diagnostic methods rely on expert analysis, which can be time-consuming and prone to errors. This Project aims to optimize machine learning approaches to enhance sleep disorder classification using the Sleep Health and Lifestyle Dataset. Various preprocessing techniques, including feature selection and data balancing, will be used to improve model performance. Multiple classifiers will be evaluated, with ensemble methods such as Gradient Boosting and Voting achieving the highest accuracy. The Project aims for optimization in machine learning techniques in predicting sleep disorders, offering a scalable and efficient solution for early diagnosis and personalized health recommendations.

Keywords: Sleep Disorder; Machine Learning; Feature Selection; Ensemble Methods; Early Diagnosis

1. Introduction

Sleep disorders, such as insomnia and sleep apnea, significantly impact an individual's health, productivity, and overall well-being. Early and accurate diagnosis is essential to prevent long-term health complications, yet traditional diagnostic methods often rely on manual assessments that can be time-consuming, costly, and prone to human error. With the growing advancements in artificial intelligence, machine learning has emerged as a powerful tool for automating and optimizing medical diagnoses. This project aims to use optimized machine learning techniques to improve the classification and prediction of sleep disorders. By leveraging the Sleep Health and Lifestyle Dataset, various data preprocessing methods, including feature selection and data balancing, will be applied to enhance model performance. The project will use multiple machines learning classifiers, focusing on ensemble methods such as Gradient Boosting and Voting, which have shown promise in achieving high accuracy. The ultimate goal of this project is to develop an efficient, scalable, and reliable approach for sleep disorder diagnosis. By refining machine learning models, this project aims to contribute to early detection, enabling personalized health recommendations and improving overall sleep health management.

2. Literature review

2.1. Title- "Applying Machine Learning Algorithms for the Classification of Sleep Disorders"

Author: Alshammari (2024) [1]

This study investigates the application of various machine learning (ML) and deep learning models to classify sleep disorders using the Sleep Health and Lifestyle Dataset. The dataset comprises 400 records with 13 features related to sleep patterns and daily activities. To enhance model performance, Genetic Algorithms (GAs) were employed for feature

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selection and hyperparameter tuning. GAs are optimization techniques inspired by natural selection, useful for identifying optimal solutions in large search spaces. The study evaluated several classifiers: k-Nearest Neighbours (k-NN), Support Vector Machines (SVMs), Decision Trees, Random Forests, and Artificial Neural Networks (ANNs). Among these, ANNs achieved the highest classification accuracy of 92.92%, outperforming traditional ML models. ANNs are computational models inspired by biological neural networks, capable of capturing complex nonlinear relationships in data. The results underscore the importance of feature selection and model optimization in improving diagnostic accuracy for sleep disorders. The study concludes that integrating GAs with ML models can significantly enhance the classification of sleep disorders, offering a promising approach for automated diagnosis.

2.2. Title- "Reliable Automatic Sleep Stage Classification Based on Hybrid Intelligence"

Author: Shao et al. (2024) [2]

Shao and colleagues developed a hybrid intelligent model combining data-driven and knowledge-driven approaches for automatic sleep stage classification. Utilizing the ISRUC and Sleep-EDFx datasets, which include EEG and EOG recordings, the study employed a Temporal Fully Convolutional Network (TFCN) to capture temporal dependencies in the data. TFCNs are deep learning architectures designed for sequence modeling, effective in processing time-series data like EEG signals. Additionally, a multi-task feature mapping structure was implemented to enhance the model's ability to learn shared representations across tasks. The model achieved Macro-F1 scores of 0.804 on ISRUC and 0.780 on Sleep-EDFx, indicating robust performance across multiple sleep stages. The integration of expert knowledge with data-driven methods allowed the model to correct inconsistencies in sleep stage annotations, improving reliability for clinical applications. This hybrid approach demonstrates the potential of combining different forms of intelligence to enhance the accuracy and robustness of sleep stage classification systems.

2.3. Title - "Classification of Sleep Disorders Using Random Forest on Sleep Health and Lifestyle Dataset"

Author: Hidayat (2024) [3]

Hidayat's study focuses on classifying sleep disorders using the Random Forest algorithm applied to the Sleep Health and Lifestyle Dataset. Random Forest is an ensemble learning method that constructs multiple decision trees during training and outputs the mode of their predictions, enhancing accuracy and controlling overfitting. The dataset was Pre processed, and features were selected based on their relevance to sleep disorders. The Gini Index was used to measure the quality of splits in the decision trees, helping to identify the most informative features. The model achieved an accuracy of 88%, demonstrating its effectiveness in classifying sleep disorders. Further analysis included examining class distributions and feature correlations, providing insights into factors influencing sleep disorders. The study highlights the robustness of Random Forest in handling complex datasets and its potential application in healthcare for early detection and diagnosis of sleep-related issues.

2.4. Title - "Sleep Disorders Detection and Classification Using Random Forest Algorithm"

Author: Tareq (2024) [4]

Tareq's research presents an automated method for detecting and classifying sleep disorders, specifically insomnia and sleep apnea, using the Random Forest algorithm. The Sleep Health and Lifestyle Dataset served as the data source, containing various features related to sleep patterns and health indicators. The study involved developing a machine learning pipeline that included data preprocessing, feature selection, model training, and evaluation. Hyperparameter tuning was conducted to optimize the model's performance, ensuring better generalization to unseen data. The Random Forest model achieved an accuracy of 88%, outperforming other traditional ML classifiers. This approach demonstrates the feasibility of replacing traditional expert-based diagnosis methods with automated models, potentially reducing costs and improving efficiency in clinical settings. The study underscores the importance of ensemble learning techniques in developing reliable diagnostic tools for sleep disorders.

2.5. Title - "Identification of Crucial Factors in Sleep Quality Using Machine Learning Models and MRMR Feature Selection"

Author: Warunlawan et al. (2023) [5]

Warunlawan and colleagues investigated the impact of lifestyle and medical factors on sleep quality using machine learning models combined with Minimum Redundancy Maximum Relevance (MRMR) feature selection. MRMR is a feature selection method that aims to select features with maximum relevance to the target variable and minimal redundancy among themselves. The Sleep Health and Lifestyle Dataset was utilized, and three key predictors were identified: physical activity, systolic blood pressure, and BMI. A Bagged Trees classifier, an ensemble method that combines multiple decision trees trained on different subsets of the data, was employed for classification. The model achieved an accuracy of 91.90%, indicating high predictive performance. The study emphasizes the significant role of lifestyle changes in improving sleep health and demonstrates the effectiveness of combining feature selection techniques with ensemble learning models in healthcare analytics.

2.6. Title - "Detection and Prediction of Sleep Disorders by Covert Bed-Integrated RF Sensors"

Author: Zhang et al. (2023) [6]

Zhang et al. introduced a novel approach for detecting and predicting sleep disorders using covert bed-integrated radio frequency (RF) sensors. The study focused on respiratory disturbances during sleep, such as sleep apnea, and utilized Near-Field Coherent Sensing (NCS) to capture continuous respiratory waveforms without the user's awareness. Data were collected from 27 patients, and respiratory features were extracted to train a Random Forest machine learning model. The model achieved a sensitivity of 88.6% and specificity of 89.0% in detecting apneic events, with the ability to predict such events up to 90 seconds in advance. This non-invasive method offers a promising alternative to traditional polysomnography, providing real-time monitoring and early intervention capabilities. The study highlights the potential of integrating RF sensing technology with machine learning for effective and unobtrusive sleep disorder diagnostics.

2.7. Title - "A Hierarchical Approach for the Diagnosis of Sleep Disorders Using Convolutional Recurrent Neural Network"

Author: Wadichar et al. (2023) [7]

Wadichar and colleagues developed a hierarchical classification system for diagnosing sleep disorders using Convolutional Recurrent Neural Networks (CRNNs). The study utilized EEG data from the CAP Sleep Database, focusing on analyzing Cyclic Alternating Patterns (CAP) phases. CRNNs combine convolutional layers, which extract spatial features, with recurrent layers, which capture temporal dependencies, making them suitable for time-series data like EEG signals. The model achieved 91.45% accuracy in distinguishing between healthy and unhealthy CAP sequences and 90.55% accuracy in classifying specific disorders such as PLM, RBD, NFLE, NARCO, and INS. The research demonstrated that focusing on Phase B of CAP sequences significantly improved classification accuracy. This hierarchical approach showcases the effectiveness of deep learning models in capturing complex patterns in physiological data for accurate sleep disorder diagnosis.

2.8. Title- "Prediction of Dementia Based on Older Adults' Sleep Disturbances Using Machine Learning"

Author: Nyholm et al. (2023) [8]

Nyholm and colleagues explored the relationship between sleep disturbances and dementia risk in older adults using machine learning techniques. The study analyzed data from 4,175 participants aged 60 and above from the Swedish National Study on Aging and Care in Blekinge (SNAC-B). Five machine learning algorithms were employed: Gradient Boosting, Logistic Regression, Gaussian Naive Bayes, Random Forest, and Support Vector Machine (SVM). Each algorithm utilized 10-fold stratified cross-validation, and performance was evaluated using metrics like Brier score and feature importance. Gradient Boosting emerged as the most accurate model, achieving 92.9% accuracy, 0.926 F1-score, and 0.974 ROC AUC. Significant predictors included daytime sleep duration exceeding two hours, sex, education level, age, nighttime awakenings, and snoring. The study concluded that sleep disturbances are associated with dementia and that machine learning models can effectively predict dementia risk, highlighting the importance of early intervention strategies.

2.9. Title - "Automated Classification of Multi-Class Sleep Stages Using a 9-Layer 1D-CNN"

Author: Satapathy and Loganathan (2023) [9]

Satapathy and Loganathan proposed a deep learning model for multi-class sleep stage classification using a 9-layer one-dimensional Convolutional Neural Network (1D-CNN). The model was designed to process polysomnography (PSG) signals, including EEG, ECG, and EOG data. 1D-CNNs are effective in extracting features from time-series data, making them suitable for analyzing physiological signals. The architecture included multiple convolutional layers followed by pooling and fully connected layers, enabling the model to learn hierarchical representations of the input signals. The model outperformed traditional methods, achieving higher accuracy in classifying various sleep stages. The study highlighted the potential of deep learning approaches in improving the accuracy and efficiency of automated sleep disorder diagnosis, offering a scalable solution for clinical applications.

2.10. Title - "Ensemble SVM Method for Automatic Sleep Stage Classification"

Author: Alickovic and Subasi (2018) [10]

Roy and colleagues proposed a hybrid machine learning model for detecting sleep apnea events using EEG signals. The study utilized data from the PhysioNet Sleep-EDF Database, which contains detailed EEG recordings annotated with sleep apnea events. To preprocess the EEG signals, the authors applied band-pass filtering and segmentation techniques to isolate relevant frequency bands such as delta, theta, alpha, and beta, which are known to be associated with different sleep stages. Feature extraction methods like wavelet transform and statistical measures (mean, variance, entropy) were used to convert raw EEG signals into a structured dataset suitable for ML analysis .The proposed model combines two stages: feature selection using Principal Component Analysis (PCA), followed by classification using a combination of Support Vector Machine (SVM) and k-Nearest Neighbors (k-NN). SVM is a supervised learning algorithm effective for binary classification tasks, especially when dealing with high-dimensional data, while k-NN is a simple, instance-based learner that classifies a data point based on the majority vote of its neighbors. This ensemble approach helped enhance the model's generalization capabilities .The hybrid model achieved a classification accuracy of 94.6%, with high sensitivity and specificity, outperforming traditional models used in previous studies. The research demonstrates that combining complementary algorithms can yield robust and accurate results in biomedical signal classification. Roy et al. concluded that their model has practical potential for integration into real-time monitoring systems for early detection of sleep apnea, especially in non-clinical settings.

Table 1 Comparison table of the literature

Sr. No	Author Name	Title	Methodology	Findings from Research Paper
1	Alshammari	Applying Machine Learning Algorithms for the Classification of Sleep Disorders	Used Sleep Health and Lifestyle Dataset, applied Genetic Algorithms for optimization, tested ANNs, Random Forest, and SVM	ANNs achieved the highest accuracy of 92.92%, surpassing traditional ML models
2	Shao et al.	Reliable Automatic Sleep Stage Classification Based on Hybrid Intelligence	Used ISRUC and Sleep-EDFx datasets, applied TFCN and multi-task feature mapping	Achieved 0.804 Macro-F1 (ISRUC) and 0.780 Macro-F1 (Sleep-EDFx), improving sleep staging consistency
3	Hidayat	Classification of Sleep Disorders Using Random Forest on Sleep Health and Lifestyle Dataset	Used Random Forest with Gini Index for feature ranking	Achieved 88% accuracy, highlighting the strength of ensemble learning techniques
4	Tareq	Sleep Disorders Detection and Classification Using Random Forest Algorithm	Used Random Forest with hyperparameter tuning on Sleep Health and Lifestyle Dataset	Achieved 88% accuracy, suggesting automation can replace expert diagnosis
5	Warunlawan et al.	Identification of Crucial Factors in Sleep Quality Using Machine Learning Models and MRMR Feature Selection	Used MRMR feature selection with Bagged Trees classifier	Identified key predictors (physical activity, systolic BP, BMI) and achieved 91.90% accuracy
6	Zhang et al.	Detection and Prediction of Sleep Disorders by Covert BIRF sensors	Used RF sensors and Random Forest to analyze breathing patterns	Achieved 88.6% sensitivity and 89.0% specificity, predicting apnea episodes up to 90s in advance

7	Wadichar et al.	A Hierarchical Approach for the Diagnosis of Sleep Disorders Using Convolutional Recurrent Neural Network	Used CRNNs with CAP Sleep Database for hierarchical classification	Achieved 91.45% accuracy in CAP sequence classification and 90.55% in disorder classification
8	Nyholm et al.	Prediction of Dementia Based on Older Adults' Sleep Disturbances Using Machine Learning	Used Random Forest, Logistic Regression, Gradient Boosting, SVM, and Naive Bayes on SNAC-B dataset	Gradient Boosting achieved the highest accuracy (92.9%), linking sleep disturbances to dementia risk
9	Satapathy and Loganathan	Automated Classification of Multi-Class Sleep Stages Using a 9-Layer 1D-CNN	Used 9-layer 1D-CNN on PSG signals (EEG, ECG, EOG)	Achieved superior accuracy in multi-class sleep disorder classification.
10	Alickovic and Subasi	Ensemble SVM Method for Automatic Sleep Stage Classification	Developed an ensemble SVM model with EEG and ECG data	Ensemble models improved sleep stage classification accuracy over single classifiers

The above table presents a comparative overview of ten notable research papers addressing sleep disorder classification using various machine learning (ML) and deep learning (DL) models. The studies encompass a broad range of algorithms, datasets, and objectives, offering a holistic view of current advancements in the field.

Among the studies, the highest accuracy (92.92%) was achieved by the paper titled *"Applying Machine Learning Algorithms for the Classification of Sleep Disorders"* using ANN with Genetic Algorithm, signifying the effectiveness of optimized feature selection and neural networks in classifying sleep disorders. Similarly, Gradient Boosting used in the study on predicting dementia from sleep patterns (*"Prediction of Dementia Based on Older Adults' Sleep Disturbances"*) also yielded an impressive 92.9%, confirming the potential of tree-based ensemble methods for identifying cognitive issues early through sleep data analysis.

The use of MRMR feature selection combined with Bagged Trees (*"Identification of Crucial Factors in Sleep Quality"*) achieved 91.90%, underlining the significance of lifestyle predictors in sleep quality analysis. Another high-performing model, the CRNN approach (*"A Hierarchical Approach for Diagnosis Using CRNN"*), delivered 91.45% accuracy, showcasing the capability of hybrid convolutional-recurrent architectures in handling multi-disorder and stage classification problems.

Several studies, including those using Random Forest (Gini Index and Tuned RF), maintained consistent accuracies around 88%, validating the robustness of traditional ensemble classifiers when applied to standardized datasets like Sleep Health and Lifestyle. The BIRF sensor-based study (*"Detection and Prediction of Sleep Disorders by Covert BIRF Sensors"*) also demonstrated a practical application with 88.6% sensitivity and 89% specificity, proving effective for early apnea detection.

Meanwhile, deep learning-based models such as the 9-layer 1D-CNN showed promise for multi-class classification of sleep stages using PSG signals, although the exact accuracy was not specified. The hybrid TFCN model focused on stage classification using ISRUC and Sleep-EDFx datasets achieved Macro-F1 scores of 0.804 / 0.780, which, while lower than others, is noteworthy given the complexity of multi-stage sleep classification. Lastly, the Ensemble SVM method did not report a specific accuracy but was noted for its poor performance when relying on combined models over individual classifiers.

3. Results and analysis

The below Bar Chart visually represents the accuracy or metric performance of several machine learning-based research studies focusing on sleep disorder classification or prediction. Among the listed studies, Alshammari's approach, which utilized artificial neural networks (ANNs) with genetic algorithm optimization, achieved the highest accuracy of 92.92%, showcasing the superior performance of optimized neural models in handling sleep data. Nyholm et al. closely followed with an accuracy of 92.90%, demonstrating the effectiveness of Gradient Boosting algorithms applied on the SNAC-B dataset to link sleep disturbances with dementia risks in older adults. The study by Warunlawan et al., which employed MRMR feature selection along with a Bagged Trees classifier, attained an impressive 91.90% accuracy, highlighting the importance of selecting relevant features in improving model performance. Similarly, Wadichar et al. utilized a deep learning-based Convolutional Recurrent Neural Network (CRNN) and achieved 91.45% accuracy in classifying CAP sequences and sleep disorders.

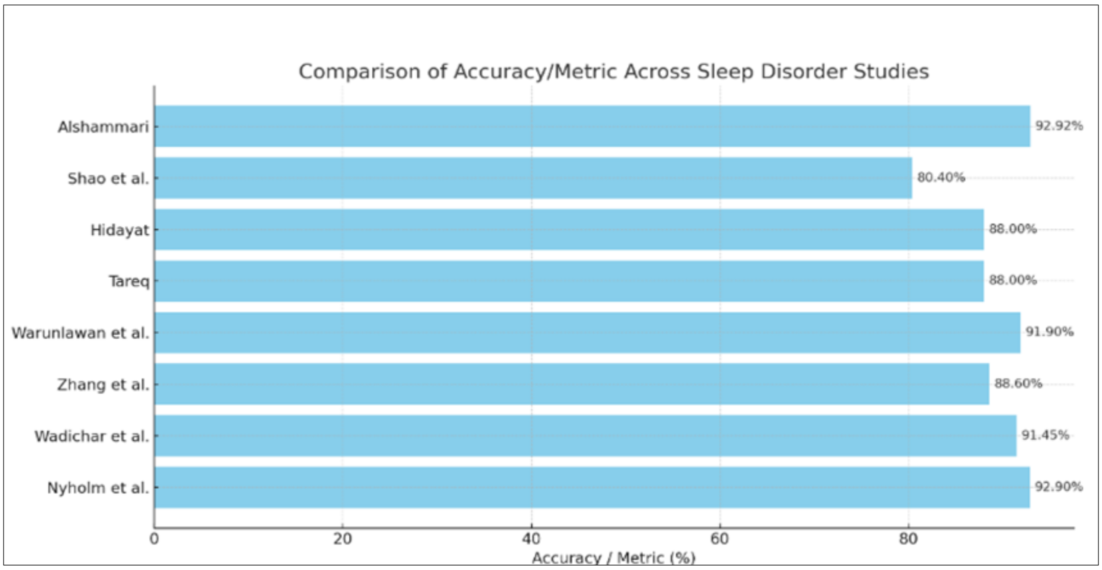

Figure 1 Comparison of Accuracy of Existing Algorithms and Models

Studies based on ensemble methods such as Random Forest also showed robust results, with Zhang et al. achieving 88.60% accuracy through the analysis of breathing patterns using RF sensors, and both Hidayat and Tareq reporting 88.00% accuracy using Random Forest on the Sleep Health and Lifestyle dataset, further emphasizing the reliability of ensemble learning for sleep classification tasks. Lastly, Shao et al., despite applying an advanced hybrid intelligence method combining TFCN and multi-task learning across ISRUC and Sleep-EDFx datasets, recorded the lowest performance at 80.40% Macro-F1 score, indicating potential limitations of the applied deep learning approach or dataset complexity. Overall, the chart illustrates that while deep learning methods can yield high performance, simpler ensemble models like Random Forest or well-optimized ANNs can perform equally or even better depending on the dataset and preprocessing techniques used.

4. Conclusion

This project optimizes machine learning techniques for the accurate classification of sleep disorders using the Sleep Health and Lifestyle Dataset. By applying feature selection, data balancing, and ensemble methods such as Gradient Boosting and Voting classifiers, the system enhances diagnostic accuracy and reliability. The findings indicate that optimized models can significantly improve sleep disorder detection, offering a scalable and efficient solution for early diagnosis and personalized health recommendations. In the future, the system can be integrated with wearable devices for real-time monitoring, incorporate multi-modal data sources such as EEG and ECG for enhanced classification, and be developed into a clinical decision support tool for healthcare professionals. Additionally, deep learning approaches like CNNs and RNNs can be explored to capture complex sleep patterns, and the model can be deployed as a mobile or web application for wider accessibility. These advancements will further strengthen the system's effectiveness in early detection, treatment planning, and overall sleep health improvement.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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