International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

Deep Insight into Sleep Health: A Predictive Modeling Approach Using AI Techniques

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***Abstract*— Growing attention toward sleep health has increased the need for systems that can analyze sleep-related data and identify disorders at an early stage. This work presents a prediction system that uses machine learning techniques to classify different types of sleep disorders based on health and lifestyle data. The application is designed with a simple interface where users can upload datasets, perform preprocessing, and observe patterns through graphical visualizations. The dataset is divided into training and testing portions to evaluate model performance effectively. Several classification methods, including KNN, SVM, Decision Tree, Random Forest, and Artificial Neural Network (ANN), are implemented and tested. Their performance is measured using accuracy, precision, recall, and F1-score, along with confusion matrix analysis. Among all methods, the ANN model provides better results by capturing complex relationships within the data. The system also allows users to test new data and obtain predictions instantly. Overall, the proposed approach offers a practical solution for analyzing sleep health data and supporting informed decision-making.**

***Keywords*—Sleep disorder prediction, healthcare data analysis, machine learning, classification, Artificial Neural Network (ANN), Random Forest, Decision Tree, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), data preprocessing, dataset upload, training-testing split, confusion matrix, performance evaluation, accuracy, precision, recall, F1-score, comparison graph, data visualization, real-time prediction, sleep health analysis, user-friendly interface**

I. INTRODUCTION

The increasing awareness of sleep health has led to the collection of large volumes of data related to sleeping patterns, lifestyle habits, and associated health conditions [11]. Such data can be effectively used to identify different types of sleep disorders at an early stage, which is essential for maintaining overall well-being [9]. However, manual analysis of these datasets is time-consuming and may lead to inconsistencies due to human limitations [4]. Traditional approaches rely heavily on domain expertise and often fail to capture complex relationships present in the data [6]. This creates a need for automated systems that can process and analyze data efficiently. Machine learning techniques provide a reliable solution by identifying hidden patterns and enabling accurate classification of sleep disorders [17]. In this project, a user-friendly system is developed that allows users to upload datasets, visualize important patterns through graphs, and perform preprocessing steps such as cleaning and splitting the dataset into training and testing portions [22]. This simplifies the process of data analysis and supports better decision-making.

With the advancement of machine learning, analyzing healthcare-related datasets has become more accurate and efficient [16]. Different classification algorithms perform differently depending on the dataset characteristics [26]. In this system, multiple algorithms such as K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Decision Tree, Random Forest, and Artificial Neural Network (ANN) are implemented to train and evaluate the dataset [3]. Each model is trained using

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the training data and tested using unseen data to measure its effectiveness. The performance of these models is evaluated using metrics like accuracy, precision, recall, and F1-score, along with confusion matrix visualization to clearly represent prediction results [24]. Among all methods, the ANN model achieves better performance due to its ability to capture complex patterns in the data [10]. The inclusion of multiple algorithms enables comparative analysis, helping to determine the most suitable model for prediction. Visualization tools further enhance understanding by presenting results in an easy-to-interpret manner [11].

The developed system offers a complete platform for sleep disorder prediction through an interactive interface [25]. Users can upload datasets, preprocess them, train different models, and compare their performance using graphical representations. One of the main features of the system is the comparison module, which evaluates all algorithms based on multiple performance measures, allowing users to identify the best-performing model [16]. Additionally, the system includes a prediction module where users can upload new test data and obtain immediate results regarding the type of sleep disorder [18]. This real-time prediction capability makes the system useful for practical applications in healthcare analysis. The confusion matrix helps in understanding model accuracy by showing correct and incorrect classifications [24]. Although the system provides reliable results, its performance depends on the quality of the dataset used [19]. Future enhancements can focus on improving dataset diversity and incorporating advanced techniques to further increase prediction accuracy and system efficiency [20].

II. RELATED WORK

Alickovic and Subasi (2018) [3] proposed an ensemble-based Support Vector Machine model for automatic sleep stage classification using EEG signals. Their study focused on improving classification accuracy by combining multiple SVM classifiers rather than relying on a single model. The approach demonstrated that ensemble learning can effectively handle the variability present in sleep data and produce more stable results. The authors evaluated their model using standard performance metrics and showed that it outperformed several traditional techniques. Their findings highlighted the importance of combining classifiers to capture complex patterns in physiological signals. This work is significant as it provides a strong foundation for using hybrid machine learning approaches in sleep analysis. It also indicates that EEG-based classification systems can be enhanced through ensemble strategies, making them more reliable for real-world healthcare applications. The study contributes to the advancement of automated sleep monitoring systems by improving prediction consistency and robustness.

Mousavi et al. (2019) [10] introduced a deep convolutional neural network model for classifying sleep stages using single-channel EEG data. Their research aimed to reduce the complexity of multi-channel systems while maintaining high accuracy. By applying deep learning techniques, the model was able to automatically extract important features from raw EEG signals without the need for manual feature engineering. The results showed that the proposed CNN model achieved competitive performance compared to traditional machine learning methods. This study demonstrated the effectiveness of deep learning in handling complex biomedical signals and highlighted its potential in sleep disorder analysis. The use of a single EEG channel also made the system more practical and cost-effective for real-world applications. Their work supports the idea that deep neural networks can significantly improve the automation and accuracy of sleep stage classification systems.

Satapathy et al. (2021) [16] conducted a comprehensive performance analysis of various machine learning algorithms applied to automated sleep staging. The study compared multiple classifiers, including traditional and advanced methods, using different feature sets extracted from sleep data. Their evaluation focused on metrics such as accuracy, precision, and recall to determine the effectiveness of each algorithm. The results revealed that no single algorithm performs best in all scenarios, as performance depends on the nature of the dataset and selected features. However, ensemble and advanced models showed better overall results compared to simpler techniques. This research emphasized the importance of selecting appropriate models and feature representations for sleep analysis tasks. It also highlighted the role of comparative studies in identifying suitable algorithms for specific applications. The findings provide valuable insights for researchers working on sleep disorder prediction using machine learning.

Han and Oh (2023) [14] explored the application of multiple machine learning techniques to predict the severity of obstructive sleep apnea. Their work involved analyzing clinical and physiological data to build predictive models capable of classifying the severity levels of the disorder. The study compared different algorithms and demonstrated that machine learning methods can effectively support clinical decision-making by providing accurate predictions.

The authors highlighted that early detection of sleep apnea severity is essential for proper treatment planning and patient care. Their results showed that advanced models can capture complex relationships within healthcare data, improving prediction performance. This work contributes to the growing field of intelligent healthcare systems by demonstrating how data-driven approaches can enhance diagnosis. It also suggests that integrating such models into healthcare systems can reduce the burden on medical professionals and improve patient outcomes.

Hidayat (2023) [33] presented a machine learning approach for classifying sleep disorders using the Random Forest algorithm on a sleep health dataset. The study focused on analyzing lifestyle and health-related factors to identify patterns associated with different sleep conditions. The Random Forest model was chosen due to its ability to handle large datasets and reduce overfitting through ensemble learning. The results indicated that the model achieved reliable accuracy and could effectively classify sleep disorders. The study emphasized the importance of data quality and feature selection in improving model performance. It also demonstrated that machine learning techniques can be applied not only to physiological signals but also to general health datasets for sleep analysis. This work provides a practical approach for developing predictive systems that assist in identifying sleep-related issues and supports further research in healthcare data analytics.

III. DATASET DETAILS

The dataset used in this project focuses on sleep health and lifestyle factors to identify different types of sleep disorders. It consists of various attributes such as age, gender, occupation, sleep duration, quality of sleep, physical activity level, stress level, BMI category, heart rate, daily steps, and other related health indicators. Along with these input features, the dataset includes a target label representing the type of sleep disorder observed, such as insomnia, sleep apnea, or no disorder. These features play an important role in helping machine learning models learn patterns associated with different sleep conditions. Initially, the dataset is uploaded through the system interface and examined to ensure data consistency. Preprocessing steps are then applied, including handling missing values, encoding categorical variables, and transforming data into a suitable format. Visualizations are generated to show the distribution of sleep disorder types, helping to understand data patterns and detect any imbalance.

After preprocessing, the dataset is divided into two parts, where 80% is used for training the models and 20% is reserved for testing. The input features consist of health and lifestyle attributes, while the output represents the predicted sleep disorder category. This split ensures that the trained models can be evaluated effectively on unseen data. Various machine learning algorithms such as K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Decision Tree, Random Forest, and Artificial Neural Network (ANN) are applied to the dataset. Proper dataset preparation improves the learning capability of these models and enhances prediction performance.

To improve understanding, graphical representations such as confusion matrices and comparison charts are used. The confusion matrix helps visualize correct and incorrect predictions for each model, while performance metrics like accuracy, precision, recall, and F1-score provide a detailed evaluation. Among all models, the ANN algorithm shows better performance due to its ability to capture complex relationships in the dataset. By combining structured data preparation and clear visualization, the system enables effective comparison of models and supports accurate prediction of sleep disorders.

IV. PROPOSED METHODOLOGY

The proposed system is designed using a structured machine learning approach for predicting sleep disorders, with a primary focus on the Artificial Neural Network (ANN) model due to its superior

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performance. Initially, the dataset related to sleep health and lifestyle is uploaded through a user-friendly interface. This dataset includes various features such as sleep duration, stress levels, physical activity, heart rate, and other health-related parameters, along with labels representing different types of sleep disorders. After uploading, preprocessing steps are performed to enhance data quality, including handling missing values, encoding categorical data, and organizing the dataset into a suitable format for model training. Visualization techniques are applied to understand the distribution of sleep disorder categories, which helps in identifying patterns within the dataset. The processed dataset is then divided into training and testing sets, typically in an 80:20 ratio, to ensure proper evaluation of the model on unseen data.

The core of the proposed system lies in the implementation of the Artificial Neural Network (ANN), which is designed to effectively learn complex and non-linear relationships present in the dataset. The ANN model consists of multiple layers, including input, hidden, and output layers, where each neuron processes the input data and passes it through activation functions. During training, the model adjusts its weights using backpropagation to minimize prediction error and improve accuracy. Compared to traditional algorithms such as KNN, SVM, Decision Tree, and Random Forest, the ANN demonstrates better capability in capturing intricate data patterns. The model's performance is evaluated using metrics like accuracy, precision, recall, and F1-score, along with confusion matrix visualization, which provides a clear representation of correct and incorrect predictions. The ANN achieves the highest accuracy among all implemented models, making it the most reliable choice for this system.

In the final stage, the trained ANN model is integrated into the application for real-time prediction. Users can upload new test data, and the system processes it using the trained ANN to predict the type of sleep disorder. The output is displayed instantly, showing both the processed input and the predicted result. Additionally, a comparison module is included to present the performance of all models through graphical representations, highlighting the superiority of the ANN model. Confusion matrices and performance graphs further assist users in understanding the effectiveness of the model. This approach ensures accurate prediction, efficient data analysis, and a practical solution for identifying sleep disorders, making the system valuable for healthcare-related applications.

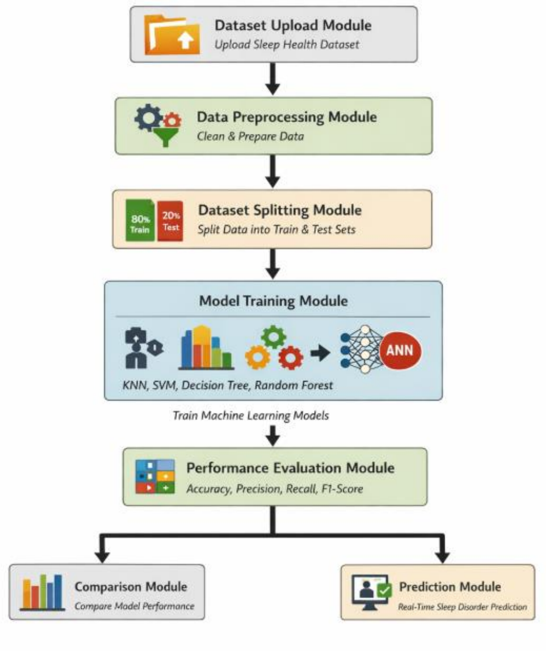

Figure [1]: System Architecture of Sleep Disorder Prediction

Figure [1] This diagram represents the overall workflow of the sleep disorder prediction system. It begins with user interaction through a graphical interface, where the user can upload the sleep health dataset, visualize data patterns, and perform predictions. After the dataset is uploaded, it moves to the preprocessing stage, where the data is cleaned, transformed, and prepared for analysis. This includes handling missing values, encoding categorical features, and generating visual graphs to understand the distribution of sleep disorder categories. The processed dataset is then split into two parts, with 80% used for training and 20% for testing, ensuring proper evaluation of the models. In the model training phase, different machine learning algorithms such as KNN, SVM, Decision Tree, Random Forest, and especially the Artificial Neural Network (ANN) are applied. Each model is trained using the training data and evaluated using metrics like accuracy, precision, recall, and F1-score, along with confusion matrix graphs to measure prediction performance. After training, the system compares all models using graphical representations, clearly showing that the ANN model provides the best results. Finally, in the prediction stage, users can upload new test data, and the system uses the trained ANN model to predict the type of sleep disorder, displaying the results directly through the interface.

V.RESULT AND DISCUSSION

The experimental results show that the developed sleep disorder prediction system works efficiently in

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classifying different types of sleep conditions based on the given dataset. After preprocessing the data, multiple machine learning algorithms were trained and evaluated, each producing varying levels of performance. Among all the models, the Artificial Neural Network (ANN) achieved the highest accuracy, demonstrating its strong ability to learn complex relationships within the dataset. Other algorithms such as Random Forest, Decision Tree, SVM, and KNN also produced satisfactory results, but their performance was comparatively lower than the ANN model.

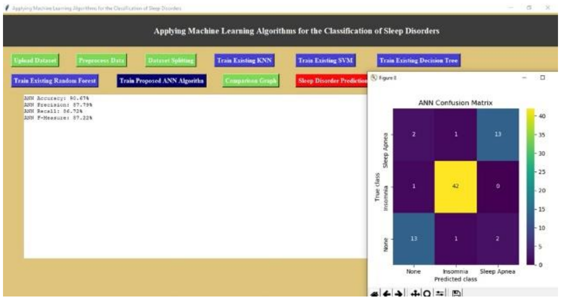
The evaluation process, which includes confusion matrix analysis and performance metrics like accuracy, precision, recall, and F1-score, indicates that most models were able to correctly classify a large portion of the data. The confusion matrices clearly show that the number of correct predictions is significantly higher than incorrect ones, reflecting the effectiveness of the trained models. The ANN model, in particular, shows better consistency in prediction with fewer misclassifications compared to other techniques.

The comparison graph further provides a clear understanding of how each algorithm performs across different evaluation parameters. This makes it easier to identify the most suitable model, where ANN stands out as the best-performing approach. In the final stage, when new test data is provided, the system successfully predicts the type of sleep disorder using the trained ANN model. This confirms that the system performs well in real-time scenarios and can deliver quick and reliable predictions. Overall, the results indicate that the system is effective in analyzing sleep health data and supporting accurate sleep disorder identification using machine learning techniques.

Algorithm Name	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Random Forest	88.00	84.10	82.56	82.96
KNN	85.33	81.23	79.70	79.67
ANN	90.67	87.79	86.72	87.22

Table [1]: Performance Evaluation of Sleep Disorder Prediction Models

Table [1] presents the comparison of different machine learning algorithms used for sleep disorder classification based on evaluation metrics such as accuracy, precision, recall, and F1-score. Among the models, the ANN algorithm achieves the highest accuracy of 90.67%, along with strong precision, recall, and F1-score values, indicating its effectiveness in capturing patterns and providing consistent predictions. The Random Forest model also shows good performance with an accuracy of 88.00% and balanced metric values, making it a reliable approach. On the other hand, the KNN algorithm records comparatively lower results with an accuracy of 85.33% and slightly reduced precision, recall, and F1-score, suggesting it is less effective for this dataset. Overall, the results highlight that the ANN model performs better than the other algorithms in terms of overall classification performance.



Figure[2]: ANN Model Performance and Confusion Matrix

The figure shows the evaluation results of the proposed Artificial Neural Network (ANN) model used for classifying sleep disorders. On the left side, important performance measures such as accuracy, precision, recall, and F1-score are displayed, highlighting how well the ANN model performs in predicting different categories. On the right side, a confusion matrix is presented, which provides a detailed view of the classification results for the three classes: “None,” “Insomnia,” and “Sleep Apnea.” Each cell in the confusion matrix indicates the number of predictions made by the model, where the diagonal values represent correct classifications and the off-diagonal values indicate errors. A higher number of values along the diagonal shows that the model is making accurate predictions for most cases, while fewer values in other positions reflect lower misclassification rates. This representation makes it easier to analyze how the model performs for each category individually. Overall, the figure indicates that the ANN model delivers strong performance with minimal errors, making it suitable for reliable sleep disorder prediction.

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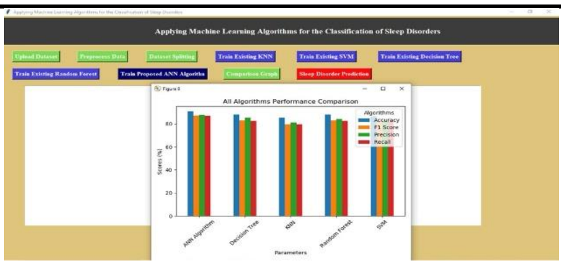

Figure[3]: Performance Comparison of Machine Learning Algorithms

The figure displays a bar chart comparing the performance of various machine learning algorithms used for sleep disorder classification. The models included in the comparison are ANN, Decision Tree, KNN, Random Forest, and SVM. The horizontal axis represents the different algorithms, while the vertical axis shows their performance values in terms of percentage. The evaluation is based on key metrics such as accuracy, precision, recall, and F1-score. From the chart, it is evident that the ANN model achieves the highest values across most of the evaluation parameters, indicating its superior performance. Random Forest and SVM also perform well and provide competitive results, whereas KNN and Decision Tree show comparatively lower scores. This visual comparison makes it easier to analyze the strengths and weaknesses of each algorithm. Overall, the figure highlights that ANN is the most effective model for this task and supports its selection for accurate and reliable sleep disorder prediction.

Figure[4]: Sleep Disorder Prediction Output Results

The figure presents the final prediction results produced by the sleep disorder classification system. It displays several input data records along with their predicted outcomes, such as “None” and “Sleep Apnea.” Each record consists of different feature values related to sleep habits and health conditions, which are processed by the trained model to determine the appropriate category.
The system evaluates these inputs based on patterns learned during training and assigns the most suitable sleep disorder label for each case. The output is organized in a clear format, making it easy to understand the relationship between input data and predicted results. This representation demonstrates the model’s ability to process multiple test samples efficiently and generate accurate predictions.
Overall, this figure reflects the final stage of the system, where users can upload new data and receive immediate prediction results. It highlights the practical usefulness of the system in real-time scenarios, supporting effective analysis and decision-making in sleep health assessment.

DISCUSSION

The results obtained from the system clearly demonstrate how effectively different machine learning models can predict sleep disorders from the given dataset. Multiple algorithms were applied, and their outputs indicate that the system is capable of classifying data into different sleep disorder categories with good accuracy. Among all the models, the Artificial Neural Network (ANN) shows the best performance, while other algorithms such as Random Forest, Decision Tree, SVM, and KNN provide reasonable but comparatively lower results. From the observations, it is evident that most of the instances are correctly classified, which means the models are successfully capturing meaningful patterns from the data.

The outcomes also emphasize the importance of proper data preprocessing. When the dataset is cleaned, organized, and divided into training and testing sets, the overall performance of the models improves significantly. The visualization graphs generated during preprocessing help in understanding how different sleep disorder categories are distributed, making the analysis more clear. Additionally, the confusion matrix provides a detailed view of prediction results, showing that correct classifications are higher than incorrect ones, which reflects the reliability of the system.

Another key point is the comparison of multiple algorithms. The comparison graph makes it easy to evaluate the performance of each model based on metrics such as accuracy, precision, recall, and F1-score. This helps in identifying the most suitable model, where ANN stands out as the most effective approach. The system also supports real-time prediction by allowing users to upload new test data and obtain immediate results. This makes the system practical and useful for real-world applications. Overall, the system provides an efficient way to analyze sleep data and compare machine learning models for accurate prediction of sleep disorders.

VI. CONCLUSION

This paper successfully developed a sleep disorder prediction system using multiple machine learning techniques, with a strong focus on the Artificial Neural Network (ANN) model. Algorithms such as KNN, SVM, Decision Tree, Random Forest, and ANN were implemented and tested on the sleep health dataset. The results indicate that the ANN model achieved the highest accuracy among all methods, showing its effectiveness in identifying complex patterns related to different sleep disorders. Proper data preprocessing, including cleaning, transformation, and splitting the dataset into training and testing sets, played an important role in improving model performance. The system not only predicts the type of sleep disorder but also provides detailed evaluation using confusion matrices and comparison graphs. These evaluation techniques help in clearly understanding how each model performs and assist in selecting the most suitable algorithm. The results demonstrate that the models, especially ANN, are capable of producing reliable predictions when trained with well-prepared data. The integration of the system with a user-friendly interface makes it simple to operate. Users can upload datasets, preprocess data, train different models, compare their performance, and test new data for prediction. The system delivers quick and accurate results, making it useful for real-time applications. Overall, this project presents an effective solution for sleep disorder prediction and highlights the importance of machine learning, particularly ANN, in healthcare data analysis.

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