# Application of Machine Learning Technology in Sleep Health

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**Abstract.** In the past, sleep has always been a very troublesome thing in people's minds. Long term sleep problems will greatly increase the risk of mental illness, especially for people with sleep disorders, which has become a major challenge. This article will conduct in-depth research on the medical issues of sleep health based on machine learning. Through the introduction of mask shaped breathing sensors, intelligent devices for real-time sleep staging, and intelligent sleep monitoring apps, as well as the operation process of these three technologies, the advantages and disadvantages of each device will be analyzed, providing long-term research solutions for future sleep medicine. Machine learning has been extended in multiple dimensions in the field of sleep health, analyzing and tracking data obtained from various sources to provide personalized guidance and suggestions for users, and ensuring people's sleep health.

**Keywords:** Machine learning, Sleep health, Real-time monitoring, K-means clustering, Artificial intelligence

## 1 Introduction

A healthy sleep is closely related to people's life and health, and its significance goes far beyond the concept of rest. It can maintain the functioning of the human body, ensure physiological health, and also enhance people's cognitive and psychological health. It has a significant impact on people's quality of life and social significance. According to experts from the National Sleep Foundation in the United States, the sleep duration for infants and young children is approximately 10 to 17 hours, for adolescents it is 8 to 10 hours, and for adults (including the elderly) it is 7 to 9 hours. Insufficient sleep time or poor sleep quality are not conducive to physical health and may even pose a threat to life. People often choose to occupy their nighttime sleep to create their own exclusive time for themselves because they have been running around all day. The significance of sleep has a significant impact, and people should truly understand and value sleep health. It not only represents sufficient sleep duration, but also is related to other factors such as time management, satisfaction, difficulty in falling asleep and falling back asleep, and the ability to maintain focus and clarity [1]. The pace of modern life is fast, and sleep problems are also very common. This article will conduct research on sleep health based on machine learning methods. Machine learning methods are highly suitable for predicting based on existing data. Therefore, researchers can use intelligent devices to record various data of

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users' sleep for medical prediction, and thus develop personalized sleep plans. For example, using user data to establish predictive models, comparing KNN, random forest, and support vector machine algorithms to standardize, tune, and evaluate the data to recommend personalized recommendations. At present, sleep disorders also have a significant impact on people's sleep health. They are widely present and pose great harm. To solve this problem, experts have conducted research combining knowledge of artificial intelligence and machine learning. Some researchers used the method of circular convolution neural network and a single unified model to simultaneously complete the PSG analysis of sleep staging, respiratory event detection, and limb motion detection. These three core tasks made important breakthroughs in improving its diagnostic rate [2]. Liu, M.Y. and Xie, Z.H. mainly study how wearable devices collect data through sensors and emphasize the combination of big data and machine learning algorithms to achieve the diagnosis and classification of sleep disorders [3]. This article mainly outlines the prediction of sleep health based on machine learning and its practical applications. Below, the paper will introduce the mainstream technologies of today one by one, including the machine learning methods used by researchers to process data, as well as the various research contents they have conducted. The paper will analyze the application and results of the experiments, identify their advantages and disadvantages, and corresponding populations. At the same time, the paper will provide suggestions and prospects related to this article.

## 2 Overview of mainstream technologies

### 2.1 Mask shaped breathing sensor

This is an intelligent sleep monitoring system created by combining machine learning with a mask type frictional nanogenerator. This system can not only accurately distinguish between oral and nasal breathing, but also has other functions, such as detecting changes in people's breathing frequency, identifying the angle of the human head, and snoring behavior during sleep. This technology introduces a new energy technology that converts mechanical energy into electrical energy, namely frictional nanogenerators, whose main principle is the coupling effect of contact electrification and electrostatic induction. Because researchers have found that if a polytetrafluoroethylene film and an aluminum electrode are in contact with each other and then separated, an electric current can be formed. Therefore, they have made the sensor in the shape of a mask to ensure that the airflow generated when the human body breathes automatically completes the contact and separation between the polytetrafluoroethylene film and the aluminum electrode, so it can output an electrical signal without the need for a battery. The monitoring system infers people's sleep stages by analyzing their breathing patterns, as factors such as respiratory frequency, depth, and regularity undergo characteristic changes during different sleep stages. M-TENG can detect subtle differences in breathing and convert these differences into corresponding signals, making it an excellent material for implementing this system. The machine learning method used in this system is K-means clustering, which automatically divides the data into five clusters through data collection and corresponds them to five sleep stages. This allows for monitoring of people's different sleep stages, enabling early detection of sleep health issues and intelligent solutions [4].

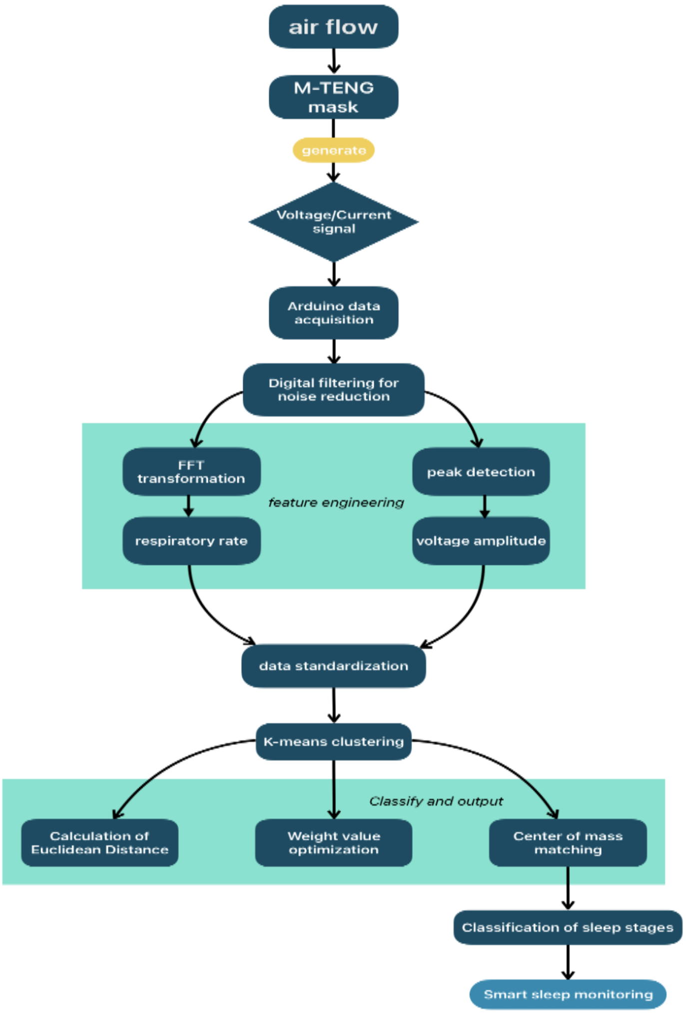


**Fig. 1.** Operation flowchart of mask shaped breathing sensor (Picture credit: Original)

The structural process of the entire technology is divided into four core stages. The first stage is the hardware setup and manufacturing. The main purpose of this stage is to use a 3D printer to print ABS-100 material to prepare the mask substrate. At the same time, optimizing the processing of PTFE film is a crucial step for the sensitivity of the entire sensor. Researchers have found that when the tilt angle is 60 degrees, the surface roughness is the highest, which means that there is a larger effective contact area, and therefore the sensor sensitivity is higher. On this technology, the aluminum electrode is placed close to the PTFE film to form a frictional nanogenerator. The second stage explains how to convert respiration into electrical signals. Research has shown that when the human body exhales, the thin film comes into contact with the electrode to form an electric current, and the signal can be output smoothly. When the human body inhales, the airflow direction is opposite, and the thin film separates from the electrode.

Therefore, every time the human body inhales, M-TENG completes a positive negative voltage waveform. The third stage is the collection and processing of data. To verify its accuracy, researchers use dual channel data synchronization acquisition, with DSI-24 dry motor EEG headset as the standard reference and M-TENG mask as the test system. The fourth stage is about machine learning classification. The first thing to clarify is the algorithm principle of K-means clustering, which completes the operation through four steps: initialization, allocation, update, and iteration [4]. Figure 1 shows the complete process of this technology, which realizes the full chain automation operation from physical energy collection to physiological information analysis, and from loading to intelligent diagnostic output.

The innovation of this technology comes from the fact that it does not require batteries, making it environmentally friendly and sustainable. At the same time, it can be designed in the shape of a face mask, which is easy to carry and wear in daily life. The monitoring system has high sensitivity and multi parameter detection, which can improve its practicality. This article argues that the advantages of this technology are not only the ability to monitor breathing, but also the ability to accurately identify people's head posture and snoring during sleep, as well as its ability to perform real-time monitoring throughout the night, which is helpful for self-management of one's health. The accompanying disadvantage is that there are few experimental subjects, and the influence of individual differences can lead to inaccurate data that requires further optimization. The solution strategy for environmental impact is not sufficient, such as weak electrical signal strength in high humidity environments, which may lead to unstable data. Another point is that this technology has not yet undergone clinical trials, and it is hoped that it can be validated in the future.

### 2.2 Intelligent device for real-time sleep staging

The core function of this design is mainly to collect and analyze dual channel EEG signals, and automatically identify various stages of user sleep. Researchers have found that TI's ADS1299 high-precision analog-to-digital conversion chip has the characteristics of low noise and 24 bit high resolution. Therefore, using this chip as an analog front-end can accurately and effectively collect EEG signals from the Fp1 and Fp2 frontal regions. The device is based on the FreeRTOS operating system for task scheduling, and uses the STM32L476RCT6 microcontroller as the main control unit for real-time preprocessing of signal segmentation, filtering, discrete wavelet transform, and other operations. For signal processing, the device decomposes EEG signals into characteristic waves such as δ, θ, α, β, spindle waves, and K complex waves, whose eigenvectors are power density and Hjorth parameters, where Hjorth parameters are activity, mobility, and complexity. The classifier of the device, combined with machine learning algorithms, uses support vector machines to implement five classifications of sleep stages in a microcontroller. At the same time, this technology can not only use Bluetooth to transmit data in real-time to external devices, but also store data in local SD cards. It is an intelligent device that combines practicality and good promotion value [5].

This technology first uses ADS1299 to collect dual channel EEG signals, and simulates the front-end integrated RC low-pass filtering and electrostatic protection circuit for isolation to reduce noise. Secondly, the signal is subjected to multiscale decomposition using discrete wavelet transform to reconstruct six characteristic waves, namely δ wave, θ wave, α wave, β wave, spindle wave, and K composite wave. Then extract features, including frequency domain features and time domain features. The researchers extracted 9 features from each channel, totaling 18 dimensional feature vectors. Then use the SVM classifier in machine learning to classify the feature vectors and output each sleep stage. Store the data on an SD card or transfer it to an external device using WH-BLE106. The final step is to verify the effectiveness of EEG signals and conduct simulation tests through open or closed eye experiments to ensure stable and normal system data [5]. Figure 2 is a schematic diagram of the technical process related to the entire device, while Figure 3 clearly presents the electrode positions of the device.

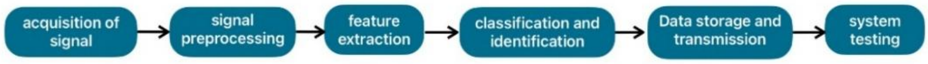


**Fig. 2.** Detailed operation process of the intelligent device technology (Picture credit: Original)

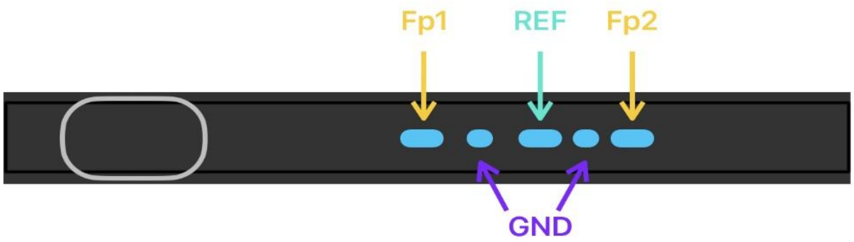


**Fig. 3.** Distribution of electrode positions (Picture credit: Original)

The feature of this intelligent device system that can be used for real-time sleep staging is its dual channel acquisition, which can help the system increase its information content and facilitate researchers to extract multi-dimensional features. At the same time, it can complete signal processing and classification on the MCU side, with a inference time of only 17.5ms, fully capable of real-time performance. The advantages of this system analyzed in this article are that it has a high degree of aggregation suitable for users to wear, and the use of SVM classifiers in resource utilization and inference speed is due to models such as MLP and RF. It cannot be ignored that the experimental verification of this study is very sufficient, which can ensure the good performance of the system. But the disadvantage is that the system lacks validation in real clinical environments, does not take into account individual differences and anti-interference capabilities, and can be further optimized in the future to enhance its usability and reliability in medical scenarios.

### 2.3 Intelligent sleep monitoring app

This app system mainly adopts a three-layer architecture consisting of a presentation layer, a business logic layer, and a data access layer. It uploads data manually entered by users or automatically collected by wearable devices to the server for storage and analysis. Its core technologies include two algorithms and a hybrid collaborative filtering model based on deep learning, among which the algorithms are Facebook Prophet algorithm and Isolation Forest algorithm. At the same time, in order to comprehensively evaluate users' sleep quality and provide personalized sleep recommendations, the system integrated the Pittsburgh Sleep Quality Index and the Ashens Insomnia Scale. Researchers collected real-time monitoring data from the system and user questionnaire evaluations [6].

The technology of the entire system is based on data. Firstly, researchers collect data on users' mood, exercise, or diet through users filling out questionnaires independently. The data such as bedtime, deep sleep duration, and number of flips are collected through the smart devices worn by users, and then uploaded to the server and stored in the database. Next, in order to predict the user's next optimal sleep time and sleep pattern, the server-side will call the Facebook Prophet algorithm to model the user's sleep data in time series and use the Isolation Forest algorithm to detect abnormal sleep data. After analyzing the data, the system generates a sleep monitoring report and provides personalized recommendations to users through the app. Finally, present the solutions provided by the system to users and ask them to rate the solutions. The system collects data and continuously optimizes the model, which will provide more reasonable recommendation results in the long run [6]. This article will present the operational process of the technology, as shown in Figure 4.

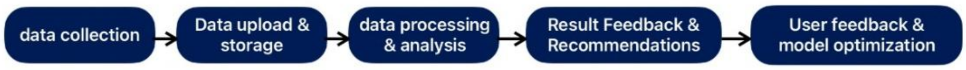


**Fig. 4.** Operation process of sleep monitoring app technology (Picture credit: Original)

The advantage of the project is that it can conduct multidimensional evaluations through user questionnaires, behavioral data, physiological data, and other dimensions. In addition, this technology can provide personalized suggestions for users and create their own sleep plans for each user. Due to the application of the Isolation Forest algorithm in this project, the system's anomaly detection capability is very strong, which is beneficial for detecting potential health issues of users. The disadvantage is that the model used in this app is highly dependent on user data and requires high user engagement. If users are not active, the effectiveness of the model will decrease. At the same time, it also faces privacy and security risks, as sensitive data may be generated during the process, so researchers need to encrypt the data.

## 3 Application and result analysis

As described in Chapter 2, the first technology utilizes M-TENG mask type respiratory sensors, which mainly monitor in real-time through respiratory airflow and the user's head angle during sleep. The experimental results show that this sensor can not only distinguish between mouth and nose breathing, snoring behavior, and user head turning, but also divide sleep stages into five categories with K-means clustering algorithm, and its accuracy is as high as 87.17% [4], Thus, it can be concluded that this technology has great potential for application in future daily life.

The system of the second technology is designed based on ADS1299 and STM32, and is composed of dual channel electroencephalogram (EEG) signals for real-time acquisition and staging. Combining wavelet transform, power spectral density (PSD), and Hjorth parameter to extract features, while introducing support vector machine for classification [5]. Researchers have verified the effectiveness of signal acquisition through experiments, improving the accuracy of data. This head mounted device has the functions of local storage and Bluetooth transportation, and will be applied in clinical and home settings in the future.

The third technology is an intelligent sleep monitoring app that can directly use user provided data, combined with Facebook Prophet algorithm and Isolation Forest algorithm to analyze the user's sleep quality, and can also predict the user's optimal sleep time, thereby providing personalized design solutions [6]. This project can optimize the model based on continuous feedback from users, achieving personalized management of user sleep.

## 4 Discussion

### 4.1 Challenge

The three technologies mentioned in this article all have machine learning based methods and basic principles, which can be applied in all fields and solve a wide range of problems. They also make significant contributions to the medical field studied in this article. However, the challenges it faces also come with it. Machine learning methods are very suitable for making predictions based on existing data, in other words, in the future, there is little possibility of achieving predictions for unknown data [7]. Although the rationality of the projects studied by the researchers is high and their technical applications are also very strong, these technologies have not been clinically tested yet. The actual situation of each user has subtle differences, so too many variables can lead to poor data quality and the accuracy of many results cannot be determined. Machine learning models need to be validated and their reliability determined before applying them to clinical medicine. Due to the lack of dataset research in the interdisciplinary field of sleep medicine and artificial intelligence, researchers need to focus more on this research and carry out more rigorous research projects to validate this model from all the different situations that patients present in clinical practice [8].

### 4.2 Prospect

Machine learning brings more opportunities to the field of sleep medicine in the future. Although it has limitations, it can enable researchers to extract large amounts of data from various sources and user generated data through wearable and mobile devices [9]. At the same time, artificial intelligence can achieve precise diagnosis and personalized management in sleep medicine, but before entering sleep clinics, all algorithms will undergo very strict supervision and very standard testing before they can be applied [10]. Machine learning is driving the transformation of sleep health from traditional models to precision medicine. Currently, this method is widely used in automatic sleep staging, personalized health management, and other areas. It optimizes sleep recommendations and provides treatment plans through methods such as EEG signals and user data. In the future, sleep devices will be applied in households, and their data information must be strictly controlled to avoid information leakage and protect users' privacy and security. At the same time, combining sleep health with the prediction of mental illness in healthcare. Studies have shown that poor sleep can lead to emotional instability, increased risk of depression and anxiety, and increased risk-taking behavior and substance use in behavior. Long term sleep problems can lead to serious mental illness and even suicide risk [11]. It can be seen that sleep health will become an important research topic in the medical field in the future.

## 5 Conclusion

In summary, machine learning has deeply embedded multiple dimensions of sleep health. This algorithm can be used to achieve sleep staging of users' brainwaves, and real-time monitoring of users can be achieved through wearable devices. Through the data, sleep structure tracking can be achieved in homes or medical settings. Based on machine learning models, personalized sleep plans can be developed for users by analyzing various data such as blood oxygen and heart rate. With its powerful fusion ability, it integrates users' physiological data, environmental data, and behavioral data to provide accurate sleep recommendations. In the future, machine learning will continue to be applied in the field of sleep health, and the various technologies mentioned in this article will be applied to clinical practice to achieve a complete and accurate sleep model. At the same time, the privacy of sleep data must be strictly managed, making sleep an actively optimized health resource.

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