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Detection of Sleep Paralysis by using IoT Based Device and Its Relationship Between Sleep Paralysis And Sleep Quality

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Abstract

When a person wakes up in the middle of the night, they are paralyzed. Despite the fact that most episodes are associated with extreme terror and some might cause clinically significant suffering, little is understood about the experience. This study will analyze existing research on the relationship between sleep paralyses and sleep in general. Many studies have connected poor sleep quality to an increased risk of sleep paralysis. Awake yet unable to act, sleep paralysis occurs. This might happen between awake and sleeping. The problem is approached in three steps: Data collection, data storage, calculation and machine learning prediction of sleep paralysis. The data came from the Smart Device. The dataset has several (independent) and dependent variables (Outcome). This device has been put to the test. Each exam has its own set of features and predicted outcomes. To assess the system's validity, we executed a posture recognition accuracy test. The device was hidden on top of the bed. The controller is in charge of measurement and data collection. Experiments were conducted by collecting pressure data from a patient lying down. The person acted out his sleeping positions on a mat for a while. Machine learning has been used to predict sleep paralysis. By comparing sleep postures to the outcome, we were able to show the link between sleep qualities and sleep paralysis. Machine learning approaches have been used to predict sleep paralysis. Comparing sleeping positions with the results showed the link between sleep quality and sleep paralysis. Sleep paralysis correlates with poor sleep quality. The Random Forest model has the highest accuracy of 91.9 percent in predicting sleep paralysis in the given dataset. SVM with Linear Kernel was 80.49 percent accurate, RBF was 42.68 percent, and Polynomial was 47.56 percent. The accuracy of logistic regression was 76.83 percent. KNN had a dismal performance of 60.98%. Decision Trees and Gradient Boosting both fared well at 85.37 percent.

Keywords: Sleep paralysis, Machine Learning, Deep Learning

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1. Introduction

When a person wakes up in the middle of the night and is unable to move, this is known as sleep paralysis. Despite the fact that the great majority of episodes are associated with acute fear and can result in clinically significant levels of pain in a small number of patients, little is understood about the experience. There is a lot of material about the relationship between sleep paralysis and sleep in general out there, and the goal of this study is to go over it all. Poor sleep quality has been associated to an increased risk of sleep paralysis in many studies when it comes to subjective sleep features. Furthermore, sleep paralysis has been connected to insomnia symptoms but not to an actual insomnia disorder. According to studies, sleep paralysis is linked to a variety of strange and frightening sleep experiences, including nightmares, exploding head syndrome, and lucid dreaming. Sleep paralysis is a "mixed state of consciousness," combining aspects of rapid eye movement sleep and alertness, according to objective tests.

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Historical history of Sleep paralysis is a condition in which voluntary muscular action is blocked at the start of sleep or after waking up from sleep. Respiratory and ocular movements are unaffected, and the surrounding environment is clearly perceived. Rapid eye movement (REM) sleep is most closely associated with sleep paralysis. Vivid dreams are linked to REM sleep. There is total muscular atonia for the whole REM sleep period (except for the eyes and respiratory system). GABA and glycine blocking motor neurons may be responsible for this paralysis, which is a natural component of normal rapid eye movement sleep. During dreaming, when the cerebral cortex, including the motor cortex, is engaged, one probable cause of muscle paralysis is to prevent unneeded harmful actions. As a result, REM-induced muscle paralysis that lasts into the waking state is assumed to be the cause of sleep paralysis.

Approximately 75% of sleep paralysis episodes are accompanied with a wide range of odd and often frightening hallucinations, in addition to chronic muscle atonia. These hallucinations are typically classified into three groups. The demonic presence in the room, as well as dramatic multi-sensory hallucinations of the intruder in the bedroom, are among the invader's hallucinations. A sensation of chest pressure, commonly accompanied by a feeling of being choked, is described as an incubus hallucination. These two sorts of hallucinations frequently happen at the same time. Vestibular movement (V-M) hallucinations are the third group, and they include hallucination, feelings beyond the body, and self-vision investigation outside the body. The awake state of dreams produced by REM may be responsible for the hallucinogenic character of sleep paralysis. The pictures of dreams and sleep paralysis, on the other hand, are very distinct. Fear is responsible for the great majority of sleep paralysis events (up to 90%). This is in contrast to the fact that roughly 30% of dreams are considered frightening. Sleep paralysis episodes are emotionally consistent, with a more aggressive "character," according to a study comparing sleep paralysis with the content of dream reports. "Dreamers" become more aggressive victims when compared to regular dreams (Parker JD and Blackmore SJ, 2002). Approximately 10% of those who have had sleep paralysis say the onset causes clinically considerable pain, and 7% say it interferes with other aspects of their lives. Nonetheless, not every experience is terrifying. According to a poll, up to 20% of sleep paralysis patients have had a happy experience.

The fact that the subject is awake during the experience distinguishes sleep paralysis from other states (such as dreaming and nightmares). However, determining sobriety, especially when using subjective accounts, can be difficult. The eyes are indeed open during the attack, and the brain activity has shifted from REM sleep activity to a combination of REM sleep and similar awake features, according to objective sleep paralysis assessments. This is more difficult to detect subjectively because the onset of sleep paralysis can be misinterpreted as a dream in which they believe they are awake rather than truly being awake. The phenomena of false waking, in fact, depicts a state that is remarkably similar. False awakening describes an individual's false belief that he has awakened, only to find later that the experienced awakening was merely a dream. False awakenings, like sleep paralysis, are said to be quite lifelike and can induce anxiety in certain people.

The lifetime prevalence of sleep paralysis is thought to be very variable. According to a systematic review, the lifetime prevalence rate is 7.6%. (individual studies estimate 2 percent to 60 percent). According to a meta-analysis of the incubus experience, the lifetime prevalence rate was found to be 11%. Sleep paralysis is caused by a variety of factors. Students and mentally ill people are more likely to have sleep paralysis. Patients with post-traumatic stress disorder and panic disorder, in particular, have been observed to have a higher risk of sleep paralysis. Increased stress and exposure to potentially dangerous events (such as family member death, anxiety, and general poor mental health) appeared to be linked to the existence of the episode in non-clinical samples. Perhaps unsurprisingly, the presence and frequency of sleep paralysis are linked to poor sleep quality in general. Understanding the nature of this link is critical for furthering our basic understanding of sleep paralysis and developing treatments to lessen or perhaps eliminate the most severe forms of the condition. The goal of this paper is to go over the latest research on sleep paralysis and sleep quality. There will be a review of research on the subjective and objective elements of sleep, as well as their relevance to sleep paralysis. Other sleep problems, such as sleep paralysis, will be discussed as well. The following are the goals of this study:

Detection of sleep paralysis by the use of different sensors

- Relationship between sleep quality and sleep paralysis.
- To assess the knowledge about Sleep Paralysis and different reasons behind this condition.
- To evaluate the effect of Sleep Paralysis on the physical and mental health of the targeted people.
- Comparison between sleep quality and Sleep Paralysis.
- Implementation of different tools and techniques to detect Sleep Paralysis.

The following are the study's main aspects and contributions: We're employing a cutting-edge technology to look for indicators of sleep paralysis to better understand the association between poor sleep quality and sleep paralysis. In contrast to other states such as dreaming and nightmares, sleep paralysis happens when the person is awake. According to a study, sleep paralysis episodes are more emotionally consistent, include more aggressive "characters," and the "dreamer" is more frequently attacked than in ordinary dreams.s

2. Related Work

Sleep paralysis occurs when a person's muscles are unable to move independently for a short period of time before or after falling asleep or waking up. There is no sign of disease if respiration and ocular movements are consistent, as well as a clear awareness of the surroundings. It is most closely connected with REM sleep, which is characterized by rapid eye movement. REM sleep allows for more vivid dreams. REM sleep is characterized by a lack of movement in the body. GABA and glycine may operate on motor neurons to cease their activity, causing natural R.E.M. sleep to feature a sort of paralysis. This muscle paralysis is most likely the result of the motor cortex of the brain being activated while dreaming. Sleep paralysis is thought to be caused by REM-induced muscular paralysis that extends into the waking state. Sleep paralysis is frequently accompanied by a wide spectrum of odd and frightening hallucinations, which can occur in up to 75% of cases. There are three sorts of hallucinations that most people experience. The intruder's hallucinations include intense multi-sensory hallucinations in the bedroom, in addition to the demonic presence. A feeling of pressure in the chest, typically accompanied by a sense of choking, characterizes incubus hallucinations. This and other hallucinations are frequently observed together. The third group of V-M (Vibration-Motion) hallucinations includes hallucinations and sensations outside of the body.

Sleep paralysis's hallucinatory nature may be due to the REM-induced waking state of dreams. Dreams and sleep paralysis, on the other hand, present very distinct visuals. Anxiety and/or anxiety are the most common causes of sleep paralysis (up to 90% of the time). Only approximately 30% of people report nightmares as frightening. The "character" of sleep paralysis episodes is more aggressive and emotionally consistent, according to a study comparing the content of dream reports with sleep paralysis experiences. Those who are victims of "dreamers" are more aggressive than those who are victims of ordinary dreams. 10% of those who have had sleep paralysis say the initial cause was clinically significant pain, and 7% say the condition interferes with other aspects of their lives. Despite this, not all of the tales are frightening. According to a poll, up to 20% of sleep paralysis patients have had a positive experience.

A person is awake during a sleep paralysis episode, which distinguishes it from other forms of sleep experiences (such as daydreaming or nightmares). Determining a person's sobriety is challenging, especially when relying on subjective reports. The objective evaluation of sleep paralysis was undertaken to confirm that the eyes are open and the brain activity has switched from REM sleep to some combination of REM sleep and similar awake features. Because the onset of sleep paralysis can be seen as a dream in which individuals believe they are awake rather than truly being awake, subjective assessment is more difficult. Even the term "false awakened" refers to a similar situation: when a person wakes up feeling he has awoken, only to discover later that the waking was only a dream, he is said to have had a false awakening. False awakenings, such as sleep paralysis, are thought to be very common and might make some people anxious.

The prevalence of sleep paralysis varies greatly throughout time. According to a comprehensive review, the lifetime prevalence rate is 7.6%. (individual studies estimate 2 percent to 60 percent). The lifetime prevalence rate of the incubus experience was found to be 11% in a meta-analysis. A variety of things can influence sleep paralysis. Sleep paralysis is more common in students and mentally ill people than in the general population. Sleep paralysis was more common in patients with post-traumatic stress disorder (PTSD) and panic disorder (panic disorder). Higher stress and exposure to potentially risky events (such as the death of a family member) were found to be linked with the occurrence of the episode in non-clinical samples. It's not surprising that poor sleep quality is linked to the occurrence of sleep paralysis. We need to better understand the nature of this link in order to develop treatments that can minimize or even eliminate the most severe cases of sleep paralysis. The major purpose of this essay is to go over the existing research on sleep paralysis and sleep quality. A review of sleep research and its application to sleep paralysis will be presented. Other sleep issues will be discussed, such as sleep paralysis.

[1] provide information about the condition of sleeping paralysis Sleep paralysis was connected to a variety of factors, and certain common features emerged. Sleep paralysis appears to be linked to post-traumatic stress disorder, panic disorder, and psychiatric diseases. The limitations of current literature, prospective research directions, and clinical implications are discussed. Each research's size, study location, participant gender and age, sleep paralysis measure, and associated variable(s) were all extracted.[2] provided new insight on the sleeping paralysis Sleep paralysis occurs when a person is about to fall asleep in a supine position and learns that she or he is unable to speak, walk, or cry. People frequently assume they are being pursued by evil entities, and patients occasionally recount similar experiences. They also get the impression that evil is following them, sitting behind them, waiting to strike. The reasons of sleep paralysis will be discussed in this article. [3] give data on the relationship between sleeping paralysis and sleep quality. The researchers wanted to see if there was a link between poor sleep and paralysis among Paraguayan medical students. An analytical cross-sectional study of first- and second-year medical students was undertaken in 2018 at Paraguay's Universidad Del Pacfico. The Pittsburgh sleep quality index, as well as self-reported sleep paralysis, were all included in the self-administered questionnaire. Simple and multivariate regression models were used to calculate prevalence ratios. Almost half of the subjects had sleep paralysis and were insomniacs. There is a relationship between sleep quality and sleep paralysis, according to our findings. Sex and age were also associated with a higher frequency of sleep paralysis among medical students.

[4] Please provide details on the sleeping paralysis. Their research looks at a variety of sleep paralysis experiences from the perspectives of enactive cognition and cultural neurophenomenology. The present state of neurophysiology and related illnesses, as well as various sleep paralysis treatment options, are described. Because it is characterized by a hybrid state of dreaming and awake, sleep paralysis provides a unique view into the phenomenology of spontaneous cognition in sleep.

[5] Paralysis patients can benefit from wearable multi-sensor gesture recognition. They propose the design, implementation, and evaluation of a multi-sensor gesture recognition system based on comfortable and low-power wearable sensors. They developed an EOG-based headpiece with textile electrodes and a glove that used flex sensors and an accelerometer to monitor eye and hand motions. We show that when utilized to control appliances remotely in a home, the gestures exhibit good accuracy, latency, and energy consumption characteristics.

[6] College students are paralyzed by sleep. A total of 1,115 college students from a large Southwest university

were surveyed. The majority of the participants were Hispanic (94%) and female (70%), with 35% having experienced sleep paralysis. SP, which is linked to increased stress and poor sleep, affects about one-third of undergraduate students.

[7] In Italy, a study is causing paralysis. According to a patient who has been diagnosed with sleep paralysis, the ailment is thought to be caused by a fabled monster known as the Pandafeche in Italy. As many as 42% of SP sufferers believe they will die as a result of the event, and 78% of people said they had some sort of hallucination while taking part in the study. The findings suggest that cultural notions about SP in Italy may have a significant impact on certain aspects of the experience — a type of mind-body contact – which is consistent with earlier research findings.

[8] Give details on the connections between sleep paralysis and sleep quality. In terms of subjective sleep characteristics, poor sleep quality has been related in a number of studies to an increased risk of sleep paralysis. In addition, insomnia symptoms have been connected to sleep paralysis (although not a confirmed insomnia disease). Sleep paralysis has been linked to other strange and/or dangerous sleep experiences such as nightmares, exploding head syndrome, and lucid dreaming. According to the limited literature known to date, sleep paralysis is a "mixed" state of awareness, combining features of rapid eye movement sleep with elements of awake.Future research should focus on longitudinal designs to clarify the direction of effects, and should more frequently use a broader assessment of sleep paralysis that better captures associated aspects including hallucinations, terror, and distress.

The [9] relationship between sleep quality and sleep paralysis is being investigated. The researchers wanted to see if there was any connection between sleep paralysis, insomnia, and sleep quality. A cross-sectional study of medical undergraduates at a Pakistani medical college was done. A survey with segment data, a sleep paralysis questionnaire, an insomnia scale called the Insomnia Severity Index, and a sleep quality scale called the Pittsberg Sleep Quality Index was completed by 100 persons. The frequency of sleep paralysis and insomnia, as well as the quality of one's sleep, are linked. Better sleep patterns, increased sleep quality, and the possible eradication of insomnia should all be implemented to avoid the horrible experience of sleep paralysis.

The [10] relationship between sleeping paralysis and waking life is being investigated. Sleep paralysis and lucid dreaming, according to anecdotal evidence, are comparable but separate phenomena. Dissociative experiences during awake are paralleled by dissociative experiences during REM sleep. Lucid dreaming was linked to a positive constructive daydreaming style, while sleep paralysis was linked to poor sleep quality, anxiety, and life stress.

The [11] sleeping paralysis is being researched. The sleep paralysis and accompanying auditory and tactile hallucinations began three years ago and have gotten worse in the preceding year, making it difficult for the patient to sleep. The episodes, which were exceedingly distressing, had a negative impact on the patient's sleep, school performance, and social function. Her symptoms were fully relieved once she was taken a selective serotonin reuptake inhibitor.

It [12] is investigated the association between sleep paralysis and sleep quality. When it comes to subjective sleep features, it's been established that poorer sleep quality is linked to a higher risk of sleep paralysis. Sleep paralysis is a form of "mixed" state of consciousness in which a person's rapid movement is combined with features of awake. In order to discern between the directions of impacts, future research should focus on longitudinal studies.

Sleep [13] duration and sleep quality are investigated in both independent and mixed connections. In both men and women, sleep duration and quality are linked to physical and mental health issues. According to the findings, chronic pain, obsessive compulsive disorder, and any mental illness are all linked to poor sleep and short sleep. The most comorbidities were shown to be associated with a mix of poor sleep and short sleep. It's likely that sleep quality, rather than sleep time, is a better determinant of psychological and general wellness.

A [14] sophisticated system for detecting sleep paralysis is being researched. Sleep paralysis is a common occurrence during REM (rapid eye movement) sleep and is closely linked to sleep atonia. The EEG, EOG, and EMG responses were used to develop an electronic circuit that reads the signal and validates whether it is positive or negative. If the reaction is positive, the circuit transmits the signal to a database for recording before sending it to a person standing next to you.

A [15]clever sleep posture recognition system based on CNN is shown. The sensors monitor the distribution of body pressure on the mat during sleep, and the authors use a convolution neural network (CNN) to analyze the data and distinguish different sleeping postures. The technology can distinguish between a person's posture and the right and left lateral postures while they are facing up or down. A real-time feedback system is also provided via a smartphone application that maintains track of the user's posture and delivers a warning if the user is about to tumble out of bed. It also creates synopses of postures and activities performed throughout a given time period. We also conducted tests to assess the prototype's accuracy, and the suggested system achieved a classification accuracy of roughly 90% in the tests.

[16] Please provide details about the isolated sleep paralysis. During periods of sleep paralysis, the subject awakens to quick eye-based atonia mixed with cognitive awareness. This is usually a frightening encounter that is followed by vivid, awake dreams (i.e., hallucinations). Sleep paralysis is referred to as "isolated" when it occurs without the presence of narcolepsy or other medical conditions. Nonsleep professionals are ignorant of the disease due to the disorder's unique nature, patients' hesitancy to disclose episodes for fear of shame, and a lack of training throughout medical residencies and graduate degrees. After addressing them and providing recommendations for correct diagnosis, differential diagnosis, and patient selection, the prospective therapy options are explored. It is discussed the relationship between sleep quality and isolated sleep paralysis. Isolated sleep paralysis (ISP) is a kind of REM sleep parasomnia with a specific meaning in Chinese culture. During REM sleep, obstructive sleep apnea (OSA) worsens more frequently. The link between ISP and OSA is murky. The researchers wanted to explore how ISP influenced sleep and quality of life in Chinese-Taiwanese OSA patients. ISP was linked to

excessive daytime drowsiness, poor sleep quality, and poor mental health-related quality of life in Chinese-Taiwanese OSA patients.

[18] Provide information on sleep paralysis as a result of a sleep disruption. We were able to generate six bouts of lSP during the sleep interruptions (9.4 percent). With the exception of one episode of ISP, all occurrences of SOREMP were induced by ISP, suggesting a strong link between the two. We documented verbal reports on ISP experiences as well as the polysomnogram during the ISP (PSG). All of the ISP participants were unable to move and were aware that they were all laying in the same laboratory. The individuals, with the exception of one, all reported auditory-visual hallucinations and negative emotions. PSG recordings during ISP showed a REM/W stage dissociated state, with many alpha electroencephalographs and muscle atonia as evidenced on the tonic electromyogram. ISP differs from other detached states such lucid dreaming, nocturnal panic attacks, and REM sleep behavior disorders, according to the PSG recordings. Some sleep factors are compared between ISP and non-ISP nights. The parallels and distinctions between ISP and sleep paralysis in narcolepsy are also discussed.

[19] Inform others about sleep paralysis. As potential predictors, psychosocial factors and subjective sleep quality (SSQ) were investigated. The retrospective online data from 159 participants aged 18 and up was evaluated using MANOVA, multiple regression, and independent samples t-tests. Participants who are more scared of ISP scored higher on two measures: external other LOC and social phobia, according to the MANOVA results. MANOVA revealed no significant differences in SSQ in relation to psychosocial variables, while independent sample t-tests failed to separate fear parameters for DBAS and SSQ (poor sleep was found for both parameters). Providers of therapeutic therapies should examine concerns such as social phobia and external other LOC when it comes to poor sleep quality for those with ISP. Sleep quality examinations may be valuable for those who are scared to report ISP sleep difficulty because long-term poor sleep can put certain people at risk for harmful health outcomes.

[20] In 11 individuals with hemi diaphragm paralysis or severe weakness, an average of 8.2 occurrences per hour during non-rapid eye movement (NREM) sleep and 26.0 percent during rapid eye movement sleep were recorded. In NREM sleep (15.35.3 against 8.9%), diaphragm EMG was double that of the control group (15.35.3 compared 8.9%), and it escalated in REM sleep (20.06.9% max), while normal participants maintained the same level of activation (6.23.1 percent max). Patients who care for them are more likely to develop sleep-disordered breathing while awake. [21] We researched connected gadgets, sensor technology, trackers, telemonitoring, wireless communication, and real-time home tracking systems for physicians. Despite the fact that these technologies have therapeutic applications, they are underutilized in the healthcare industry. Wearable sensors could improve physician-patient relationships, increase patient autonomy and involvement, and enable new remote monitoring systems that will change healthcare administration and spending.

[22] For all phases of sleep, recordings of healthy adults yielded F1 values above 0.8, with the exception of stage 1, which had an F1 score of 0.5. Performance on patient data improved after patient data was integrated into the training process. MSEs are short sleep fragmentation that last between 3 and 15 seconds. Future MSE detection approaches should utilize the neural network's temporal structure. Engineering features were employed to detect the MSE using a support vector machine and a random forest.

A medical issue known as sleep disturbance causes a person's natural sleeping schedule to be interrupted. Several sleep problems can have serious consequences for a person's physical, emotional, and social well-being, as well as mortality, if left untreated. Some of the most common sleep disorders include restless leg syndrome, narcolepsy, sleepwalking, and sleep paralysis. The primary method for diagnosing sleep apnea is polysomnography, which is usually done in a supervised clinic. The vital signs and biological processes of the patient are continuously monitored and documented. As part of this proposed study, researchers developed a continuous monitoring device that measures spo2, blood pressure, and heart rate in real time. On a liquid crystal display, these parameters are presented. The observed physiological parameters can be transferred to a smartphone [23] through Bluetooth or Wi-Fi for further analysis. The researchers were able to show that this wearable gadget can dependably provide diagnostic data using a non-invasive cuff-less manner. The low-cost equipment that allows continuous monitoring of sleep apnea disorder was created to avoid a lengthy and time-consuming operation.

EEG signal analysis was utilized to detect sleep paralysis during REM sleep. The signals from your EEG, EOG, and EMG are read by a circuit that checks whether they are positive or negative before transmitting them to a database and then to another person standing next to you. Atonia The paralysis that occurs spontaneously as a result of REM (rapid eye movement) sleep is known as REM Atonia. Rapid eye movement and EMG signals, which are generated by muscular activity, are crucial components of REM Atonia, which is closely associated to REM sleep. A person suffering from sleep paralysis is unable to communicate, and an EMG interface can determine whether or not muscular activation is possible. [24].

The rapid detection and treatment of stroke is critical to a positive clinical outcome. It can be difficult to pinpoint when a stroke occurred in those who have Wake-Up Stroke (WUS), and as a result, the best window of opportunity for treatment is usually missed. [25] demonstrate a wristband-based gadget that detects strokes in real time while sleeping (RISK- Sleep). It's a low-cost, practical approach for detecting early strokes in the sleep environment that may be utilized on a daily basis. The RISK-Sleep model is built around an abnormal sleep motion model with abnormal intensity and frequency. Hemiparesis sleep motion patterns and full hemiparesis and paralysis emergency are the two forms of problems. Based on the model, we're searching for the best classifier that can use a sliding window to examine the two anomalous motion patterns indicated above in real time. For performance evaluation, the authors collected sleep data from 30 healthy subjects and 14 stroke patients with hemiparesis. RISK-classification According to the findings of the evaluation, sleep's accuracy in abnormal intensity with a 146-minute window in the KNN classifier with SFS feature selection is 96.00 percent. Without feature selection, the SVM classifier achieves 100% classification accuracy with a 108-minute window of aberrant frequency. In patients with Bell's palsy, Functional Electrical Stimulation (FES) can help restore function to the orbicularis oculi (an eyelid-closing muscle). This study [26] proposes synchronized blink function restoration, in which EMG [26] electrodes are utilized to monitor the healthy orbicularis oculi and a corresponding pulse is supplied to the non-functional muscle almost instantly. This study shows a low-power blink restoration system that only uses low-power analogue blocks. A basic analogue design replaces typical digital noise reduction and filters. As a result, power was reduced by two orders of magnitude, while surface area was reduced by almost a hundred orders of magnitude. A motion artifact-related false positive is also taken care The technology also handles false positives caused by motion artifacts. When the system is not in use, it goes into a simple monostable system-based auto sleep mode. This UMC 180nm CMOS-based analogue blink restoration system has a pre-amplifier gain of 20dB at 270Hz to 470Hz, a CMRR of 70dB, and input referred noise of less than 2 Vrms. It requires 6 NW of power and takes up 0.095 mm2 of area at 1.2V supply voltage.

Academics have been captivated by how the human brain works for the past decade. The development of BCIs is becoming an increasingly important aspect of brain research. [27] A variety of techniques can be used to record and evaluate brain signals. This method can be used to record the electrical activity of the scalp. Investigate the difference between the signal of the mind awake and the signal of the mind asleep in this study. Only a few research in the field use EEG sensors with many channels to measure mind activity. In this experiment, employ an EEG instrument with a single channel technique to evaluate activity. This research does not include human paralysis or coma.

Sleeping takes up over a third of a day, and it is a necessary part of a human's intellectual and physiological recovery. For the body's green rejuvenation, a good night's sleep is important. Sleep apnea can have a significant impact on a person's ability to work. Obstructive sleep apnea hypopnea is one of the most frequent sleep disorders (OSA). The ECG and respiration signals are the most commonly studied aspects of apnea, rather than the entire Polysomnographic signal set (PSG). [28]One or a few PSG signals, rather than all PSG signals, must be considered in order to detect Apnea-related sleep difficulties. This study's findings can be used to diagnose and treat sleep disorders, and it offers a strategy for doing so. By examining the sleep EEG and uncovering novel sleep stages, doctors can better understand and treat sleep problems. According to this theory, scientists have used EEG data from Physionet and the MIT-BIH polysomnographic database to study and predict sleep ranges. On 18 records with 10197 epochs, an Apnea detection accuracy of 95.9% was achieved using a Machine Ensemble Bagged Tree classifier is a learning classifier.

Sleep quality has a substantial impact on physical and emotional well-being, daytime productivity, and nighttime safety. Getting adequate excellent quality sleep has been demonstrated to reduce the risk of acquiring chronic disease and depression. Sleep helps the brain work normally, which can boost productivity and lower the risk of an accident caused by tiredness. In order to assess the quality of sleep, a reliable continuous monitoring system is required. With the rapid growth of sensor and mobile technologies, as well as the advent of internet-of-things technology, a reliable system for monitoring sleep quality might be developed. This research looked into the internet of things for sleep quality monitoring devices. The internet of things can help with sleep quality monitoring, but there are still many questions to be solved in this area. [29Sleep paralysis, or the inability to move or talk during the transitional periods between sleep and waking, such as when you first fall asleep or when you first wake up, is conceivable. A multitude of vivid and intense sensory feelings, including mentation in visual, aural, and tactile modalities, as well as a distinct sense of presence, may be experienced in addition to the sensation of paralysis [4].

In a ubiquitous computing environment, "Helena" is a breakthrough health and sleep nursing assistant that can be mounted on a bed frame to continually monitor sleep activities (entry and exit of bed, movement and posture changes), vital signs (heart rate and respiration rate), and falls from bed. The smart sensor detects bed vibrations induced by body movements and analyzes them using modern signal processing techniques and machine learning algorithms to characterize sleep activities and vital markers. Among other things, the device can provide information on sleep patterns, generate real-time results, and facilitate continuous sleep assessment and health tracking. The novel technology for detecting falls from bed has never been tried before and has the potential to transform the lives of those who live in high-risk regions, such as the elderly. The system's performance was evaluated with extensive tests and validations using FDA-approved and wearable devices, and the results were published. [30]. In terms of accuracy, our system identifies on-bed (entries) movements 99.5 percent of the time, off-bed (exits) movements 99.73 percent of the time, movements on the bed 97.92 percent of the time, posture changes 92.08 percent, and falls from bed 97 percent of the time. When compared to an Apple Watch Series 4, the system's estimate of respiration rate (RR) was 0.89 respirations per minute lower than an FDA (Food and Drug Administration) oximeter and a metronome, which were both higher than the estimate of an Apple Watch Series 4.

3. Proposed Work

This section provides a full summary of the approach, sensors, and dataset description. The sense of being awake but unable to act is known as sleep paralysis. This phenomena can occur while a person is transitioning from waking to sleeping. During these transitions, a few seconds or minutes of inactivity may occur. It's not just that you'll wake up unable to move a muscle or make a sound; it's also that, as in the preceding example, this experience is frequently accompanied with terrifying hallucinations. To try to solve the problem, a three-step technique is used: Construction of a pressure sensor mat (A), data collection (B), data storage (C), calculation (D), and machine learning prediction of sleep paralysis (E). The flow of this research project is depicted in the diagram below:

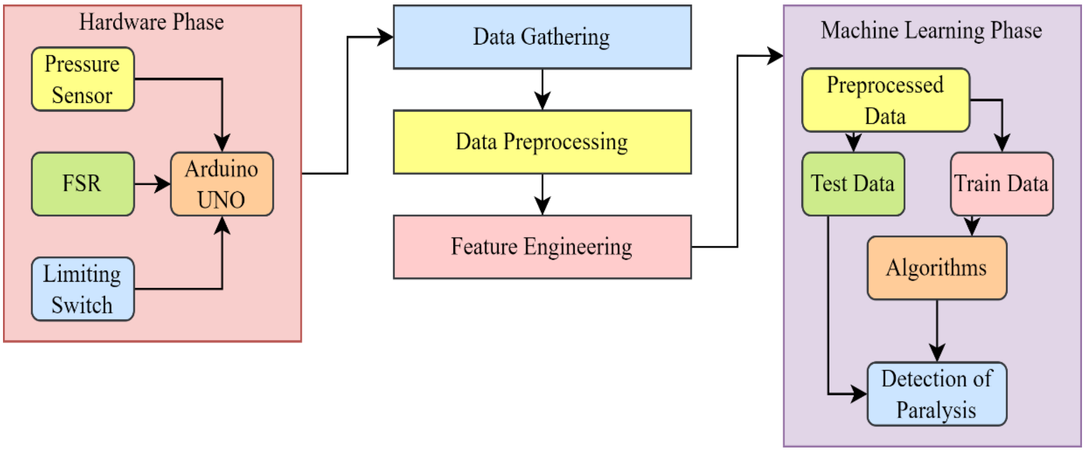


Figure 1. Proposed Workflow

3.1. Hardware Description

Sensors that could measure pressure points and the area of contact between the user's body and the mattress were essential. Readymade mattress sensor arrays, limit switches, and FSRs, as well as piezo-resistant materials, were among the alternatives for investigation. They were judged on their physical and technical attributes in addition to their pricing. The options were weighed against the following ideal sensor requirements: The advantages of this technology include a flat sensor form, a wide pressure range, and a lower cost. Force-sensing resistors (FSRs), for example, are simple tactile devices that sense pressure fluctuations. Some of the materials used to make these are polymers, elastomers, semiconducting polymers, piezo-resistive material, conductive wires, fiber optics, and fiber gratings.The sensors used in this model has been briefly described in below sections:

3.1.1. Pressure Sensors

The pressure sensor generates an electrical signal that is analogue. Pressure measurement tools were in high demand throughout the steam era. To electronically sense pressure, pressure transducers and pressure switches are now widely utilized. A pressure sensor is used to collect data on various human postures in this study's technology.

Figure 2. Pressure Sensor

3.1.2. Limiting Switch

A limit switch activates a switch by using the motion of a machine part or an item. Limit switches can be used to control machinery; they can also be used as safety interlocks, counting how many items have passed past the point where they are activated. It's used to see if an object is still present or has vanished.

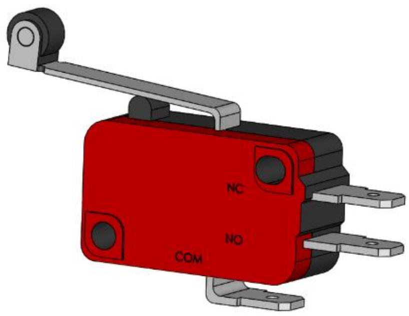


Figure 3. Limiting Switch

3.1.3. Force Sensitive Senor (FSR)

When we apply force or pressure to a force sensitive resistor (FSR), its resistance changes. It's a physical force detector that measures pressure, squeezing, and weight.

Figure 4. Force Sensitive Senor

3.1.4. Arduino UNO with its specifications

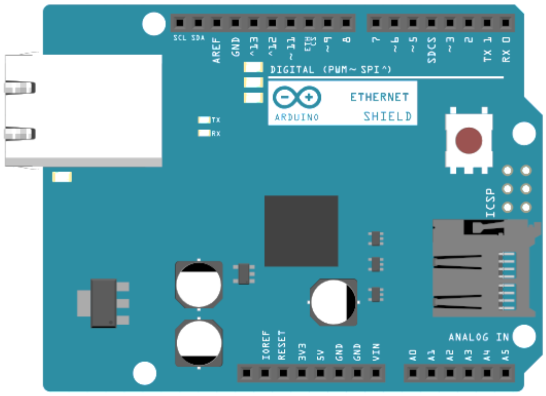


Figure 5. Microcontroller Arduino UNO

The Arduino environment can be accessed by connecting an Arduino to a computer through USB (IDE). The user writes code in the IDE and then uploads it to the microcontroller, which runs it and interacts with sensors, motors, and lights.

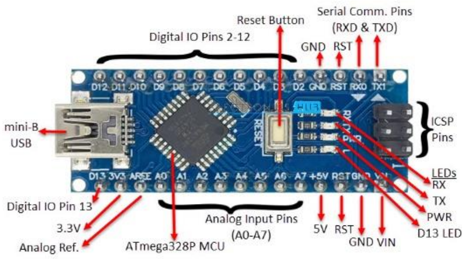


Figure 6. Microcontroller Arduino Nano

Our board has two labels: TX (transmit) and RX (receive) (receive). The speed of the flashing is controlled by the board's baud rate. RX flashes while the receiver is receiving. Each Arduino board has an own microprocessor (11). Let's pretend it's the board's brain. The principal IC (integrated circuit) of the Arduino board may vary depending on the board. Microcontrollers made by ATMEL are widely utilized. You must know which IC your board is equipped with before uploading a new program using the Arduino IDE. On the top of the IC is printed this information. From A0 to A5, the Arduino UNO board has six analogue input pins.

3.1.5. Arduino IDE

The Arduino IDE (Integrated Development Environment) is the software that is used to create Arduino-based projects. It's a text editor that looks like a notepad but offers more features. This tool has a number of functions, including writing code, compiling it to check for flaws, and uploading it to an Arduino. The Arduino compiler/IDE supports them as-is, aside from C and C++. C++ is used in many of the libraries. Although this could change in the future, a substantial component of the system is now not object-oriented. As a result, "the Arduino language" refers to the programming languages C++ and C. The Arduino IDE is a program available for download from the Arduino website (Integrated Development Environment). You can store and run code created on a real board using an Arduino. The term "Arduino" is used in both software and hardware. You'll need a special piece of software called the Arduino IDE installed on your computer to write sketches for various Arduino boards. Arduino is based on Processing, a hardware programming language similar to C. The Arduino IoT Cloud program allows designers to create connected goods fast, easily, and securely. Many devices can be linked and real-time data can be shared. You may also keep an eye on them from anywhere by using a simple user interface. An Atmel 8-bit AVR microprocessor is found on a number of Arduino boards. The ATmega8 (ATmega168), ATmega328 (ATmega1280), and ATmega2560 are just a few examples. In 2012, the Atmel SAM3X8E-based Arduino Due was released. The IDE interface is depicted in the figure below.

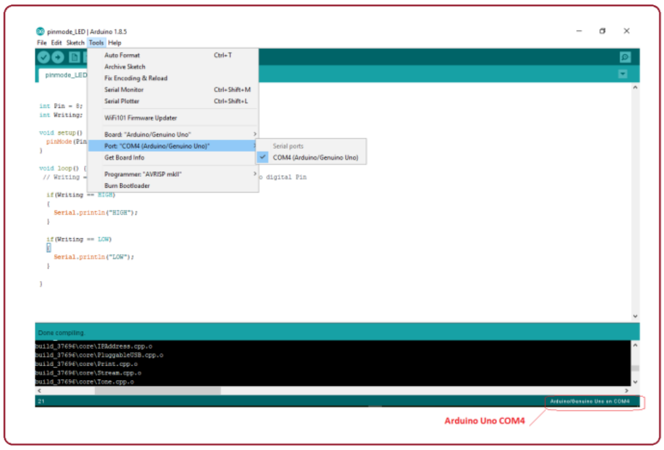


Figure 7. Arduino IDE

3.1.6. USB 2.0 Cable

This cable connects the computer to the Arduino Nano microcontroller or any other board. It's a low-cost, high-quality cable with simulated strain and PVC overmolding that ensures error-free data transfer for the rest of your life. To prevent interference, aluminum is employed behind a melded barrier. It works perfectly on a computer. The cable measures around 30cm in length.

Figure 8. USB 2.0 Cable

3.2. Data Collection

This information was obtained from the Smart Device. The dataset contains many (independent) variables as well as one (dependent) variable (Outcome). This device has been used in a variety of tests. The following is a list of each test's features and predicted outcome.

Table 1. Dataset Attributes

Feature	Description	Values
Pressure	When it comes to basic industrial pressure sensors, the range can be as low as zero to twenty-five pounds per square inch (psi) or as high as fifty pounds per square inch (psi), depending on the application.	Decimal Value
Force	Force is the value strength or energy as a physical property of movement or action.	Integer Value
Limiting Switch	It is the proximity of for the detection of an object	0 or 1
Unoccupied	Unoccupied area during test	0 or 1
Face Up	When a patient is in any one of these four different positions—Face Up, Face Down; Right Lateral; or Left Lateral—the prototype can identify the patient's position and alert the caregiver to the patient.	0 or 1
Face Down	When a patient is in any one of these four different positions—Face Up, Face Down; Right Lateral; or Left Lateral—the prototype can identify the patient's position and alert the caregiver to the patient.	0 or 1
Left Lateral	When a patient is in any one of these four different positions—Face Up, Face Down; Right Lateral; or Left Lateral—the prototype can identify the patient's position and alert the caregiver to the patient.	0 or 1
Right Lateral	When a patient is in any one of these four different positions—Face Up, Face Down; Right Lateral; or Left Lateral—the prototype can identify the patient's position and alert the caregiver to the patient.	0 or 1
Edge	When a patient is in any one of these four different positions—Face Up, Face Down; Right Lateral; or Left Lateral—the prototype can identify the patient's position and alert the caregiver to the patient.	0 or 1
Outcome	On the basis of postures, the outcome will be predicted as having a normal posture or a patient with sleep paralysis.	0 (normal) or 1 (sleep paralysis)

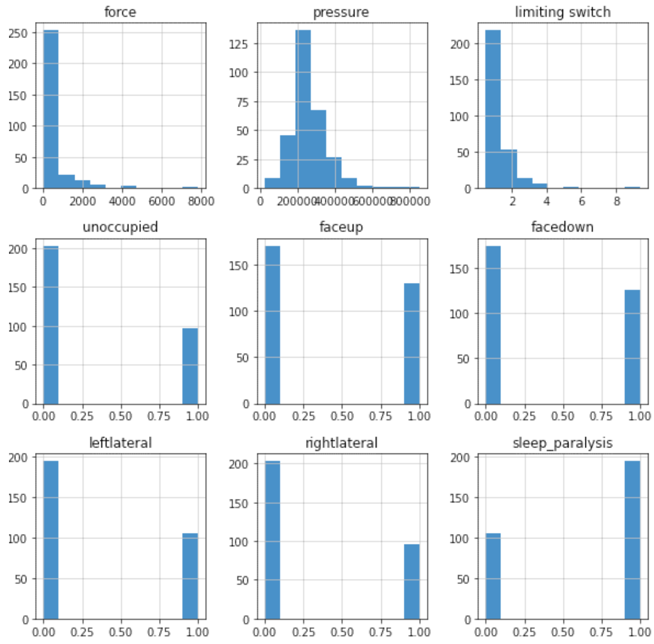


Figure 9. Data Attributes Visualization

3.3. Data Pre-processing

Because it includes changing or eliminating data before it is used, data pre-processing is a critical step in the data mining process. The process of cleaning and organizing raw data before using it to develop and train machine learning models is known as data pre-processing in machine learning. Pre-processing is necessary for high-quality data. Data cleansing, data integration, and data reduction are the four phases of data pre-processing used to make the process easier. Pre-processing our data before feeding it into a machine learning model is crucial since our model's capacity to learn is dependent on the quality and usable information that can be gleaned from it. The normalized dataset was created after data balancing and data pre-processing, and the results are shown in the figure below:

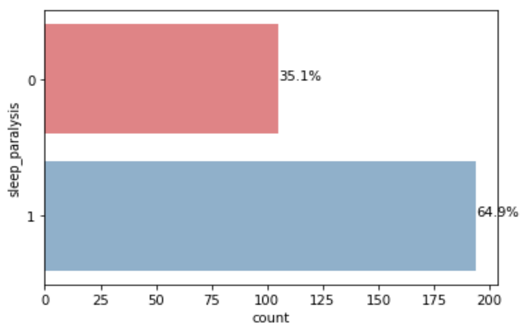


Figure 10. Sleep Paralysis

3.4. Features Engineering

Both machine learning and statistical modeling employ feature engineering to select and modify key traits in raw data before feeding them into a prediction model. Feature engineering cannot be overstated when it comes to machine learning and data science in general. Feature engineering's main purpose is to boost algorithm performance. Feature engineering is more than just selecting and altering features in machine learning. Additionally, feature engineering enhances the performance of machine learning models by ensuring that the dataset is compatible with the algorithm. The following figure shows the characteristics correlation matrix.

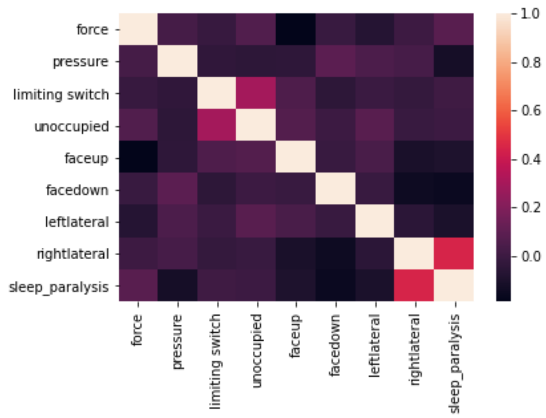


Figure 11. Features Correlation Matrix

3.5 Classification Algorithms

3.5.1. Support Vector Machine (SVM)

Outliers can be detected and classified using support vector machines (SVMs), which are a collection of supervised learning methods. There are several benefits to using support vector machines. This is useful in multi-dimensional settings. When the number of dimensions exceeds the number of samples, however, it can be used.

3.5.2. Logistic Regression

When the dependent variable is dichotomous (binary), logistic regression is the most appropriate regression approach to utilize. Statistics and mathematical modeling are used to describe data and explain relationships between a single dependent binary variable and one or more nominal, ordinal, interval, or ratio-level independent variables.

3.5.3. K-Nearest Neighbors

The supervised machine learning method k-nearest neighbors (KNN) is simple and quick to construct. It can solve both classification and regression issues.

3.5.4. Gradient Boosting Classifier

One of the most powerful machine learning approaches is gradient boosting. The gradient boosting technique may forecast both continuous and categorical target variables (in the form of a Regressor) (as a Classifier).

3.5.5. Random Forests

Random forests, also known as random choice forests, are an ensemble learning method that can be used to solve classification, regression, and other issues. A large number of decision trees are created during the training process. Random forests beat choice trees in terms of overall performance, but their accuracy is lower than that of gradient boosted trees.

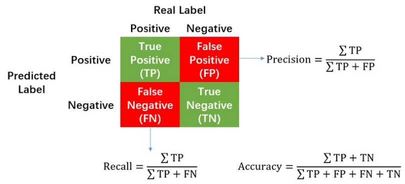
3.5.6. Decision Trees

Decision Trees are a type of Supervised Machine Learning (in which you explain what the input data is and what the related output data is in the training data) in which the data is constantly segregated according to a specific parameter, as opposed to unsupervised machine learning (in which you explain what the input data is and what the related output data is in the training data). A decision tree is a denotative model of a decision-making process. Artificial intelligence uses decision trees to arrive at conclusions based on evidence from prior decisions. As a result, in the context of supervised learning, decision tree models are powerful tools.

3.6. Model Evaluation Parameters

Accuracy, precision, recall, and F1 Score criteria were used to assess the effectiveness of the solutions under consideration. The contrast between misclassified and classified clauses was highlighted using a confusion matrix. The outcomes of the measurements employed in this study are shown in the following table:

Table 2. Description of Metrics

Metric	Description
Accuracy	$\text{Accuracy} = \frac{TP}{(TP+TN)*100}$
Confusion Matrix	

4. Results and Discussions

To check the correctness of the recommended system, we executed a posture recognition accuracy test. The device was hidden on top of the user's bed. The controller is responsible for data collection and measurement. Experiments were carried out by extracting pressure data from a lying-down patient and establishing a data collection. The subject acted out his sleeping positions on a mat for a period of time. Sleep paralysis has been predicted using a variety of machine learning techniques. By comparing sleep postures to the outcome, we were able to show a relationship between sleep quality and sleep paralysis using pressure sensors.

4.1. Relationship between sleep qualities and sleep paralysis

4.1.1. Unoccupied Face

If the person is in an out-of-focus posture or is absent from the mat, the face may be empty. The figure below depicts a positive relationship between patients' vacant faces.

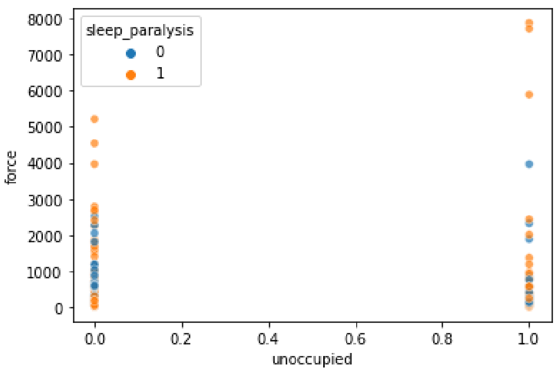


Figure 12. Unoccupied Face vs Sleep Paralysis

4.1.2. Face Up

Face can be Up if the person is in the posture which is out of focus or can be absent on the mat which can be a condition to sleep paralysis. The figure below shows the positive correlation of posture with sleep paralysis.

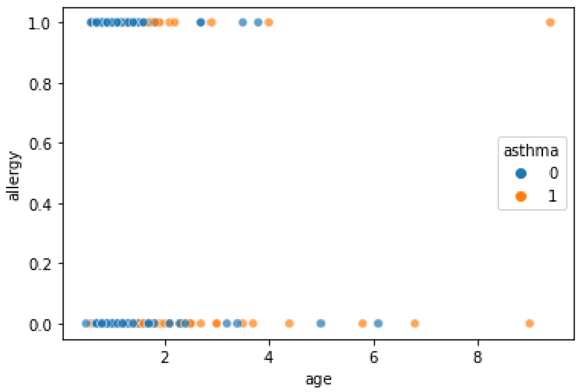


Figure 13. Face Up vs Sleep Paralysis

4.1.3. Face Down

Face can be down if the person is in the posture which is out of focus or can be in paralysis on the mat. The figure below shows the positive correlation of face down posture with sleep paralysis.

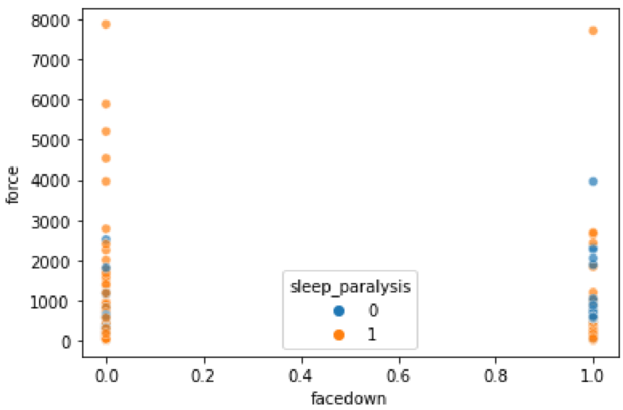


Figure 14. Face Down vs Sleep paralysis

4.1.4. Left Lateral

Lateral can be on left, if the person is in the posture which is out of focus or can be on left lateral on the mat. The figure below shows the positive correlation of left lateral with paralysis.

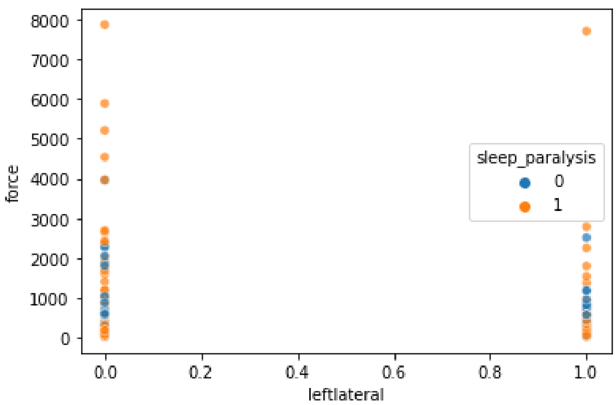


Figure 15: Left Lateral vs Sleep paralysis

4.1.5. Right Lateral

Lateral can be on right, if the person is in the posture which is out of focus or can be on right lateral on the mat. The figure below shows the positive correlation of right lateral with paralysis.

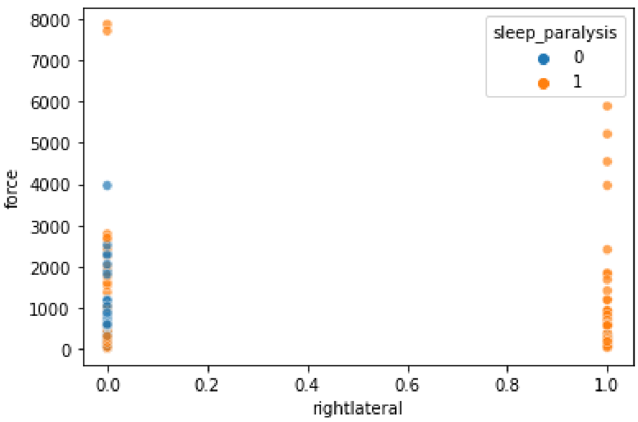
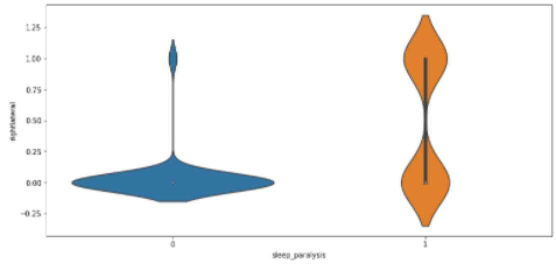
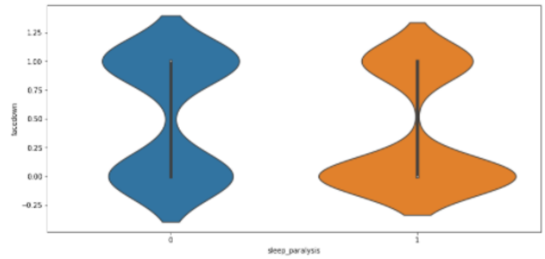


Figure 16. Right Lateral vs Sleep paralysis

The figure below shows the violin plots of correlation between the sleep paralysis and relation between the postures:



Violin plots of Lateral Postures vs Sleep Paralysis



Violin plots of Face Postures vs Sleep Paralysis

After finding out the relationship between sleep postures and quality we have found the total numbers of sleep paralysis patients and with no paralysis.

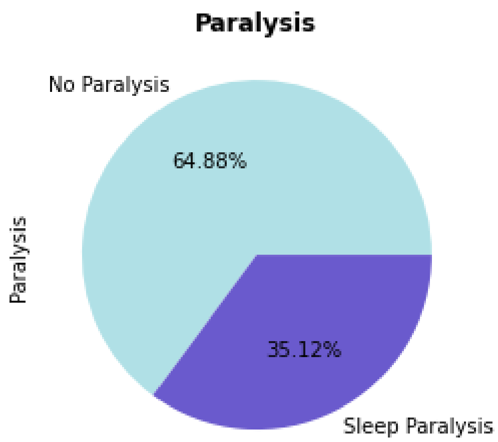


Figure 17. Classes of Outcome (Target Variable)

4.2. Detection of Sleep Paralysis

4.2.1. Support Vector Machine (SVM)

With a combination of supervised learning algorithms, support vector machines (SVMs) can be used to discover and categorize outliers. There are numerous advantages of using support vector machines. In cases where the number of dimensions exceeds the number of samples, the SVM can still be employed. The SVM's findings are as follows, with a variety of kernel types used to demonstrate them:

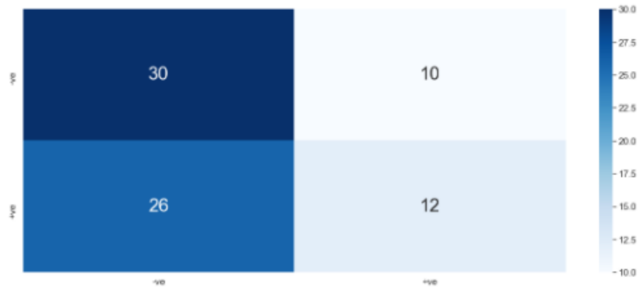


Figure 18. SVM Confusion Matrix with Linear Kernel

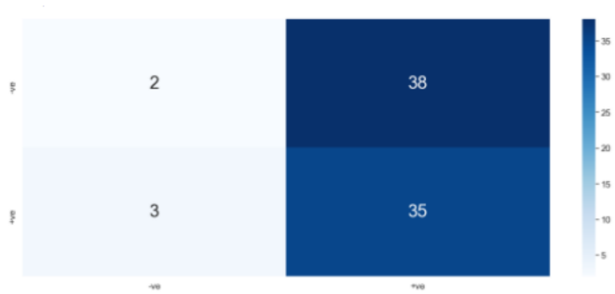


Figure 19. SVM Confusion Matrix with Polynomial Kernel

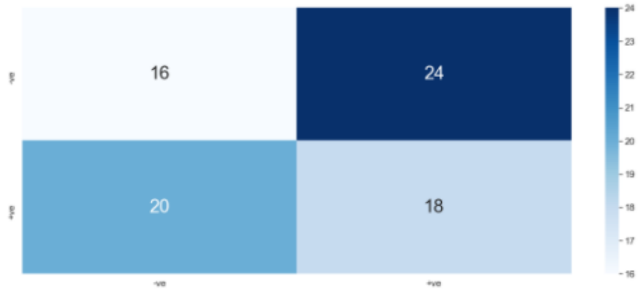


Figure 20. SVM Confusion Matrix with RBF Kernel

4.2.2. Logistic Regression

The best strategy to use when the dependent variable is binary is logistic regression (either true or false). The relationship between a single dependent binary variable and one or more nominal, ordinal, interval, or ratio-level independent variables is investigated using statistics and mathematical modeling. The following table shows how LR performs:

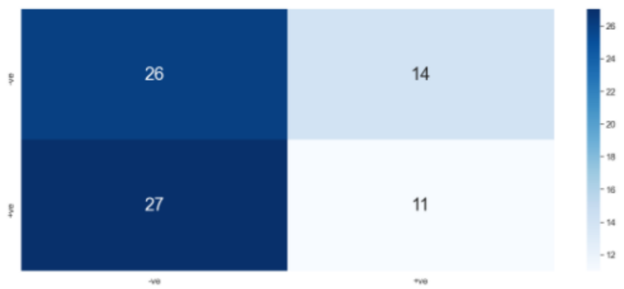


Figure 21. Performance of LR

4.3.3. K-Nearest Neighbors

The K-nearest neighbors (KNN) technique can be used to quickly and efficiently develop sophisticated machine learning algorithms. It can be used as a classifier as well as a regressionmodel.

Figure 22. Performance of KNN

4.3.4. Gradient Boosting Classifier

The technique of gradient boosting is one of the most powerful in machine learning. Although regressors are the most common target variables for gradient boosting, predicted categorical target variables can also be used (as a Classifier).

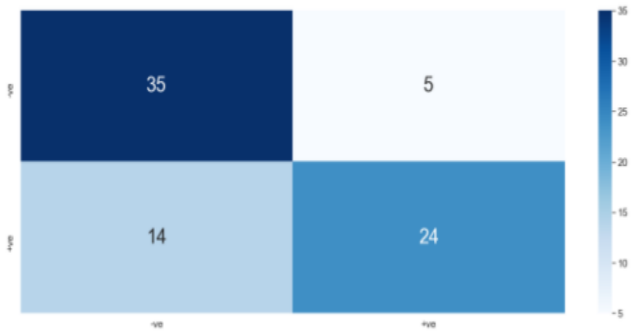


Figure 23. Performance of GBC

4.3.5. Random Forests

Random forests, also known as random choice forests, are a type of classification and regression algorithm that can be used to solve problems like classification and regression. During the training phase, random forests generate a lot of decision trees. Gradient enhanced trees outperform random forests in terms of overall effectiveness.

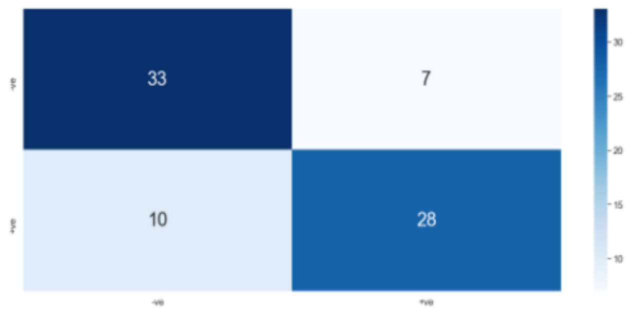


Figure 24. Performance of RF

4.3.6. Decision Trees

Decision Trees are a type of Supervised Machine Learning (in which you explain what the input data is and what the corresponding output data is in the training data) in which the data is constantly segregated according to a given parameter, in contrast to unsupervised machine learning. A decision tree is a diagram that depicts the process of making a choice. Artificial intelligence makes decisions based on previous judgments using decision trees. As a result, in the context of supervised learning, decision tree models are useful.

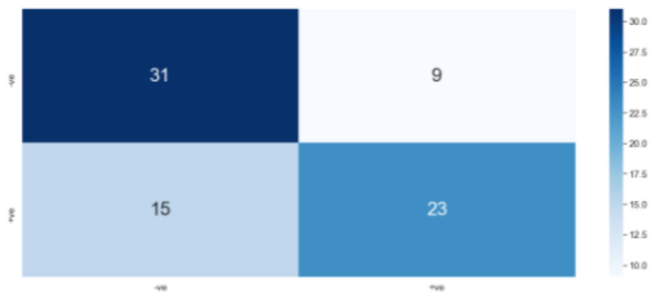


Figure 25. Performance of Decision Trees

4.4. Classification Performance Comparison

Figure shows that random forests are more accurate at predicting the sleep paralysis than other machine learning models in this dataset based on true positive categorized values.

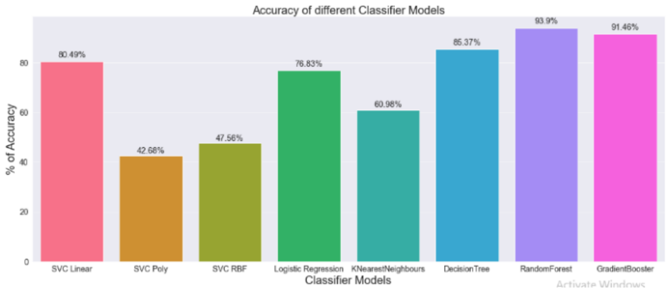


Figure 26. Machine Learning Classification Models Performance

5. Discussion

Tests were conducted to check the proposed system's accuracy in posture recognition. The device was scarcely visible from the user's position on top of the bed. The controller is in charge of gathering and analyzing the data produced by the system. Experiments were carried out by obtaining pressure data from a lying-down patient and building a data collection system. The person imitated his sleeping positions while lying on a mat. A variety of machine learning algorithms have been used to predict sleep paralysis. By contrasting sleeping postures with the results, it was feasible to demonstrate the link between sleep quality and sleep paralysis. The sleep paralysis has a direct relationship with sleep quality.

In addition, the Random Forest model was found to have the maximum accuracy of 91.9 percent in predicting sleep paralysis in the given dataset. SVM with Linear Kernel achieved an accuracy of 80.49 percent, 42.68 percent with RBF, and 47.56 percent with Polynomial. The average accuracy of logistic regression was 76.83 percent. With a score of 60.98 percent, KNN had a dismal performance. With 85.37 percent and 91.46 percent, respectively, Decision Trees and Gradient Boosting performed well.

6. Conclusions

Some people's hallucinations in sleep paralysis may be caused by the fast eye movement waking them up from their dreams (REM). The visuals of dreams and sleep paralysis, on the other hand, are vastly different. Anxiety and/or anxiety are the most common causes of sleep paralysis (up to 90 percent of the time). Only a small fraction of people say their nightmares are truly terrifying. In a study comparing the content of dream reports with sleep paralysis, the "character" of sleep paralysis episodes was found to be more aggressive and emotionally consistent. The victims of dreamers are more aggressive than the victims of ordinary dreams. 10% of those who have had sleep paralysis report clinically significant pain, and sleep paralysis has a detrimental influence on other aspects of their lives. It's also worth mentioning that the supernatural isn't present in all of the stories. According to a survey, up to 20% of sleep paralysis sufferers have had a positive outcome. To predict sleep paralysis, a variety of machine learning techniques have been explored. It was possible to illustrate the link between sleep quality and sleep paralysis by comparing sleeping positions with the results. Sleep paralysis is directly associated with the quality of one's sleep. With a 91.9 percent accuracy rate, Random Forest was proven to be the best accurate model for predicting sleep paralysis. In SVM, a linear kernel achieved 80.49 percent accuracy, RBF kernels 42.68 percent, and polynomial kernels 47.56 percent. Logistic regression was correct 76.83 percent of the time on average. KNN only worked 60.98 percent of the time. Gradient Boosting and Decision Trees both scored well, with 85.37 percent and 91.46 percent, respectively.

References

[1] D. Denis, C. C. French, and A. M. Gregory, "A systematic review of variables associated with sleep paralysis," *Sleep Med. Rev.*, vol. 38, pp. 141–157, 2018, doi: 10.1016/j.smrv.2017.05.005.

[2] B. Ganesh, S. Venkata, V. Pisipati, M. Shivashanker, V. Sirisha, and B. Ch, "Sleep paralysis," no. June, 2012.

[3] C. O. Johanna Magalí, G. S. Jonathan Ulises, T. R. Aveiro-Róbalo, G. T. Luciana Daniela, and M. J. Valladares-Garrido, "Association between sleep quality and sleep paralysis in medical students from a private university in Paraguay," *Pakistan J. Med. Heal. Sci.*, vol. 14, no. 3, pp. 1162–1166, 2020.

[4] E. Solomonova, "Sleep paralysis: Phenomenology, neurophysiology, and treatment," *Oxford Handb. Spontaneous Thought Mind-Wandering, Creat. Dreaming*, pp. 435–456, 2018, doi: 10.1093/oxfordhb/9780190464745.013.20.

[5] A. Nelson *et al.*, "Wearable multi-sensor gesture recognition for paralysis patients," *Proc. IEEE Sensors*, no. 1, pp. 1–4, 2013, doi: 10.1109/ICSENS.2013.6688531.

[6] G. Benham, "Sleep paralysis in college students," *J. Am. Coll. Heal.*, vol. 0, no. 0, pp. 1–6, 2020, doi: 10.1080/07448481.2020.1799807.

[7] B. Jalal, A. Romanelli, and D. E. Hinton, "Sleep paralysis in Italy: Frequency, hallucinatory experiences, and other features," *Transcult. Psychiatry*, vol. 58, no. 3, pp. 427–439, 2021, doi: 10.1177/1363461520909609.

[8] D. Denis, "Relationships between sleep paralysis and sleep quality: Current insights," *Nat. Sci. Sleep*, vol. 10, pp. 355–367, 2018, doi: 10.2147/NSS.S158600.

[9] H. B. E. Riaz, A. Ikhlaq, I. Bashir, F. Ijaz, R. K. Aftab, and A. Ijaz, "Association of Sleep paralysis with Insomnia and Sleep Quality," vol. 6, no. 3, pp. 1–4, 2021, doi: 10.19080/ARR.2021.06.555689.

[10] D. Denis and G. L. Poerio, "Terror and bliss? Commonalities and distinctions between sleep paralysis, lucid dreaming, and their associations with waking life experiences," *J. Sleep Res.*, vol. 26, no. 1, pp. 38–47, 2017, doi: 10.1111/jsr.12441.

[11] D. F. Ramos, J. Magalhães, P. Santos, J. Vale, and M. I. Santos, "Recurrent sleep paralysis – Fear of sleeping," *Rev. Paul. Pediatr.*, vol. 38, pp. 2018–2021, 2020, doi: 10.1590/1984-0462/2020/38/2018226.

[12] D. Denis, "Relationships between sleep paralysis and sleep quality: Current insights," *Nat. Sci. Sleep*, vol. 10, no. November, pp. 355–367, 2018, doi: 10.2147/NSS.S158600.

[13] L. S. E. Seow *et al.*, "Independent and combined associations of sleep duration and sleep quality with common physical and mental disorders: Results from a multi-ethnic population-based study," *PLoS One*, vol. 15, no. 7, pp. 1–17, 2020, doi: 10.1371/journal.pone.0235816.

[14] A. Tiwari and R. Tiwari, "Design and implementation of a smart system for detection of sleep paralysis using LabVIEW/Matlab tool," *Proc. Int. Conf. Inven. Syst. Control. ICISC 2017*, no. April 2018, 2017, doi: 10.1109/ICISC.2017.8068690.

[15] K. Tang, A. Kumar, M. Nadeem, and I. Maaz, "CNN-Based Smart Sleep Posture Recognition System," *IoT*, vol. 2, no. 1, pp. 119–139, 2021, doi: 10.3390/iot2010007.

[16] B. A. Sharpless, "A clinician's guide to recurrent isolated sleep paralysis," *Neuropsychiatr. Dis. Treat.*, vol. 12, pp. 1761–1767, 2016, doi: 10.2147/NDT.S100307.

[17] S. W. Hsieh, C. L. Lai, C. K. Liu, S. H. Lan, and C. Y. Hsu, "Isolated sleep paralysis linked to impaired nocturnal sleep quality and health-related quality of life in Chinese-Taiwanese patients with obstructive sleep apnea," *Qual. Life Res.*, vol. 19, no. 9, pp. 1265–1272, 2010, doi: 10.1007/s11136-010-9695-4.

[18] T. Takeuchi, A. Miyasita, Y. Sasaki, M. Inugami, and K. Fukuda, "Isolated sleep paralysis elicited by sleep interruption," *Sleep*, vol. 15, no. 3, pp. 217–225, 1992, doi: 10.1093/sleep/15.3.217.

[19] Y. Kushkituah, "Subjective sleep quality of isolated sleep paralysis: Fear parameters and psychosocial correlates.," *Diss. Abstr. Int. Sect. B Sci. Eng.*, vol. 80, no. 7-B(E), p. No-Specified, 2019.

[20] J. Steier *et al.*, "Sleep-disordered breathing in unilateral diaphragm paralysis or severe weakness," *Eur. Respir. J.*, vol. 32, no. 6, pp. 1479–1487, 2008, doi: 10.1183/09031936.00018808.

[21] E. C. Geoff Appelboom1 *et al.*, "Smart wearable body sensors for patient self-assessment and monitoring.," *Arch. Public Heal.*, vol. 72, no. 28, pp. 1–9, 2014.

[22] A. Malafeev, "Automatic Sleep Classification with Machine Learning," p. 190, 2018.

[23] S. Arulvallal, U. Snekhalatha, and T. Rajalakshmi, "Design and development of wearable device for continuous monitoring of sleep apnea disorder," *Proc. 2019 IEEE Int. Conf. Commun. Signal Process. ICCSP 2019*, pp. 50–53, 2019, doi: 10.1109/ICCSP.2019.8697961.

[24] A. Tiwari and R. Tiwari, "for Detection of Sleep Paralysis Using," pp. 1–6, 2017.

[25] S. Jeon, T. Park, Y. S. Lee, S. H. Son, H. Lee, and Y. Eun, "RISK-Sleep: Real-Time Stroke Early Detection System during Sleep Using Wristbands," *Proc. - 2018 IEEE Int. Conf. Syst. Man, Cybern. SMC 2018*, pp. 4333–4339, 2019, doi: 10.1109/SMC.2018.00732.

[26] M. G. L. Kumar, R. S. Sairam, G. D. V. S. Kumar, and S. R. K. Vanjari, "Low power, low area, analog blink restoration system with auto sleep mode for unilateral facial paralysis patients," *2017 IEEE Biomed. Circuits Syst. Conf. BioCAS 2017 - Proc.*, vol. 2018-Janua, pp. 1–4, 2018, doi: 10.1109/BIOCAS.2017.8325064.

[27] M. Choubisa and P. Trivedi, "Analysing EEG signals for detection of mind awake stage and sleep deprivation stage," *Proc. 2015 Int. Conf. Green Comput. Internet Things, ICGCIoT 2015*, pp. 1209–1211, 2016, doi: 10.1109/ICGCIoT.2015.7380647.

[28] V. Gurrala, P. Yarlagadda, and P. Koppireddi, "Detection of Sleep Apnea based on the analysis of sleep stages data using single channel EEG," *Trait. du Signal*, vol. 38, no. 2, pp. 431–436, 2021, doi: 10.18280/TS.380221.

[29] N. Surantha, G. P. Kusuma, and S. M. Isa, "Internet of things for sleep quality monitoring system: A survey," *Proc. - 11th 2016 Int. Conf. Knowledge, Inf. Creat. Support Syst. KICSS 2016*, no. November, 2017, doi: 10.1109/KICSS.2016.7951426.

[30] M. Valero, J. Clemente, F. Li, and W. Z. Song, "Health and sleep nursing assistant for real-time, contactless, and non-invasive monitoring," *Pervasive Mob. Comput.*, vol. 75, p. 101422, 2021, doi: 10.1016/j.pmcj.2021.101422.