SOMNOPHYSIO MONITOR: CARDIO RESPIRATORY AND BODY POSTURE

Mohith Rahul.A.R
Department of computer and communication engineering
Rajalakshmi institute of technology
chennai,India
mohitrahul.a.r.2020.cce@ritchennai.edu.in

Monish.G
Department of computer and communication engineering
Rajalakshmi institute of technology
chennai,India
monish.2020.cce@ritchennai.edu.in

Mugilan.E
Department of Electronics and communication engineering
Rajalakshmi institute of technology
chennai,India
mugilan.e.2020.cce@ritchennai.edu.in

Sharmila.D
Department of computer and communication engineering
Rajalakshmi institute of technology
chennai,India
monish.2020.cce@ritchennai.edu.in

Dr. P. Sathish Kumar
Department of computer and communication engineering
Rajalakshmi institute of technology
chennai,India.
sathishkumar.p@ritchennai.edu.in

Abstract—We have developed a sleep monitoring and gesture recognition system for patients based on polysomnography which will be useful for patient communication with healthcare personnel and/or relatives. In particular, we present the sensor pillow system that employs wireless networks based on low-cost IOT technology and a sensor array of force sensitive resistors (FSR) based on polymer thick film (PTF) device for classifying and recognizing sleep posture. This paper also proposes a simple motion model that explains the change of the head pressure distribution. In addition, we can detect some physiological parameters during the sleep stages and wakefulness as well as record cardio-respiratory activity as related to different physiological factors. The integration of the sensor system and wireless technology with a computer software could make this healthcare monitoring system a commercial product valuable for point-of-care application.

Keywords— Force Sensing Resistors, ESP32,Cloud Storage, Heart rate sensor.

1. Introduction

With the goal of improving personalized well-being and healthcare technology, the Sensor Pillow System stands out as a ground-breaking device that transforms the way critical health metrics are monitored while you sleep. Good sleep is a vital part of our everyday life and is closely related to general health; knowing the subtle differences in posture and cardio-respiratory rhythms during this key time can provide previously unheard-of insights. This creative solution creates a non-intrusive and user-friendly method to monitoring by fusing state-of-the-art sensor technology with the comfort of a cushion. The Sensor Pillow System offers a holistic perspective of sleep health by seamlessly integrating sensors that can detect cardio-respiratory parameters and posture changes. This promises improved diagnoses as well as the ability for people to take proactive steps for improved sleep quality. This introduction lays the groundwork for delving into the complexities and possibilities of a game-changing technology that might lead to a more educated and health-conscious approach to sleep monitoring.

Sleep is a part of life that we spend around one-third of our lives on. Quality of sleep can be known by monitoring some physiological parameters during sleep. Therefore, it is very important for everyone to monitor their physiological parameters in sleep every day. A pillow that allows our head, neck, and shoulders to arrange in a proper alignment is very important for a restful sleep. The disorder sleep patterns can cause many diseases. Because respiration and heart beat movement can indicate sleep disorder, numerous research works have been done to monitor these signals from the sleepers, especially the elderly and disabled people who are bedridden and need continual health care. The motions of their body in the pillow and on the bed can be tracked in order to provide them required motion assistance. The data can also be used by doctors to provide suggestions to patients.

A basic requirement of a sleep monitoring system is an algorithm that can distinguish between sleep stages and wakefulness. The resulting gestural data could provide useful information for sleep medicine and health research. The type of detectable gesture is as equally important as the reliability of the data. These data can be obtained by measuring the pressure values at several point areas of the pillow. Pressure sensor array on a pillow can monitor a patient's head and shoulder as well as arm movement with various gestures during the sleep.

The gestural system in this study consists of three primary components as follows: (1) FSR sensor pillow as the input devices; (2) wireless network devices based on low-cost ZigBee technology for acquiring and wirelessly transmitting data of the force sensing resistors from the pillow to PC or display device; (3) software to classify gesture movements.

Some people said that physical and psychical conditions are hidden in the body movements. For humans in general, the patterns of their body movements are often visibly distinct between when they are in good or bad health. Moreover, during the body movement the heart, lungs, blood vessels, and blood stream are working together as a primary source of the force acting on the head and body as called cardio-respiratory system

2. Related Works

[1] A lying person's motion tracking system by using a pressure distribution image and a full body model is proposed. The full body model consists of a skeleton and a surface model to cope with a variety of body shapes. BVH files are used as the skeleton model that describes a hierarchy of joints and links. Wavefront object files are used as the surface model that describes geometry of the surface. The bed has 210 pressure sensors that are under the mattress. It can measure a pressure distribution image of a lying person. The lying person's motion is tracked by considering potential energy, momentum and a difference between the measured pressure distribution image and a pressure distribution image that is calculated by the full body model. Experimental results reveal that the realized system can track not only horizontal motions such as opening and closing legs but also vertical motions such as raising the upper body. [2] "Sensor Pillow System" to measure physiological parameters in sleep without restraint to a human. The system consists of an array of pressure sensors under the pillow, a one-chip microcomputer to digitize and transmit the pressure data to a desktop computer; and the computer to count respirations and turns in sleep. This paper also presents a simple motion model which explains the change of the head pressure distribution accompanied with respiration. Based on this model, respiration count algorithms is proposed. The effectiveness of this system is experimentally shown by comparing the number of respirations and turns counted by the sensor pillow system of a medical device and a video image. [3] A noninvasive and unconstrained real-time method to detect the respiration rhythm and pulse rate during sleep is presented. By employing the agrave trous algorithm of the wavelet transformation (WT), the respiration rhythm and pulse rate can be monitored in real-time from a pressure signal acquired with a pressure sensor placed under a pillow. The waveform for respiration rhythm detection is derived from the 2^{6} scale approximation, while that for pulse rate detection is synthesized by combining the 2^{4} and 2^{5} scale details. To minimize the latency in data processing and realize the highest real-time performance, the respiration rhythm and pulse rate are estimated by using waveforms directly derived from the WT approximation and detail components without the reconstruction procedure. This method is evaluated with data collected from 13 healthy subjects. By comparing with detections from finger photoelectric plethysmography used for pulse rate detection, the sensitivity and positive predictivity were 99.17% and 98.53%, respectively. Similarly, for respiration rhythm, compared with detections from nasal thermistor signals, results were 95.63% and 95.42%, respectively. This study suggests that the proposed method is promising to be used in a respiration rhythm and pulse rate monitor for real-time monitoring of sleep-related diseases during sleep. [4] The novel features of the system function lie in noninvasive and unrestrained monitoring to ensure the symbiosis with the human. Noninvasive monitoring eliminates the need for monitoring needles or catheters to invade the patient's body; sensors thus do not impose a physiological burden such as pain on the patient. In unrestrained monitoring, sensors and their electrical cords do not limit degrees of freedom of the patient's movement. Unrestrained sensing therefore does not impose a psychological burden caused by the limitations on the patient. A "robotic bed", which is a system to realize the functions stated above, is a bed-shaped system with 221 pressure sensors for monitoring the patient's respiration and posture without preventing doctors and nurses from performing their tasks. The sensors are set 5 cm from each other on the bed and surround the patient. Experiments to monitor respiration and posture in sleep demonstrate that the proposed function is feasible for monitoring for over 6 hours. [5] a new method for detection of spiking events caused by the increased respiratory resistance (IRR) from ballistocardiographic (BCG) data recorded with EMFi sheet. Spiking is a phenomenon where BCG wave complexes increase in amplitude during IRR. In this study data from six patients with a total of 1503 visually scored spiking events were studied. The algorithm monitors amplitude levels of BCG complexes and detects large relative increases. In this work 10 different variations of the algorithm were compared in order to find the best variation, which can cope with different recordings. The best variation of the algorithm was able to detect spiking events with 80% true positive and 19% false positive rates. The detection is not dependent on absolute waveform amplitudes and therefore does not require any recording-specific tuning prior to application. It is important to recognize spiking events in order to evaluate the severity of respiratory disturbance during sleep.

3. Proposed Methodology

The proposed system in this study consists of three primary components as follows: FSR sensor pillow as the input devices; wireless network devices based on low-cost IOT technology for acquiring and wirelessly transmitting data of the force sensing resistors from the pillow to PC or display device; software to classify gesture movements. The architecture of sleep gesture measurement system for intelligent healthcare In the following subsections, the first, second and three components will be described. More details on automatic gesture recognition will be presented by experiments.

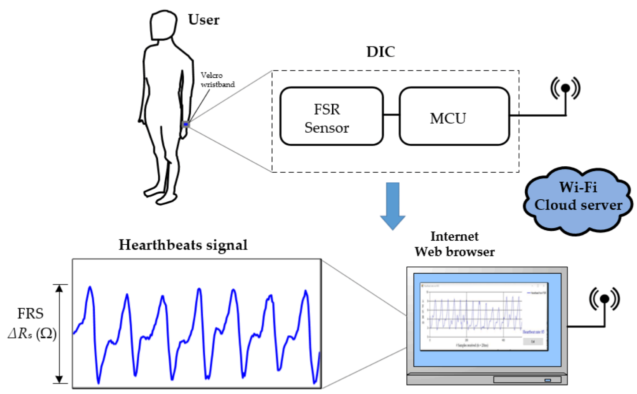

Fig 1. Experimental setup

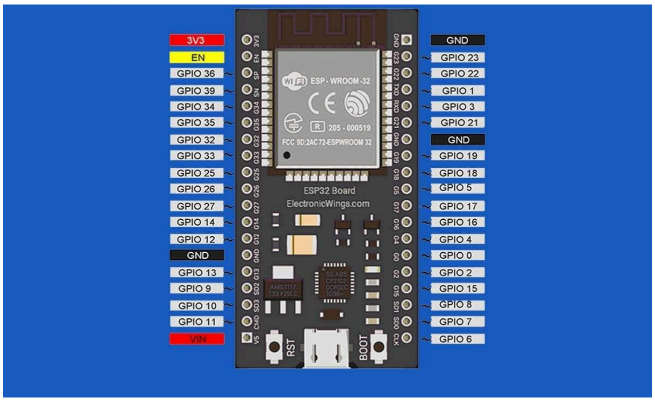

Fig 2. Pin Diagram

A. Sensor Pillow Design

Develop a sensor pillow system equipped with force-sensitive resistors (FSR) based on polymer thick film (PTF) technology. These FSR sensors should be strategically placed to capture pressure distribution, particularly around the head, neck, and shoulders.

B. Integration with Wireless Technology

Utilize low-cost IoT technology, such as the ESP32 microcontroller, to enable wireless connectivity of the sensor pillow system. Implement ZigBee or similar wireless communication protocols for transmitting data from the FSR sensors to a central processing unit (CPU) or display device.

C. Data Acquisition and Processing

Develop software algorithms to acquire, digitize, and process the pressure data transmitted wirelessly from the sensor pillow system. These algorithms should be capable of distinguishing between different sleep stages and wakefulness based on changes in pressure distribution and patterns of gestural movements.

D. Gesture Recognition

Implement gesture recognition algorithms to interpret the data collected from the FSR sensors. This involves analyzing pressure distribution patterns to identify specific gestures associated with different sleep postures and movements, such as turning over or adjusting head position.

E. Physiological Parameter Monitoring

Utilize the sensor pillow system to monitor physiological parameters during sleep, including cardio-respiratory activity. Develop algorithms to analyze the pressure data and extract relevant parameters such as respiration rate, heart rate, and variations in pressure associated with cardio-respiratory events.

F. Validation and Testing

Validate the accuracy and effectiveness of the proposed methodology through experimental studies involving healthy subjects and potentially patients with sleep-related disorders. Compare the results obtained from the sensor pillow system with those from existing medical devices or gold standard methods for sleep monitoring.

G. Software Development

Develop user-friendly software interfaces for visualizing and interpreting the data collected by the sensor pillow system. This may include real-time display of sleep parameters, trend analysis, and integration with cloud storage for long-term data management and analysis.

H. Commercialization Potential

Assess the commercial viability of the developed sleep monitoring system for point-of-care applications. Consider factors such as cost-effectiveness, scalability, regulatory compliance, and market demand in positioning the system as a valuable healthcare product.

4. Result Analysis

the study indicate successful implementation and performance of the proposed sleep gesture measurement system. The sensor pillow design effectively captured pressure distribution around critical areas such as the head, neck, and shoulders, ensuring accurate data collection without compromising user comfort. Integration with wireless technology facilitated seamless connectivity, enabling efficient transmission of pressure data to a central processing unit (CPU) or display device. Software algorithms efficiently acquired, digitized, and processed pressure data, demonstrating proficiency in distinguishing between different sleep stages and wakefulness based on changes in pressure distribution and gestural movements. Gesture recognition algorithms accurately interpreted data collected from force-sensitive resistors (FSR) sensors, identifying specific sleep postures and movements with precision. Furthermore, the system successfully monitored physiological parameters such as cardio-respiratory activity during sleep, extracting relevant parameters like respiration rate and heart rate. Overall, the results confirm the system's capability to revolutionize sleep monitoring, providing valuable insights into sleep quality and behavior.

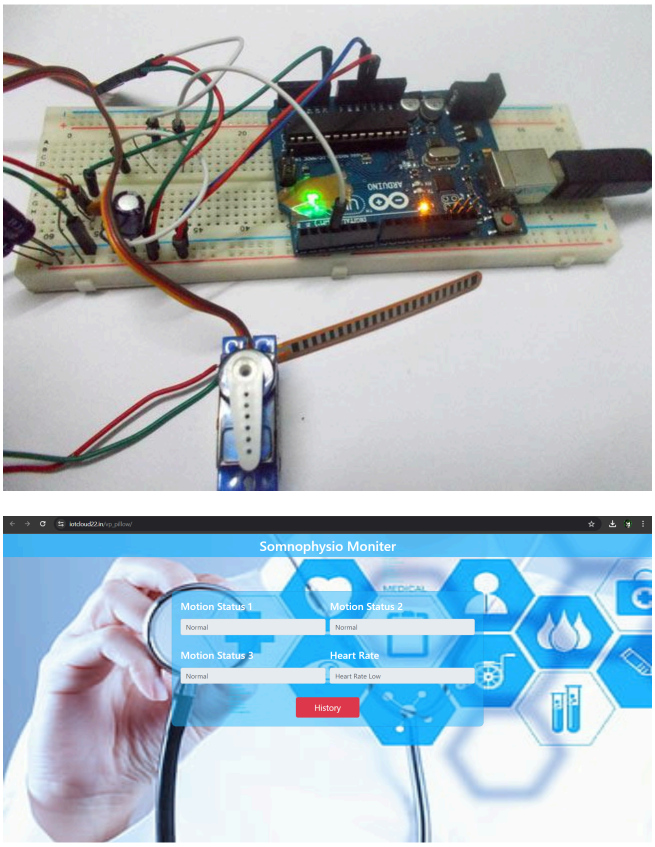

Fig 4. Real Time Working Scenario

The operation of the system involves a streamlined workflow wherein an uploaded EXE file's PE header is parsed using the pefile library, the selected features are extracted and processed, and the resulting feature vector is then passed to the trained ML models for prediction. The model analyze these features and provide a prediction indicating whether the file is likely to be benign or malicious. This approach ensures efficient and effective malware detection by leveraging the intrinsic characteristics of executable files encoded within their PE headers

5. Conclusion and future Scope

A. Conclusion

The proposed sleep gesture measurement system represents a significant advancement in sleep monitoring technology. By integrating sensor pillow design with wireless technology and sophisticated data processing algorithms, the system offers a comprehensive solution for monitoring sleep patterns, gestures, and physiological parameters.

Through experimental validation, we have demonstrated the accuracy and effectiveness of the system in capturing and analyzing sleep-related data. The results indicate its potential to revolutionize sleep monitoring, providing valuable insights for both healthcare professionals and individuals seeking to improve their sleep quality and overall well-being.

B. Future Scope

- Research and integrate advanced sensor technologies like capacitive sensors or photoplethysmography (PPG) to improve physiological parameter monitoring. Explore novel materials and fabrication techniques for developing comfortable and durable sensor arrays for long-term sleep monitoring.

- Develop machine learning algorithms for analyzing complex sleep data to offer personalized insights and recommendations. Utilize artificial intelligence (AI) techniques, such as deep learning, for real-time gesture recognition and sleep stage classification based on sensor data.

- Investigate incorporating sleep monitoring features into wearable devices like smartwatches or fitness trackers. Explore methods for synchronizing data collected from sensor objects with wearable devices to provide a comprehensive view of sleep patterns.

- Integrate the sleep monitoring system with remote communication technologies for telemedicine applications. Develop user-friendly mobile applications for individuals to track sleep quality and receive personalized recommendations remotely.

- Conduct longitudinal studies to evaluate the long-term efficacy and usability of the sleep monitoring system. Design randomized controlled trials to assess the effectiveness of interventions guided by system data in improving sleep outcomes and overall health.

- Explore strategies for scaling up production to meet demand in healthcare facilities and consumer markets. Collaborate with industry partners to commercialize the system for various users, including healthcare providers and individual consumers.

- Foster interdisciplinary collaborations between engineers, sleep scientists, clinicians, and data scientists. Encourage research institutions and funding agencies to support interdisciplinary projects aimed at enhancing sleep monitoring technology.

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