JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

SLEEP DISORDER DETECTION AND ALERT SYSTEM USING mmWAVE RADAR SENSOR

Rohan C[1], Vignesh B G [2], Siddaraju N C [3], Dr. Rajeshwari Devi [4]
Student[1], Student[2], student[3], professor[4]
Department of Electronics and Communications Engineering,Global Academy of Technology,Bengaluru,Karnataka

Abstract-- Sleep apnea, a severe sleep disorder associated with various health risks and potentially fatal conditions, has long posed diagnostic challenges due to the discomfort and disruption caused by traditional detection methods, which involve wearing multiple sensors during sleep; in response, the introduction of ApneaRadar marks a significant advancement in sleep monitoring technology by harnessing the capabilities of a 24GHz radar to offer a non-intrusive approach to tracking chest movements and analyzing breathing patterns during sleep, eliminating the need for physical contact and complemented by a real-time detection algorithm to provide a more comfortable and efficient alternative to the conventional polysomnography (PSG) method, which ApneaRadar has surpassed in accuracy, exceeding 90% in detecting sleep apnea, with profound implications for improving patient comfort and compliance, enabling earlier diagnosis and intervention, and ultimately leading to improved health outcomes and enhanced quality of life, warranting further research and development to refine the system, explore its broader applications, and maximize its impact in the realm of sleep medicine and healthcare.

Keywords: **- mmWave radar, ApneaRadar, FMCW. Breathing Status and sleep disorders.**

I. INTRODUCTION

Sleep disorders causes a wide range of conditions that affect the quality and duration of our sleep. Sleep apnea is a common disorder that causes repeated interruptions or shallow breathing during sleep. The most prevalent type is obstructive sleep apnea (OSA), which occurs when the upper airway becomes blocked or collapses. Other types include central sleep apnea (CSA), where the brain fails to control breathing properly, and a combination of the two. Symptoms of sleep apnea include loud snoring, breathing pauses, choking sensations, daytime fatigue, and poor sleep quality. If left untreated, sleep apnea can lead to serious health issues like high blood pressure, heart problems, memory difficulties, and an increased risk of accidents due to daytime drowsiness. Risk factors include being overweight, family history, allergies, enlarged tonsils, asthma, and certain medical conditions. Men are more prone to developing this disorder compared to women.

Existing System
Traditional methods like Polysomnography (PSG) to wearable sensors utilizing EEG, EMG, and PPG technologies, the field is rapidly advancing. Non-contact systems, such as Novel Acoustic and Movement Sensors and thermal imaging, offer promising avenues for detecting sleep apnea without direct patient contact. These technologies showcase the interdisciplinary nature of addressing sleep disorders, merging engineering expertise with medical knowledge to enhance diagnostic accuracy and treatment efficacy.

Proposed System
Innovative technology like mmWave radar technology is utilized for sleep detection by monitoring human sleep quality through the detection of body movement and breathing rate. This radar system operates independently of environmental factors like temperature, humidity, and noise, ensuring accurate monitoring. It offers privacy protection and can be integrated into smart home applications for functions like sleep safety alarms and movement monitoring. Compared to traditional sensors, mmWave radar sensors provide continuous and high-sensitivity detection of human activities, making them valuable in various settings such as living rooms, hotels, and even correctional facilities that require constant monitoring. The radar's ability to detect both moving and stationary individuals simultaneously, along with respiratory sleep patterns, makes it a versatile tool for monitoring sleep quality effectively.

II. LITERATURE SURVEY

Qian Zhai et.al present a contactless on-bed radar-based respiration monitoring system. The system has advantages of easy and convenient usage in personal daily sleep and home environments. One single-chip MIMO radar is used to obtain 2-D radar profiles of the target and surroundings. A simplified human trunk model is used to detect the trunk presence and location information. A spatial correction on the thoracic motion is presented in the 2-D radar profiles. A mode-decomposition-based reconstruction is then developed to extract the respiration motion from background [1].
Aloysius Adya Pramudita et.al enlighten how development of a radar system for human respiration noncontact sensor will contribute to the healthcare field, particularly in the monitoring of patients' respiration for a long period with all the while providing more advantages, such as hygiene and comfort. The radar system must be able to detect the small displacement with millimeters or centimeters scale on the human body

associated with the respiratory activity. The minimum power of electromagnetic wave radiation is also needed to avoid unsafe usability in patients' respiration monitoring. To attain low power operation and efficient frequency spectrum usage, the multifrequency continuous-wave (MFCW) radar system is proposed in this article as a noncontact sensor for human respiration. The simulation study and laboratory experiment of the MFCW radar system in detecting human respiration were performed, and the comparison study with frequency-modulated continuous-wave (FMCW) radar was discussed in this article [2].

Majdi Bsoul et.al research on real-time sleep apnea monitoring systems using ECG-based approaches reveals significant advancements and trends, explored the use of ECG signals for sleep apnea detection due to its non- invasive nature and potential for real-time monitoring. Research has focused on developing algorithms and models to extract relevant features from ECG signals for accurate detection of apnea episodes. The system achieves a high degree of accuracy, with a classification F-measure of 90% and a sensitivity of 96% for the subject-independent SVC model [3].

hardware APIs for interfacing with microcontroller peripherals. The device's small footprint, energy efficiency, and wireless communication capabilities make it suitable for integration into cloud services, enabling scalable monitoring systems. Compared to other wireless technologies, Wi-Fi offers broader coverage and integration possibilities. The adoption of Free RTOS simplifies software design, with a small code footprint and potential for portability to other microcontroller architectures. Overall, the Wireless Infant Monitoring Device presents an effective tool for SIDS prevention through continuous monitoring and timely alerts [4].

Razan.A Alhamad et.al Introduce a user-friendly system designed to detect and monitor sleep apnea at home, offering a cost-effective alternative to In-Lab sleep studies. Sleep apnea, characterized by pauses in breathing during sleep, can lead to serious health issues. The proposed system utilizes a nasal temperature sensor to detect breathing changes indicative of sleep apnea events. In case of severe apnea, the device can wake the patient and send an SMS to a designated person. Data visualization is enabled through a mobile application, allowing users to share recorded data with healthcare professionals. The system hardware includes sensors, Arduino Mega2560 microcontroller, GSM, and Wi-Fi shield. The methodology involves temperature sensing, data transmission via GSM and Wi-Fi, and emergency notification using a vibrating bracelet [5].

III. METHODOLOGY

Fig :1 Methodology flow chart

1) Identify sleep disorders in infant babies, person who gone through cardiac related operations.
2) Analyze age category and gender in which sleep disorder can be often seen.
3) Utilizing current technology to tackle problem.
4) Its done by interfacing 24GHz mmWave RADAR technology.

3.1 System Requirement Specification

The block diagram (fig.2) shows implementation of system by using node MCU, LCD, buzzer and breathing sensor(24GHZ mmWave RADAR sensor), as RADAR sensor plays major role identifying problem by monitoring breathing status parallelly alerts guardian using notification platform that works with help of Wi-Fi module, which is present on chip Node MCU.

3.1.1.1 Hardware Requirements

a) Node MCU with on-chip Wi-Fi module: A microcontroller board with Wi-Fi connectivity, multiple communication interfaces, programmable with various languages, and specific power supply requirements.
b) 24 GHz mmWave RADAR sensor: A sensor that can detect objects and humans within a range of up to 9 meters, used for human presence detection, breathing detection, with a compact design and high sensitivity.
c) LCD Display with I2C module: A 16x2 LCD display with an I2C interface, requiring 5V operating voltage, and supporting custom characters.
d) Power Supply: A versatile power supply with 12V DC input and specific DC outputs at 3.3V and 5.0V, featuring an output power switch and LED indicator.

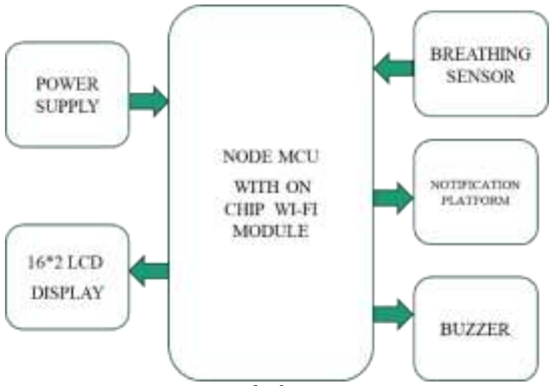

Fig 2: Block Diagram

e) Buzzer: A buzzer with a maximum input voltage of 5V, resistance of 42 Ω, resonance frequency of 2048 Hz, and specific physical dimensions and material composition.

3.1.2 Software Requirements

a) Arduino IDE - The Arduino Integrated Development Environment (IDE), also known as Arduino Software, includes a code editor, message area, console, toolbar, and menus. It interfaces with Arduino hardware for program uploading and communication.

b) Notification Platform using Telegram app: Utilizes the Telegram app for real-time alerts from an ESP32 Dev module, involving the creation of a Telegram bot, obtaining a Telegram user ID, integration with ESP32, and sending and receiving notifications.

IV. IMPLEMENTATION

4.1 Flow chart:

The flowchart(fig3) depicts the behind-the-scenes setup process for a breathing status. It starts by preparing itself by initializing pre requisites, defining how often it will collect data and what constitutes a normal breathing rate. it checks for an internet connection. Then it configures how it interacts with 24Ghz mmWave RADAR sensor that tracks your breathing – and how it will display information to you 16*2 LCD and potentially alert you with a sound and mobile notification if breathing seems irregular. Finally, it continuously monitors breathing and provides feedback based on whether it falls within range.

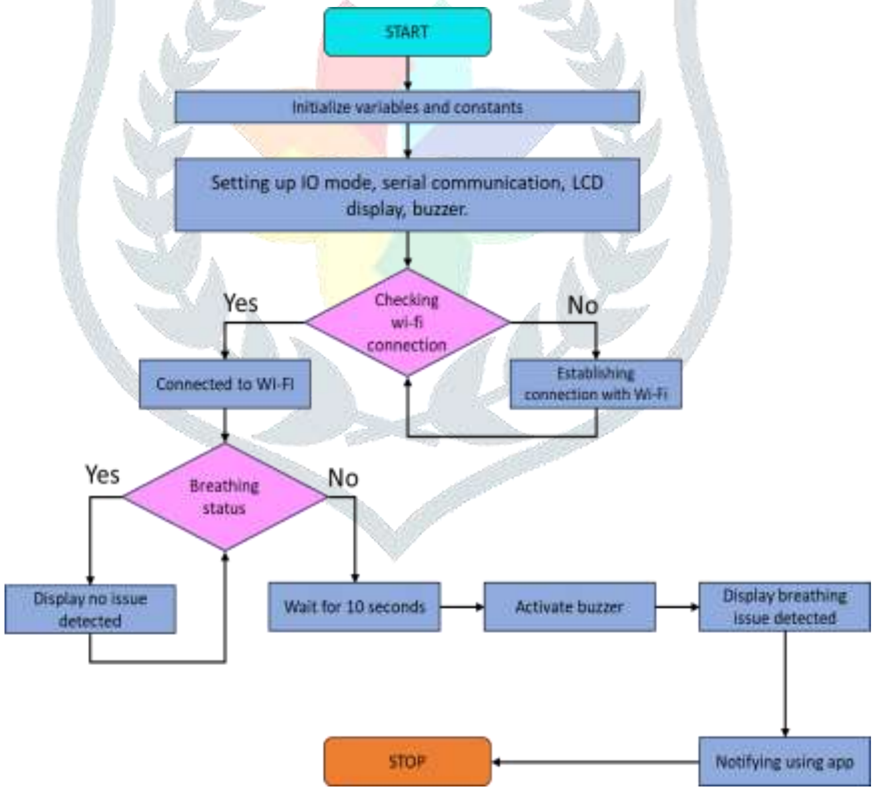

Fig 3: simulation flow chart

V. RESULT AND ANALYSYS

Fig. 4: Wi-Fi connection status

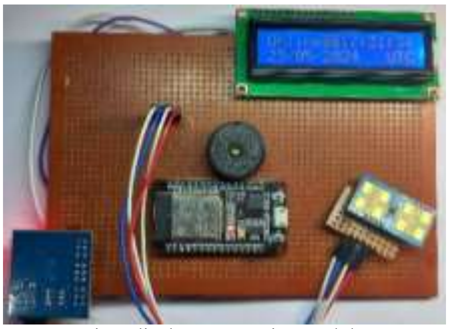
Fig.5 display current time and date


Fig.6 sleep apnea detection

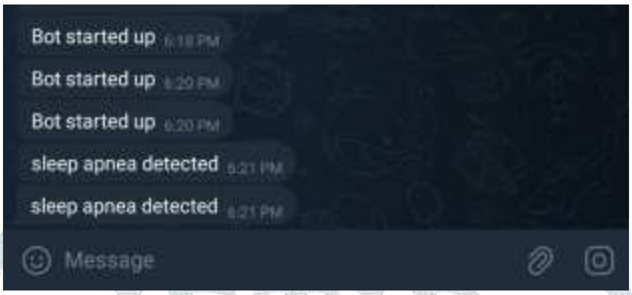

Fig..7 notification message which is available in the app.

5.1 Testing and result

1) The ESP32 wi-fi module must first establish a connection with the wi-fi network and displays "Wi-Fi CONNECTED", at onboard LCD display. After the connection to internet has been made successfully. Or else displays error "network not connected" (fig4).
2) It uses NTP (network time protocol) to access time and date. And connect to telegram app via provided API. And sends connection status notification to mobile via notifications messages (Fig.5).
3) Once all the steps are initialized, it is ready to detect events, this gadget should be placed near patient. So that it can capture the readings at regular interval. And with good accuracy.

Note: the threshold can be varied depending on the user requirement, for example the threshold can be set as it capture reading every 200 m seconds for 10 readings, if it finds that all 10 readings values match it is detected as an event.

4) check the app whether notification is updated regularly or by checking display. As shown (Fig.5, Fig.6 & Fig.7)

VI. CONCLUSION AND FUTURE SCOPE

The sleep apnea detection and alert systems using 24GHz millimeter-wave radar sensors demonstrates the potential of radar technology in revolutionizing the monitoring and diagnosis of sleep-related conditions, offering a non-invasive and effective approach to improving sleep quality assessment and healthcare outcomes.

6.1 Future scope:

To enhance the radar system for sleep apnea detection, several advancements can be implemented. Firstly, expanding the system to monitor multiple individuals simultaneously in a shared space requires developing techniques to differentiate and track individual breathing patterns accurately, associating apnea events with specific persons for precise diagnosis. Integrating the radar with other unobtrusive sensors like microphones or pressure mats can improve apnea detection by fusing data from various sources, including wearable devices like smartwatches, to correlate apnea events with other physiological signals. Additionally, leveraging the radar's motion tracking abilities can enable the detection of sleep stages and quality alongside apnea events. To validate the system's effectiveness, large-scale clinical trials should be conducted to assess its accuracy, reliability in diagnosing apnea severity, monitoring treatment outcomes, and evaluating user acceptance and compliance with the non-intrusive radar monitoring approach.

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