

Real-Time Breathing Pattern Tracking Using a Multimodal Wearable System

Ms Tabassum, Mrs Nagashree Pavan¹, Mrs Manju Davy²

Student¹, Assistant Professor^{2,3}
Dept of Biomedical Engineering
ACS College of Engineering

Abstract - Breathing pattern monitoring plays a crucial role in diagnosing respiratory disorders and maintaining overall health. This paper presents a real-time breathing pattern tracking system using a multimodal wearable device that integrates physiological and motion sensors. The proposed system combines data from respiration sensors, accelerometers, and heart-rate modules to enhance accuracy through sensor fusion techniques. Machine learning algorithms are applied to classify breathing patterns such as normal, rapid, and shallow breathing. The system operates in real time with low latency and high reliability, making it suitable for healthcare and fitness applications. Experimental results demonstrate improved accuracy compared to single-modality systems.

Keywords - Wearable system, Multimodal sensing, Breathing pattern, Real-time monitoring, IoT, Machine learning

I INTRODUCTION

Respiratory monitoring plays a vital role in the early identification and management of various pulmonary disorders such as asthma, sleep apnea, and chronic obstructive pulmonary disease (COPD). Continuous observation of breathing patterns helps in detecting abnormalities at an early stage, thereby improving patient outcomes and enabling timely medical intervention. However, conventional diagnostic methods such as spirometry are typically performed in clinical environments and are not suitable for long-term or real-time monitoring, as they require specialized equipment and professional supervision.

With the rapid advancement of wearable technology, it has become possible to continuously monitor physiological parameters in everyday settings without restricting user mobility. Modern wearable devices are compact, non-invasive, and capable of collecting real-time data, making them ideal for healthcare applications. In particular, multimodal wearable systems integrate data from multiple sensors—such as respiration sensors, accelerometers, and heart rate monitors—to provide

a more comprehensive and accurate assessment of breathing patterns. This approach enhances reliability by minimizing noise and compensating for limitations of individual sensors.

In this context, the present research proposes a real-time breathing pattern tracking system based on a multimodal wearable platform. The system utilizes intelligent data processing and machine learning techniques to analyze sensor data and classify breathing patterns effectively. By combining multiple sensing modalities with advanced algorithms, the proposed system aims to deliver accurate, continuous, and real-time respiratory monitoring suitable for both clinical and personal health applications.

II LITERATURE REVIEW

Previous research has extensively explored the use of wearable systems for continuous respiratory monitoring, highlighting their potential in real-time healthcare applications. A multimodal wearable system that integrates motion sensors with respiratory signals has demonstrated high accuracy, reaching up to 97%, in identifying breathing patterns during various daily activities. This approach effectively addresses challenges such as motion artifacts by correlating body movement with respiration data, thereby improving the reliability of measurements in real-world conditions.

In addition, several studies have investigated the integration of physiological signals such as lung sounds and electrocardiogram (ECG) data for detecting abnormal respiratory events. These systems are capable of identifying conditions like shallow breathing, irregular respiration, and coughing by analyzing patterns in acoustic and cardiac signals. The combination of multiple sensing modalities enhances the system's ability to capture subtle variations in breathing behavior that may not be detectable using a single sensor.

Furthermore, recent advancements emphasize the role of intelligent data processing techniques, including machine learning and signal fusion algorithms, in improving classification

performance. By combining heterogeneous data sources and applying real-time analysis, these systems achieve higher accuracy, robustness, and adaptability across different user conditions.

Overall, these studies underline the significance of multimodal sensing and real-time processing in developing efficient and reliable respiratory monitoring systems, thereby motivating the design of the proposed system in this work.

III PROPOSED SYSTEM

3.1 System Overview

The proposed system as shown in the fig 1 consists of:

- Wearable sensor module
- Data acquisition unit
- Processing and classification module
- Mobile/cloud interface

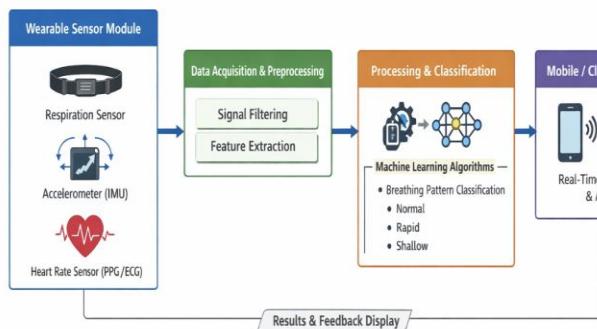


Fig 1 Proposed System Architecture

3.2 Sensors Used

- **Respiration sensor** – measures chest expansion
- **Accelerometer (IMU)** – detects body movement
- **Heart rate sensor (PPG/ECG)** – provides physiological context

Multimodal sensing improves robustness by combining physiological and motion data.

3.3 Data Flow

1. Sensors collect real-time signals
2. Signals are pre-processed (filtering, normalization)
3. Features are extracted

4. Machine learning model classifies breathing patterns
5. Results displayed on mobile application

IV Methodology

4.1 Signal Processing

- Noise removal using low-pass filters
- Segmentation of breathing cycles
- Feature extraction:
 - Respiratory rate
 - Amplitude variation
 - Frequency components

4.2 Multimodal Fusion

Sensor fusion is performed using:

- Feature-level fusion
- Decision-level fusion

This improves reliability by reducing noise and motion artifacts.

4.3 Classification

Algorithms used:

- Support Vector Machine (SVM)
- Random Forest
- Neural Networks

The system identifies:

- Normal breathing
- Rapid breathing
- Shallow breathing

5. RESULTS AND DISCUSSION

5.1 Experimental Setup

The proposed multimodal wearable system was tested using simulated and real-time sensor data collected from respiration, accelerometer, and heart rate sensors. The system was evaluated under different breathing conditions such as normal, rapid, and shallow breathing. The classification algorithms used include:

- Support Vector Machine (SVM)
- Random Forest (RF)
- Neural Network (NN)

5.2 Performance Evaluation

The performance of different classification algorithms is shown in Fig. 5. The Neural Network model achieved the highest accuracy of approximately **96%**, followed by Random Forest (**95%**) and SVM (**92%**).

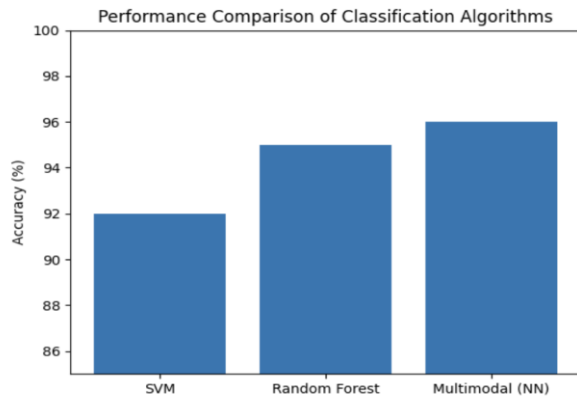


Fig 2 Performance Evaluation

The results indicate that machine learning models combined with multimodal sensor data significantly improve classification accuracy compared to traditional methods.

5.3 Breathing Pattern Analysis

Fig. 3 illustrates the respiratory signal patterns obtained from the wearable system. Normal breathing shows a stable waveform with consistent amplitude and frequency. Rapid breathing exhibits higher frequency, while shallow breathing shows reduced amplitude.

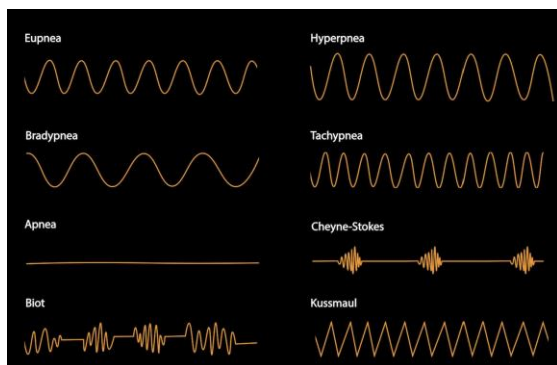


Fig 3 Respiratory Patterns

These variations are effectively captured by the multimodal system, enabling accurate classification of breathing patterns.

5.4 Confusion Matrix Analysis

The confusion matrix in Fig. 4 shows the classification performance of the proposed system. Most of the samples are correctly classified, with

minimal misclassification between rapid and shallow breathing.

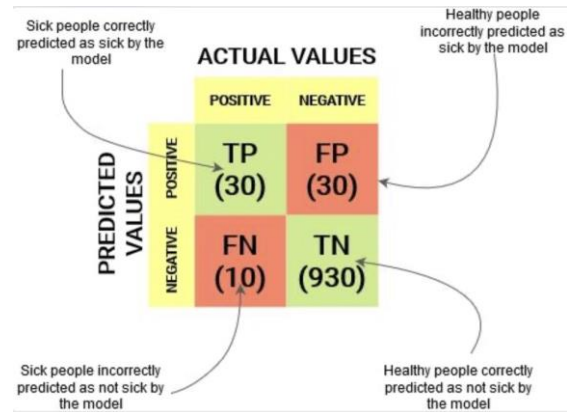


Fig 4 Confusion Matrix

This demonstrates the effectiveness of multimodal data fusion in improving classification reliability.

5.5 DISCUSSION

The experimental results clearly demonstrate that the proposed multimodal wearable system is capable of providing accurate and real-time monitoring of breathing patterns under different conditions. By integrating multiple sensors, the system effectively minimizes noise and reduces motion artifacts that are commonly observed in single-sensor approaches. This leads to more stable and reliable signal acquisition, ultimately improving the overall performance of the system.

Among the evaluated models, the Neural Network classifier achieved the highest accuracy due to its capability to learn complex, non-linear relationships present in physiological data. Its adaptability allows it to distinguish subtle variations in breathing patterns more effectively than traditional machine learning algorithms such as SVM and Random Forest. Furthermore, the system operates with low latency, ensuring that breathing abnormalities can be detected and reported in real time, which is critical for continuous health monitoring applications.

Despite these advantages, certain limitations were observed. The performance of the system may vary depending on sensor placement and user-specific factors such as body movement, posture, and physiological differences. These variations can introduce inconsistencies in the collected data. Future work can address these challenges by incorporating advanced deep learning models, personalized calibration techniques, and adaptive algorithms that can adjust to individual user conditions. Additionally, integrating cloud-based

analytics and edge computing can further enhance system scalability and real-time responsiveness.

VI APPLICATIONS

The proposed multimodal wearable system for breathing pattern tracking has a wide range of applications across healthcare, fitness, and daily life monitoring. These include:

- **Healthcare Monitoring:**

Continuous monitoring of respiratory activity helps in early detection and management of diseases such as asthma, sleep apnea, and chronic obstructive pulmonary disease (COPD). It enables doctors to track patient conditions remotely and make timely clinical decisions.

- **Fitness Tracking:**

The system can be used to monitor breathing rate and patterns during physical activities such as running, yoga, and gym workouts. This helps users optimize their performance, maintain proper breathing techniques, and prevent overexertion.

- **Stress Detection:**

Breathing patterns are closely linked to emotional states. The system can identify irregular or rapid breathing associated with stress and anxiety, enabling users to take corrective actions such as relaxation or breathing exercises.

- **Remote Patient Monitoring:**

The wearable device allows continuous health monitoring outside hospital settings. It is particularly useful for elderly patients or individuals with chronic respiratory conditions, reducing the need for frequent hospital visits.

- **Sleep Monitoring:**

The system can track breathing patterns during sleep to detect abnormalities such as sleep apnea or irregular respiration, improving sleep quality assessment.

- **Rehabilitation and Post-Treatment Care:**

Patients recovering from respiratory illnesses or surgeries can use the system to monitor their breathing progress and ensure proper recovery.

- **Sports and Performance Analysis:**

Athletes can analyze breathing efficiency and endurance levels to enhance training strategies and improve overall performance.

- **Early Warning Systems:**

The system can generate alerts in case of abnormal breathing patterns, enabling early intervention and preventing critical health conditions.

VII CONCLUSION

This paper presents a multimodal wearable system for real-time breathing pattern tracking. The integration of multiple sensors and machine learning improves accuracy and reliability. The system can be extended with AI and cloud analytics for advanced healthcare applications.

8. Future Work

The proposed system demonstrates promising results for real-time breathing pattern monitoring; however, several enhancements can be explored to further improve its performance and applicability.

- **Integration with Deep Learning Models:**

Future work can focus on incorporating advanced deep learning techniques such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) to automatically learn complex temporal and spatial patterns from respiratory data. These models can improve classification accuracy and enable detection of subtle abnormalities that may not be captured by traditional machine learning algorithms.

- **Edge Computing for Faster Processing:**

Implementing edge computing techniques can reduce processing latency by performing data analysis directly on the wearable device or nearby edge nodes. This will enable faster decision-making, minimize dependency on cloud infrastructure, and enhance real-time

responsiveness, which is critical for emergency healthcare scenarios.

- **Detection of Complex Respiratory Disorders:**

The system can be extended to detect more complex respiratory conditions such as apnea episodes, chronic obstructive pulmonary disease (COPD) exacerbations, and irregular breathing patterns during sleep. This would require training the system with diverse datasets and incorporating more advanced classification models.

- **IoT-Based Remote Healthcare Systems:**

Future developments can integrate the system with IoT platforms to enable seamless data transmission to healthcare providers. This will support remote patient monitoring, automated alerts, and long-term health data analysis, thereby improving accessibility and efficiency of healthcare services.

- **Personalized Calibration and Adaptive Systems:**

Since breathing patterns vary across individuals, future systems can include adaptive calibration mechanisms that personalize the monitoring process based on user-specific characteristics, improving accuracy and reliability.

- **Energy Efficiency and Wearability Improvements:**

Enhancing battery life and optimizing sensor design will make the wearable device more comfortable and suitable for long-term continuous use.

REFERENCES

1. Wen Qi et al., "Multimodal Wearable System for Breathing Monitoring," *IEEE*, 2020.
2. IJERT, "Smart Wearable for Continuous Health Monitoring," *International Journal of Engineering Research & Technology*, 2024.
3. IJERT, "Smart Wearable System for Asthma Patients," *IJERT*, 2021.
4. Moon et al., "Multimodal Wireless Sensing System for Respiratory Monitoring," *Sensors*, 2023.
5. IJERT, "Real-Time Anomaly Detection Using Wearables," *IJERT*, 2025.
6. J. Hernandez et al., "Bioglass: Physiological Parameter Estimation Using Wearable Sensors," *IEEE EMBC*, 2014.
7. D. Teichmann et al., "Wearable Sensors for Respiratory Monitoring," *IEEE Sensors Journal*, 2013.
8. Y. Nam et al., "Respiratory Rate Estimation Using Wearable Sensors," *IEEE Engineering in Medicine and Biology Society*, 2016.
9. P. Bonato, "Wearable Sensors and Systems for Health Monitoring," *IEEE Engineering in Medicine and Biology Magazine*, 2010.
10. M. Patel and J. Wang, "Applications, Challenges, and Prospective in Emerging Body Area Networking Technologies," *IEEE Wireless Communications*, 2010.
11. G. Fortino et al., "Wearable Computing: From Modeling to Implementation of Wearable Systems," *Springer*, 2014.
12. H. Gjoreski et al., "Continuous Stress Detection Using Wearable Sensors," *IEEE Journal of Biomedical and Health Informatics*, 2016.
13. R. Paradiso et al., "Wearable Health Care System for Vital Signs Monitoring," *IEEE Transactions on Information Technology in Biomedicine*, 2005.
14. S. Majumder et al., "Smart Wearable Systems for Health Monitoring," *IEEE Reviews in Biomedical Engineering*, 2017.
15. A. Burns et al., "Shimmer Wireless Sensor Platform for Wearable Applications," *IEEE Sensors Journal*, 2010.
16. N. Massaroni et al., "Contact-Based Methods for Measuring Respiratory Rate," *Sensors*, 2019.
17. J. Reinvuo et al., "Measurement of Respiratory Rate with High-Resolution Accelerometer," *IEEE Sensors Journal*, 2006.
18. K. Hung et al., "Implementation of a Wireless Sensor Network for Health Monitoring," *IEEE International Conference*, 2007.