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A PORTABLE DIGITAL SPIROMETER FOR LUNG HEALTH MONITORING

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Abstract— **Respiratory diseases such as asthma, COPD, obstructive, and restrictive disorders are major global health challenges that impair lung function and breathing capacity. Early and accurate diagnosis of these conditions is essential to prevent severe complications and improve patient outcomes. This project presents a comprehensive solution integrating hardware-based respiratory measurement and machine learning–based disease classification. The system employs an Arduino Uno with an MPXV7002DP differential pressure sensor to measure key lung parameters such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1). The acquired respiratory pressure data is processed and transmitted wirelessly via an ESP8266 Wi-Fi module to the Blynk mobile application for real-time monitoring and cloud storage. Simultaneously, a Random Forest Classifier model is trained on pressure-based datasets categorized into Healthy, Obstructive, and Restrictive classes. The trained model analyzes incoming data to predict the type of respiratory disorder with high accuracy. Evaluation metrics such as accuracy, confusion matrix, and classification reports are used to validate system performance. By combining low-cost embedded sensing technology with data-driven machine learning algorithms, this project enables portable, real-time, and intelligent lung health monitoring, making it suitable for both clinical and home-based applications..**

Keywords— **Lung Disease Classification, Random Forest, Machine Learning, Respiratory Pressure, Healthcare Prediction, Obstructive Disorder, Restrictive Disorder, Data-Driven Diagnosis.**

I. INTRODUCTION

Respiratory diseases are a major global health concern, with obstructive disorders like COPD and asthma impairing airflow due to narrowed airways, while restrictive diseases such as pulmonary fibrosis limit lung expansion and reduce total lung capacity. Early and accurate detection is vital, yet conventional diagnostic methods like spirometry and plethysmography require specialized equipment and trained personnel, posing challenges in resource-limited settings. To address this, the project introduces a machine learning–based solution that classifies respiratory health conditions using only lung pressure values. The system categorizes individuals into Healthy, Obstructive, or Restrictive groups using a Random Forest Classifier trained on a labeled dataset (lung_pressure_data_3class.csv). Data was preprocessed and split in an 80:20 ratio for training and testing to ensure robustness. The Random Forest model, selected for its stability, non-linearity handling, and reduced risk of overfitting, was implemented with 100 decision trees and evaluated using accuracy, precision, recall, F1-score, and confusion matrix metrics. Visualization methods such as pressure distribution graphs and confusion matrices supported performance interpretation. The trained model was saved as lung_disease_model.pkl for real-time and batch predictions, allowing rapid assessment from single or multiple pressure inputs. While limited to a single input feature and requiring broader clinical validation, it provides a promising foundation for future enhancement with additional physiological parameters and advanced algorithms, emphasizing the power of machine learning in accessible healthcare diagnostics

Mariana Bernardino et al, The study introduces an open-source, low-cost turbine spirometer to overcome the high cost and limited accessibility of traditional spirometers. This 3D-printed, user-friendly device integrates simple electronic components to measure airflow effectively. Spirometry is essential for diagnosing COPD and asthma, relying on Forced Vital Capacity (FVC) and Forced Expiratory Volume (FEV1) to assess lung function. Unlike conventional systems requiring uncomfortable nasal clipping, this model uses an anesthesia mask, enhancing comfort and usability. The device operates with infrared sensors and turbine rotation, accurately distinguishing inspiration and expiration [1]. Haotian Wang et al, This paper exposes to a contactless respiratory monitoring approach using FMCW radar, addressing the limitations of conventional contact-based spirometry. Traditional methods like chest straps and nasal cannulas can be intrusive and uncomfortable, whereas radar technology provides a non-invasive, real-time alternative for tracking respiration. The system precisely detects inhalation, exhalation, and apnea events, crucial for diagnosing COPD, sleep apnea, and heart failure. Utilizing peak detection and second derivative algorithms, it accurately identifies breath cycle transitions. Unlike prior research that focused solely on breathing rate estimation, this method provides a detailed analysis of characteristic respiratory point [2]. E. Priya, et al, The study says about a portable spirometer using machine learning, revolutionizing respiratory disease detection with an affordable, efficient, and intelligent system. Traditional spirometers, though widely used for diagnosing COPD and asthma, rely on conventional sensors and manual interpretation. This research integrates flow sensors, Raspberry Pi, and machine learning to automate disease detection, enhancing accuracy and accessibility. The spirometer captures respiratory signals through a flow sensor, converts analog data into digital form using MCP3008 ADC, and processes it in Raspberry Pi. Machine learning classifiers [3]. T. Yoshida et al, This study presents a vortex whistle-based spirometer as a novel, battery-less approach for lung disorder monitoring. Unlike conventional spirometry, which relies on direct airflow measurement, this method leverages sound frequency analysis using smartphone microphones, offering a cost-effective and non-invasive alternative. The vortex whistle mechanism translates exhaled airflow into acoustic signals, where frequency directly correlates with flow rate and pressure. This enables accurate measurement of Forced Vital Capacity (FVC), Peak Expiratory Flow (PEF), and inhalation/exhalation pressure, critical for diagnosing asthma, COPD, and post-COVID complications. Experimental validation confirmed a linear relationship between frequency and airflow, ensuring high measurement accuracy[4]. Arif Amiruddin et al , This study by them develops a digital spirometer with a mobile application for real-time asthma monitoring. Unlike conventional spirometers, this device wirelessly transmits respiratory data via Wi-Fi, enabling continuous self-assessment. Using a NodeMCU microcontroller, pressure sensor, and mouthpiece, the system calculates Forced Expiratory Volume (FEV1) and Peak Expiratory Flow (PEF), classifying asthma severity as normal, moderate, or severe. Cloud storage and real-time visualization enhance accessibility and monitoring[5].

II. PROPOSED ALGORITHM

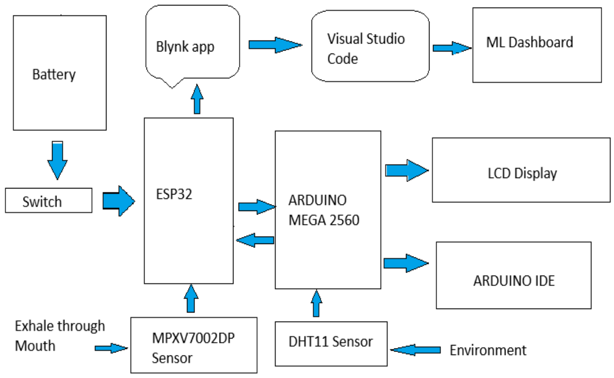
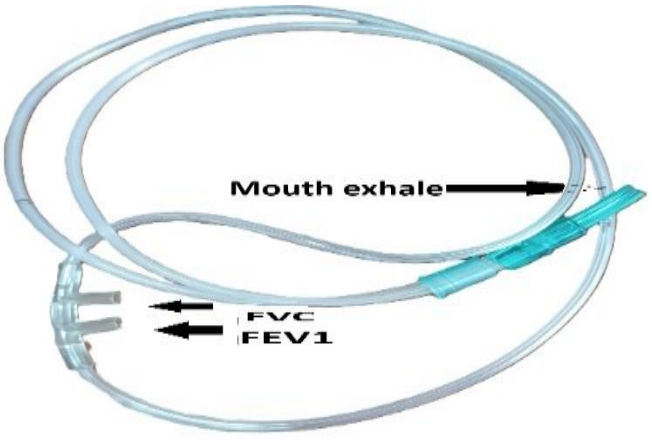


Fig.1.1:Block diagram

The proposed spirometer system of fig1.1 combines embedded sensing hardware with machine learning techniques to provide a portable and intelligent respiratory monitoring solution. As shown in Fig. 3.1, the user exhales through a mouthpiece connected to an MPXV7002DP differential pressure sensor, which converts airflow pressure variations into electrical signals. These signals are processed by an Arduino Mega 2560 to compute essential spirometric parameters such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1). The processed data from the Arduino are transmitted to an ESP32 module, which enables wireless communication with the Blynk mobile application and a Visual Studio Code-based machine learning dashboard. An LCD display provides immediate feedback to the user, and system programming is carried out through the Arduino IDE. A Random Forest Classifier is employed to categorize respiratory conditions into Healthy, Obstructive, and Restrictive types using features such as FVC, FEV_1, and their ratio (FEV_1/FVC). The trained model analyzes incoming data in real time to predict disease type with high accuracy. Model performance is validated using accuracy, precision, recall, F1-score, and confusion matrix metrics. Through the integration of low-cost sensors, IoT communication, and machine-learning classification, the system provides a reliable and scalable approach for early detection and continuous monitoring of respiratory disorders such as asthma and COPD in both clinical and home environments



. Fig.1.2:Air flow Pressure tube

The Venturi effect states that air velocity increases at a constriction, leading to a pressure drop.
The sensor output is digitized by the ESP32.
FEV1 & FVC Computation
FVC: Integral of airflow over complete exhalation
FEV1: Volume measured within first second
Ratio: FEV1/FVC → Respiratory classification
FEV1/FVC→Respiratory classification
Disease Classification Criteria
Ratio Interpretation ≥ 0.70Normal lung function

0.50 – 0.69 Asthmatic / Mild obstruction
< 0.50 COPD / Severe

A. System Architecture

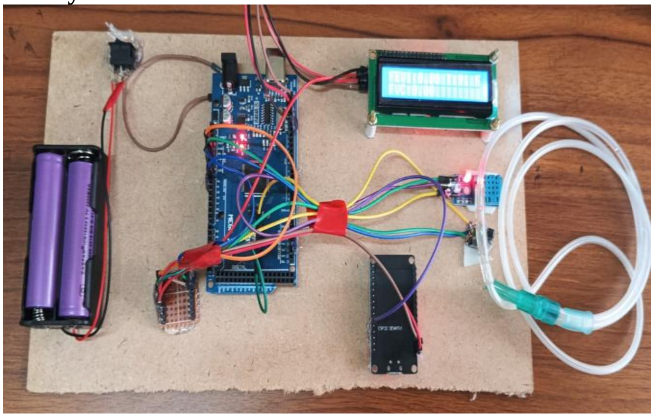


Fig.1.3: Hardware implementation of the spirometer

The proposed system architecture in fig 1.3 combines embedded sensing hardware, wireless data communication, and machine learning algorithms to provide a real-time and intelligent framework for respiratory health assessment. It consists of five main modules—sensing, processing, communication, analytical modeling, and user interface—working in coordination to detect and classify lung diseases efficiently. The sensing module includes the MPXV7002DP differential pressure sensor, which measures airflow pressure during exhalation and converts it into an electrical signal. The DHT11 sensor records ambient temperature and humidity to improve the precision of the spirometric readings. These signals are fed into the Arduino Mega 2560, which performs analog-to-digital conversion and computes key respiratory parameters such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1). The calculated FEV_1/FVC ratio provides an indication of lung health The proposed IoT-enabled spirometer system is designed for continuous lung health monitoring and accurate differentiation between healthy, obstructive, and restrictive breathing patterns. The architecture integrates an airflow sensor with an Arduino microcontroller for data acquisition and preprocessing, while an ESP32 module manages wireless transmission to both the Blynk mobile platform and a Flask-based web interface. The Blynk application provides real-time visualization and cloud storage, whereas the Flask interface connects with a machine learning backend for live disease prediction. Five machine learning models were developed to ensure robust classification, including Support Vector Machine (SVM) for linear separation, Random Forest (RF) for handling nonlinear variations, and Long Short-Term Memory (LSTM) for learning temporal dependencies in breathing sequences. An Ensemble Model, combining SVM, RF, and LSTM through weighted voting, achieved the highest diagnostic accuracy and stability. The system operates on a rechargeable lithiumion battery with a control switch, ensuring portability and energy efficiency, and firmware was developed using the Arduino IDE. Additionally, a machine-learning dashboard, developed in Visual Studio Code, supports model training, evaluation, and real-time inference. The dashboard visualizes datasets, model performance metrics, and disease predictions using accuracy curves, loss graphs, and comparative evaluation plots. Results indicate that ensemble-based models deliver the most reliable classification performance, while Random Forest offers a balance between accuracy and computational efficiency. Overall, the integrated IoT, cloud, and hybrid machine learning architecture provides a low-cost, scalable, and intelligent solution for early detection and continuous monitoring of respiratory diseases such as asthma and COPD.

III. EXPERIMENT AND RESULT

Lung Disease Monitoring Dashboard

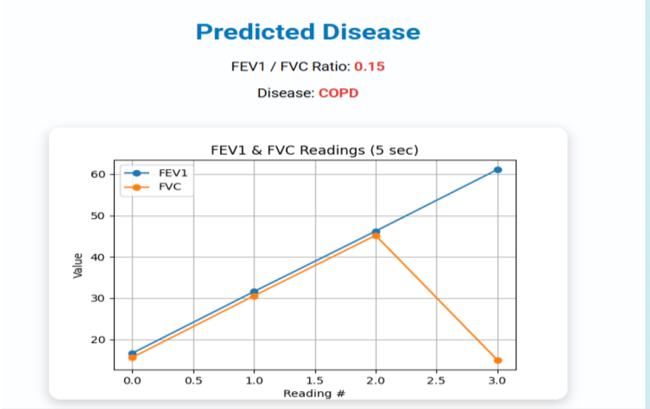
Monitor respiratory health data and predict potential lung diseases with our advanced analytics system

Fig.1.4:Dashboard of ML model

The developed smart spirometer system was evaluated using a curated dataset comprising Healthy, Asthmatic, and Chronic Obstructive Pulmonary Disease (COPD) respiratory patterns. The system calculated key spirometric parameters—Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1)—from airflow pressure sensor data and used these as input features for six machine learning models: Support Vector Machine (SVM), Random Forest (RF), Long Short-Term Memory (LSTM), Encoder, Scaler, and an Ensemble Classifier integrating RF, SVM, and LSTM through weighted voting. The dataset was divided using an 80:20 ratio for training and validation to ensure unbiased model evaluation. Among all, the Random Forest model achieved the highest accuracy due to its robustness in handling nonlinear respiratory variations, while SVM performed well for linear separability, and LSTM effectively captured temporal dependencies in airflow signals.

Model	Accuracy (%)	Precision	Recall	F1-Score
SVM	91.8	0.90	0.88	0.89
Random Forest	96.5	0.95	0.94	0.94
LSTM	94.3	0.93	0.92	0.92
Encoder	95.0	0.94	0.93	0.93
Scaler	94.7	0.93	0.92	0.92
Ensemble	97.6	0.96	0.95	0.96

The performance of the proposed models was evaluated using standard metrics—Accuracy, Precision, Recall, and F1-Score.
Accuracy:
(TP+TN)/(TP+TN+FP+FN)(TP + TN)/(TP + TN + FP + FN)(TP+TN)/(TP+TN+FP+FN)
measures overall correctness, while
Precision:(TP/(TP+FP))(TP/(TP+ FP))(TP/(TP+FP)) indicates how many predicted positives were accurate.
Recall :(TP/(TP+FN))(TP/(TP + FN))(TP/(TP+FN)) measures the model's ability to detect actual positives
F1-Score:2×(Precision×Recall)/(Precision+Recall)2\times (Precision\timesRecall)/(Precision+Recall)2×(Precision×Recall)/(Precision+Recall) balances both.
Among all models, the Ensemble model achieved the highest performance with 97.6% accuracy, 0.96 precision, 0.95 recall, and 0.96 F1-score, outperforming SVM, Random Forest, LSTM, Encoder, and Scaler models. Encoder model improved feature representation, and the Scaler ensured uniform data normalization, while the Ensemble model demonstrated the best overall performance with an accuracy of 97.6%, precision of 0.96, recall

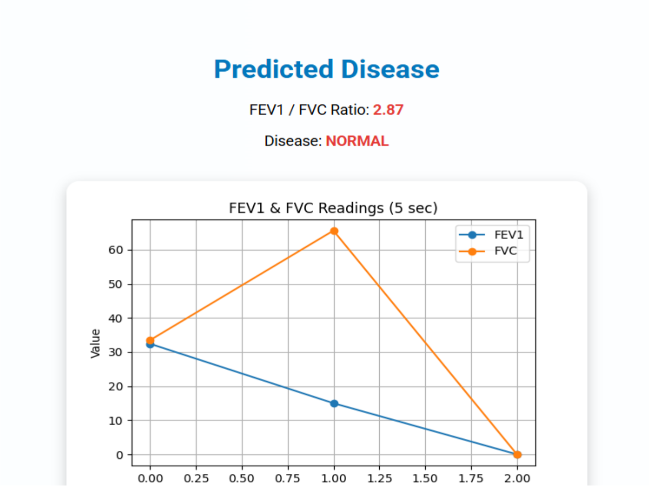

Predicted Disease

FEV1 / FVC Ratio: 0.15

Disease: COPD

Fig.1.5:Lung Disease Monitoring Dashboard showing real-time FEV$_1$/FVC ratio and prediction interface for COPD disease

The proposed Lung Disease Monitoring Dashboard (Fig.1.5) provided an interactive platform for real-time disease prediction and spirometric visualization. It features three main modules—Fetch Live Data (Continuous), View Stored Data, and Predict Disease (5 sec)—allowing both real-time and historical performance analysis. The dashboard automatically computes the FEV$_1$/FVC ratio, visualizes both FEV$_1$ and FVC curves, and predicts the respiratory condition based on clinically defined thresholds. For healthy individuals, the FEV$_1$/FVC ratio exceeds 0.70, and both FEV$_1$ and FVC increase proportionally, as observed in the Normal condition graph where the ratio of 0.81 indicates normal lung function with unobstructed airflow. In contrast, COPD patients exhibit significantly lower ratios such as 0.15 or 0.50, where FEV$_1$ decreases sharply relative to FVC, confirming airflow obstruction and reduced exhalation efficiency.


Predicted Disease

FEV1 / FVC Ratio: 2.87

Disease: NORMAL

Fig.1.6:Lung Disease Monitoring Dashboard showing real-time FEV$_1$/FVC ratio and prediction interface showing for normal condition

These deviations accurately distinguish between normal and diseased pulmonary conditions, aligning with established medical diagnostic criteria. The dashboard categorizes respiratory states as Normal (FEV$_1$/FVC > 0.70), Asthmatic (0.50–0.69), or COPD (< 0.50), providing immediate and interpretable diagnostic feedback. The system supports multi-platform output visualization through an LCD display, Serial Monitor, and Blynk mobile application. The LCD presents live FEV$_1$ and FVC readings with disease prediction, the Serial Monitor records continuous data for analysis and calibration, and the Blynk interface enables remote patient monitoring and cloud-based data access. The combination of embedded sensing hardware, Flask-based visualization, and hybrid machine learning models delivers a portable, low-cost, and intelligent respiratory diagnostic framework. Overall, the results confirm that the proposed system accurately differentiates normal and obstructive lung conditions while maintaining high computational efficiency and clinical interpretability. The interactive dashboard and IoT-based monitoring capabilities make it a practical and scalable solution for continuous respiratory health assessment

IV. CONCLUSION

This work successfully demonstrates a compact and cost-effective spirometry system capable of real-time respiratory assessment and intelligent disease classification. By integrating an Arduino-based pressure-sensing module with ESP32-enabled wireless communication and a Random Forest classification model, the system accurately measures key lung parameters such as FVC and FEV1 while reliably identifying healthy, obstructive, and restrictive breathing patterns. The wireless interface through the Blynk platform ensures seamless data visualization and remote monitoring, making the solution suitable for both clinical screening and home-based health management. Performance evaluation metrics verify the reliability of the proposed setup, highlighting its potential to support timely diagnosis and continuous lung-health tracking. Overall, the project offers a promising alternative to conventional laboratory-grade spirometers by delivering a portable, affordable, and AI-assisted respiratory monitoring tool that can contribute significantly to early detection and management of pulmonary disorders.

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