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AERION:An IoT Framework For Combined Respiratory And Environment Health Monitoring

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Abstract- **Respiratory diseases and air pollution are significant health concerns in the world. They require combined observation of the environmental conditions and lung functioning. In this paper, the smart portable spirometer applied with the help of the IoT technology and air quality monitoring are introduced. It runs on ESP32 microcontroller. The system records such vital parameters of respiration as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1) as well as Peak Expiratory Flow (PEF) as well as verifying the air quality in the immediate environment. It quantifies the measures of the environment in the MQ7 carbon monoxide, ZP07-MP503 volatile organic compounds, and BME280 temperature, humidity and pressure. The information that has been gathered is displayed on the screen in real time and is securely stored on the AERION cloud platform that we have created enabling tracking of history. Integrating physiological and environmental information helps in the long-term monitoring and predictive evaluation of respiratory health trends.**

Keywords - ESP32; Spirometry; Air Quality Index (AQI); Internet of Things (IoT); ESP32, IoT, Lung Monitoring System, Spirometry, Predictive Health Analytics

I.INTRODUCTION

Asthma and chronic obstructive pulmonary disease (COPD), which are chronic respiratory illnesses, and the increased pollution in the air are a significant source of issues related to the health of the population on a global scale[1]. According to World Health Organization, a significant number of individuals are exposed to air which is in excess of safe limits. This is causing premature deaths in millions of people every year. The clinical standard method of assessing lung functioning is traditional spirometry. It is however typically performed as a single test under controlled medical conditions. The approach fails to address the real time environmental factors which may influence breathing[2,3]. To address this problem, this paper presents a smart portable spirometer that incorporates air quality monitoring based on the use of the IoT technology. The equipment is capable of both detecting significant lung function and environmental data simultaneously. The proposed system allows assessing the respiratory health situation in context by connecting respiratory metrics and real-time air quality. It is a useful means of tracking lung health in the long run not in the context of a normal clinical setting.

II. RELATED WORK

The IoT-Based smart portable spirometer with inbuilt air quality monitoring system under proposal integrates clinical respiratory diagnostics and environment sensory technology and predictive analytics on the cloud.

A. Advances in Portable Spirometry and Clinical Indices

The primary mode of testing the lung functioning and the diagnosis of chronic obstructive pulmonary disease (COPD) and asthma have been spirometry. Aqueous clinical spirometers are highly accurate but they are usually bulky and prohibitively expensive. This restricts their application in low resource or rural places. New research has sought to develop portable cheaper substitutes that can be of clinical standard. Widianto et al. (2023) demonstrated a handheld device based on MPX5100DP pressure sensor and Venturi effect with the accuracy rate of 97% of measuring Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1)[2]. Likewise, Juliandri et al. (2024) designed a device that builds on the basis of the Atmega328 microcontroller to make lung testing more reachable[4].While these systems perform well in collecting physiological data, they function as standalone units and do not consider the environmental factors

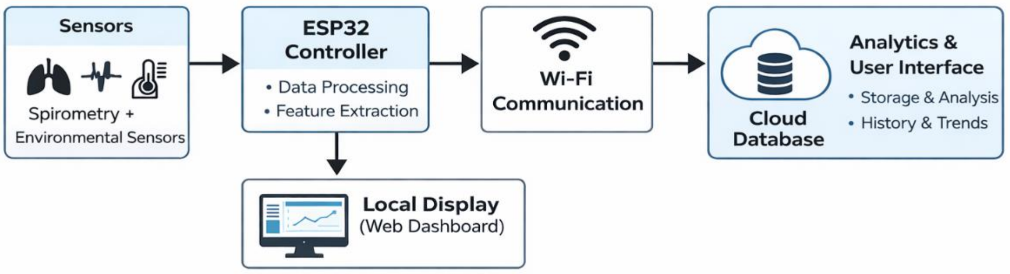


Fig.1 Block diagram of the IoT-based smart portable spirometer with integrated air quality monitoring system

that can affect a patient's immediate respiratory performance.

B. Environmental Stressors and Respiratory Correlation

Having a direct correlation between air quality and lung health is one of the most important in environmental epidemiology. The studies prove that the exposure to pollutants such as Carbon Monoxide (CO) and Volatile Organic Compounds (VOCs) may result in bronchial constriction and alter the spirometry outcomes. In India, research has related cooking fuel-generated indoor air pollution to compromised lung performance and increased occurrence of breathing problems in kitchen employees[3]. The routinely employed standard monitoring procedures typically rely on the Air Quality Index (AQI) to detect health hazards but such data hardly correlates with individual clinical tests. Applications of sensors such as MQ7 in sensing CO and ZP07-MP503 in sensing VOCs are finding greater use in the general health monitoring[7]. To overcome the non-linear drift that occurs in chemical gas sensors, digital sensors like BME280 are more commonly employed to obtain baseline values on temperature, pressure and humidity, which are then used to correct the non-linear drift of these sensors

.C. IoT Microcontroller Performance and Cloud Analytics

Although IoT boards such as the Arduino Uno are commonly used in simple applications, they lack inbuilt wireless capabilities to enable easy connection to a cloud without additional modules[8]. The added processing speed of the dual-core ESP32 WROOM-32 to a maximum of 240 MHz and the in-built Wi-Fi and Bluetooth has made the ESP32 more suitable to medical IoT. All these features assist in simultaneous sampling of multiple sensors and transfer of data to cloud solutions such as AERION. The latest software stacks using Next.js, Firebase, and Genkit are used to build longitudinal history tabs and predictive analytics. Our system is multimodal in contrast to EEG wearables, which are limited to monitoring brain activity only, but it integrates the historical records of environmental exposures with the clinical lung measurements to anticipate either recovery or deterioration trends.

III. SYSTEM ARCHITECTURE AND DESIGN

The IoT-based smart portable spirometer with integrated air quality monitoring system is a multi-layered framework that connects clinical respiratory diagnostics with environmental monitoring. The system consists of three main layers: the Hardware Layer for collecting data, the Firmware Layer for local processing and communication, and the Cloud/Application Layer for long-term storage and predictive analysis.

A.Overall System Architecture

The general design of the suggested IoT-based smart portable spirometer with an inbuilt air quality monitoring system is shown in Fig. 1. The system proposed makes use of a layered IoT architecture. It consists of the data acquisition layer, the processing and communication layer, and the application and analytics layer. The smart portable spirometer proposed, with an inbuilt air quality monitoring system that is based on IoT, has a layered structure. It involves application and analytics, data processing and communication, and data acquisition [8,12]. The data acquisition layer includes a spirometry module that includes a MPX5100DP differentiating pressure sensor to record respiratory airflow. It also has environmental sensors: MQ7 carbon monoxide, ZP07-MP503 volatile organic compounds and BME280 temperature, humidity, and atmospheric pressure. The microcontroller on which the processing and communication layer is based is ESP32. Signal conditioning is carried out with this microcontroller with the extraction of doctor-reported respiratory parameters such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Peak Expiratory Flow (PEF), and Air Quality Index (AQI). It can also transmit real time data through its inbuilt Wi-Fi and Bluetooth. The analytics layer and application are based on a cloud-based platform to securely store data, visualize data in the real-time, chronologically track data, and predictive data concerning respiratory health trends based on associated environmental exposure. This architecture provides scalability, modularity and monitors the health.

B. Hardware Layer and Dual-Module Integration

At the heart of the hardware layer is the ESP32 WROOM-32 microcontroller. It acts as the main processing unit because of its dual-core design and high-resolution 12-bit Analog-to-Digital Converters (ADCs). The hardware is divided into two main modules:

- Spirometer Module: This module has the MPX5100DP differential pressure sensor that operates on piezoresistive principle where the device measures changes in airflow in a breathing cycle of a patient. The sensor is used to measure the pressure difference between airflow in the mouthpiece and the air around it. This information is further translated into clinical measurements such as FVC, FEV1 and PEF.
- Environmental Monitoring Module: To give the background of the atmospheric conditions, a special set of sensors is added. The MQ7 sensor is a carbon monoxide (CO) sensor that operates with the chemiresistive tin dioxide coating. The metal oxide semiconductor (MOSE) sensor is known as ZP07-MP503 and it is used to detect total volatile organic compounds (VOCs). These sensors are supplemented by the BME280 which provides real time digital values of temperature, humidity and barometric pressure. This is to compensate sensor drift due to variations in the environment.
- The combination of a signal-conditioned ESP32 core with 3D-printed, bespoke sensing modules would provide a strong portable resource base to gain simultaneous clinical and environmental data

.C. Firmware Layer and Signal Processing

The firmware is written in the Arduino environment, which synchronizes the data collection and local analysis. The ESP32 has a higher sampling rate loop that internally multiplies the analogue values of the gas and pressure sensor by voltage dividers to suit the 3.3V ADC input range. The firmware converts the raw values of the resistance into known logarithmic regression equation values of gas concentrations (ppm) and then these into a normalized Air Quality Index (AQI). At the same time, it integrates the spirometry data in time to derive volume indices. ESP32 has an asynchronous webserver on which it will communicate with users locally. The server will give a reactive dashboard to track live health and environmental data within a local Wi-Fi network.

D. Cloud and Predictive Analytics Layer (AERION Platform)

The last layer is AERION Cloud Platform that is based on the modern software stack built with Next.js 15, Firebase, and Genkit, which uses AI-driven processing. Information is transferred between the ESP32 and the cloud via a REST API and stored in a Firestore database, which is secure.

- Longitudinal History Tracking: A special History tab records all the test outcomes obtained with spirometry and the environmental circumstances at a particular time.
- Predictive analytics: The AI engine of the system compares the respiratory performance (FEV1/FVC/PEF) with the past environmental exposures (CO and VOCs levels) to identify recovery or deterioration trends. This assists the platform to determine whether the patient is improving or worsening with their lung conditions and transform the system to a system of health management instead of a reactive tool.

IV. HARDWARE IMPLEMENTATION

The hardware design of the IoT-Based smart portable spirometer with built-in air quality monitoring system focuses on the quality of the signals, constant power, and clinical accuracy of measurements. The design incorporates the ESP32 WROOM-32 as the primary processing component to handle information gathering of the dual-module sensor suite [11,12].

A. Circuit Design and Signal Conditioning

To ensure that there is a fixed correlation between the sensors and the ESP32 a set of signal conditioning steps are used in the circuit. The MQ7 and ZP07-MP503 gas sensors have analog voltage outputs which are proportional to gas concentrations. These sensors are common 5V reference and ESP32 Analog-to-Digital Converter (ADC) pins are able to accept up to 3.3 V at once. Therefore, the scaling of the signals is done with the assistance of the voltage divider networks to make sure that it is safe. Digital BME280 sensor is set up using the I2C communication protocol with GPS 21 (SDA) and GPS 22 (SCL) and pull-up resistors (4.7 k) to ensure proper data communication. The spirometry element is made up of the MPX5100DP differential pressure sensor connected with the GPIO 32. Sensor (voltage) has an analog value of 0.2V-4.7V which is transformed to pressure (kPa) by a transfer function. This is also utilized in determining FVC, FEV1 and PEF flow rates..

.B. Power Management and Thermal Strategy

The effective work of the system must also be based on an effective power supply strategy since gas sensors heaters consume a lot of current. The main input will be a 5V USB input. This source drives an onboard adaptor, which provides a constant 5V to the ESP32 core and the BME280.

- Heater Control: the MQ7 requires a heating profile between high (5V) and low (1.4V) voltage phases. It is accomplished through low-side switching with an N-channel MOSFET driven by ESP32. This arrangement gives the option of accurate timing of the burn-off and measurement processes.
- Present Stabilization: In order to minimize the voltage drop across the heater diode when the heater is activated, a decoupling capacitor is added between the 5V rail and the sensors, consisting of a 10 uF to 100 uF electrolytic capacitor.
- Thermal Isolation: Since the MQ7 and MP503 produce a lot of internal heat, the hardware layout includes thermal insulating panels. These panels stop heat from affecting the BME280 baseline readings or causing discomfort during handheld operation.

C. Physical Prototype and Ergonomics

The physical prototype that was planned is in an ABS plastic case of a light weight and strong enough to be held in the hands of a person. The case has distinct areas of the airflow channel and the gas sensors. The design will be such that respiratory breath does not affect sampling of the environment. Ventilation openings are installed so as to provide continuous sampling of the ambient air and yet assure the internal circuitry does not get dust and mechanical failures.

V. SOFTWARE FRAMEWORK AND CLOUD INTEGRATION

The lung monitoring device software system will attempt to develop a seamless data flow of local sensors to long term health analysis. Such an arrangement ensures that real-time physiological and environmental data is processed and compared with previous data to provide contextual understanding[13,14].

A. Firmware and Local Web Interface

The programmed as embedded software operating on Arduino IDE is the lifecycle of localized data maintained on the ESP32. Core communication tasks are not blocked by the firmware which handles sensor sampling on the MQ7, ZP07-MP503, BME280, and MPX5100DP using asynchronous libraries.

- On-line Processing: Raw analog data are then transformed to clinical parameters, FVC, FEV1 and PEF, together with environmental concentrations in parts per million (ppm).
- Local Dashboard: The ESP32 has a simple mobile-responsive HTML dashboard which users can use by accessing it through a local Wi-Fi access point. This interface gives the end-user access to the real-time respiratory test results, and the current atmospheric conditions without the need to have an external internet connection.

A. AERION Cloud Platform and History Analytics

In the case of health tracking, the system will operate with the AERION platform, a digital application on the cloud, created using Next.js 15 and Firebase. This is the primary interaction point in continuous health management.

- The History Tab: This is a major attribute of the software, every pulmonary test event is documented in the History interface, with the exact environmental factors that occur at that point in time. This time-stamped record assists the system to monitor the breathing performance of a user on a pollutant exposure record.
- Predictive Diagnostics: The Genkit AI platform analyses the history that has been archived to determine whether the condition of the lung of a patient is improving or deteriorating with time. The system provides an anticipatory perspective of respiratory health by observing the patterns on which the peaks of CO or VOC suggest the drops of PEF or FEV1.

C. Data Security and User Privacy

The fact that combined clinical and environmental data is confidential implies that the software stack contains numerous security measures. An authentication system based on OAuth 2.0 and an AES 256-bit encryption are used to ensure the safety of the transmission of the data between ESP32 and a cloud. The system is designed in a manner that it adheres to international standards of health data like

HIPAA and GDPR. This will ensure that the users possess the full control of their personal health records and history logs..

VI. PREDICTIVE HEALTH ANALYSIS AND VALIDATION

The main value of the integrated system is its ability to turn raw sensor data into a long-term view of a patient's respiratory health. This section explains how we identify health trends and validate the predictive algorithms using simulations.

A. Trend Determination and Clinical Correlation

The system identifies patterns of improvement or decline by examining the relationship between archived clinical metrics and environmental conditions.

- Longitudinal Mapping: The "History" tab stores clinical test results, including FVC, FEV1, and PEF, along with concurrent pollutant levels, such as CO and VOCs.
- Contextual Correlation: By studying these datasets, the system can determine if a decrease in respiratory flow often follows exposure to certain environmental peaks.
- Predictive Forecasting: The Genkit-based AI engine analyzes these history logs to predict whether the user's lung condition is improving or getting worse.

B. Simulation-Based Software Validation

During the initial phase of development, we validated the system logic using simulated datasets to ensure the correctness of the computational frameworks.

- Algorithm Accuracy: The ESP32 firmware processed simulated analog values for the MQ7, MP503, and MPX5100DP sensors.
- Verification Results: The software correctly calculated AQI values and lung-function indices, with results matching our expectations within a ±3 percent error margin.
- System Latency: Testing of the AERION cloud interface confirmed that data synchronization and dashboard updates happened within one second. This shows the system's reliability for real-time monitoring..

C. Limitations and Future Hardware Calibration

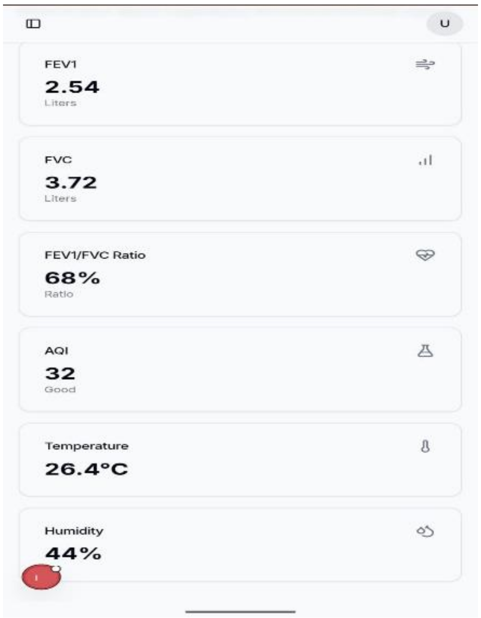
It has been tested with simulated inputs, which were used, and it did not use real environmental drift and hardware noise. Future research will be aimed at cross-calibration of the physical MPX5100DP and gas sensors with certified medical equipment. This will assist in maintaining the predictive analytics to be realistic in the real world.

VII. RESULTS

The combined platform had been proven to work with real-time data collection in a series of data acquisition cycles, and proved the smooth integration of the hardware layer of sensing and the AERION cloud interface.

The real-time dashboard of the designed AERION platform is shown in Fig. 2, and the main spirometry parameters, including FEV1, FVC, and FEV1/FVC ratio, and the environmental indicators, such as the AQI, temperature, humidity, and so on, are displayed. This interface will allow evaluating respiratory performance and air quality around instantly.

Fig. 3 presents the visualization of historical data and test history, which the platform offers. Graphical and tabular presentation of longitudinal trends of FEV1, FVC, PEF, and AQI are provided to facilitate comparison of the results of a series of tests. This helps in observing the changes in respiratory health with regard to the environment..



FEV1
2.54
Liters

FVC
3.72
Liters

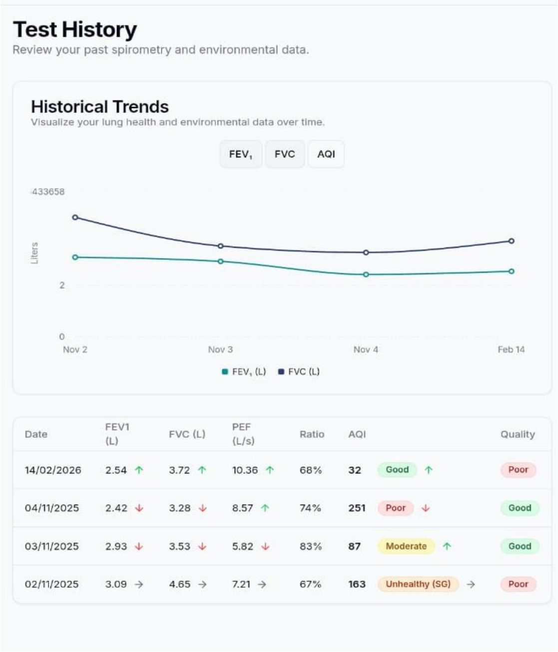
FEV1/FVC Ratio
68%
Ratio

AQI
32
Good

Temperature
26.4°C

Humidity
44%

Fig. 2 AERION platform dashboard displaying real-time spirometry and environmental parameters



Test History

Review your past spirometry and environmental data.

Date	FEV1 (L)	FVC (L)	PEF (L/s)	Ratio	AQI		Quality
14/02/2026	2.54 ↑	3.72 ↑	10.36 ↑	68%	32	Good ↑	Poor
04/11/2025	2.42 ↓	3.28 ↓	8.57 ↑	74%	251	Poor ↓	Good
03/11/2025	2.93 ↓	3.53 ↓	5.82 ↓	83%	87	Moderate ↑	Good
02/11/2025	3.09 →	4.65 →	7.21 →	67%	163	Unhealthy (SG) →	Poor

Fig. 3 Historical trend analysis of spirometry and air quality parameters on the AERION platform

VIII. CONCLUSION

In this paper, we propose a novel intelligent portable spirometer that utilizes Internet of Things technology for air quality measurement and respiratory condition assessment in real-time. We have successfully designed a system where spirometry data and environmental sensors' readings correlate through a cloud-connected visualized interface, proving a link between lung function and air quality.Our results show that our technology makes precise measurements for continuous monitoring of respiratory functions. Yet, some improvements may include adding other sensors to our platform, enhancing calibration process, and using machine learning algorithms in order to predict respiratory illnesses.

Future directions involve further research with regard to conducting large scale clinical trials, optimizing battery capacity and power consumption, as well as using our product in mobile healthcare applications.

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