IR-BASED LOW-COST PORTABLE TURBINE SPIROMETER

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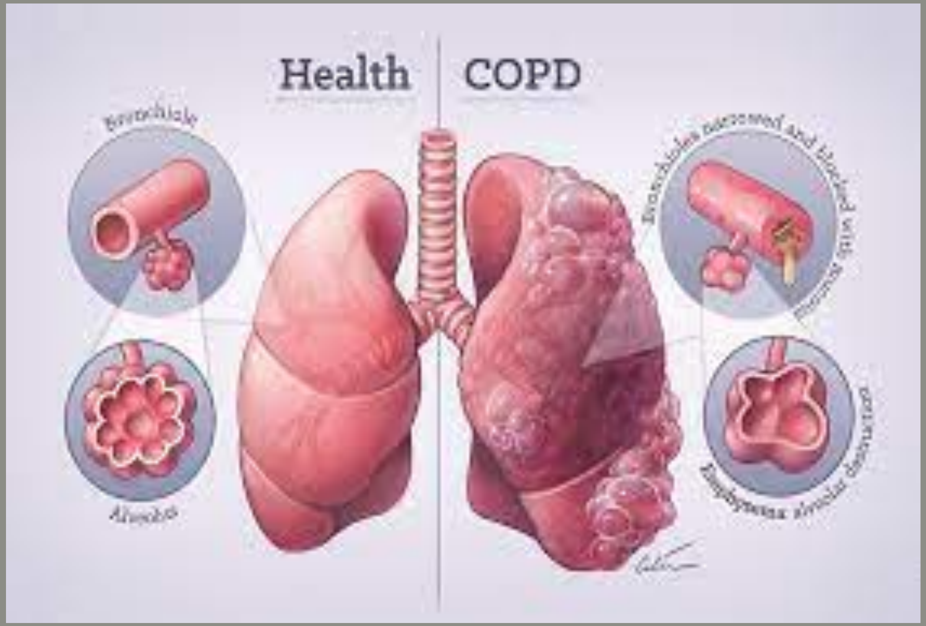
ABSTRACT

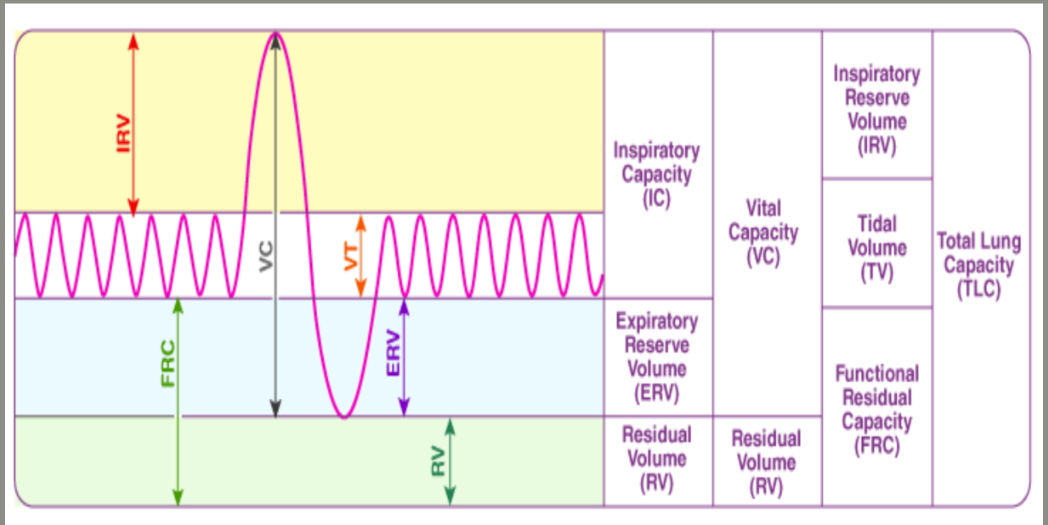
- The escalating costs of medical instruments have led to a growing need for affordable alternatives. This research project focuses on developing a **low-cost spirometer** using readily available materials to measure lung volumes and flow rates accurately.
- **Spirometry** plays a crucial role in assessing lung function by measuring airflow and pressure. It enables the evaluation of airway pressures, flows, volumes, compliance, and resistance. The spirometer records the volume of exhaled air as numerical data, which can be analysed to assess the mechanical characteristics of the lungs. The flow rate is determined using rotational velocity, and the integration of the flow rate over time provides the volume of gas passing through the tube. Our model incorporates a single, lightweight **IR sensor** to measure these parameters.
- While spirometry is essential for diagnosing various **pulmonary diseases** such as COPD, its current cost limits its accessibility. This study aims to develop a comprehensive spirometer equipped with essential sensors, including a flow meter, and programmable through an **Arduino UNO** Rev3 Microcontroller. We aim to create a functional and user-friendly spirometer that fulfils all the necessary requirements.

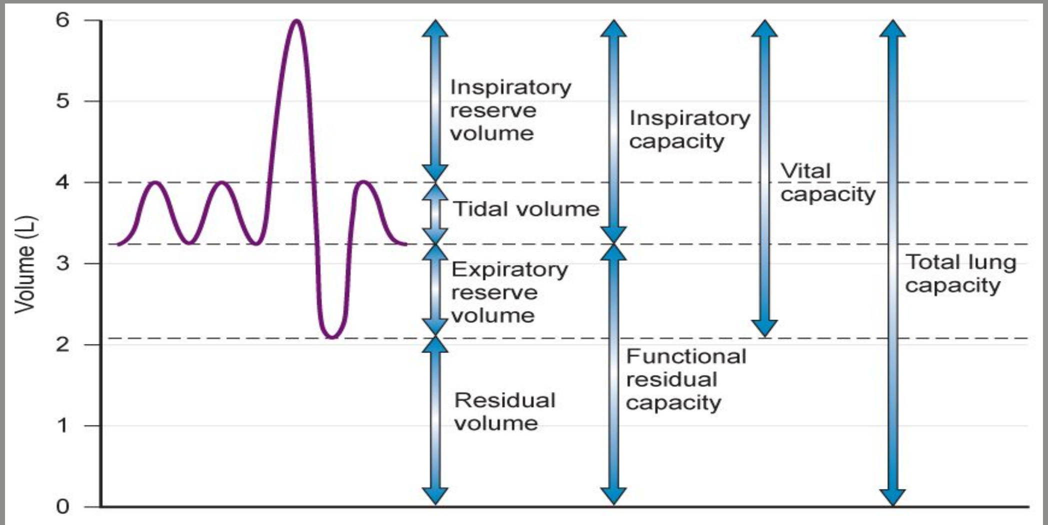
- Keywords: Spirometer, Flow rate, Lung Volume, Low-cost, COPD (Chronic Obstructive Pulmonary Disease)



INTRODUCTION

- Galen, a Roman physician, conducted early experiments measuring lung capacities between 129 and 200 A.D., contributing to the understanding of the respiratory system's vital functions in oxygen distribution and carbon dioxide elimination.
- In medicine, the main objective is disease prevention and early treatment, which should be affordable. **COPD**, the fourth leading cause of death worldwide, affects over 500 million people, particularly in developing nations where the expense of spirometric equipment poses a barrier to healthcare practitioners.
- **Lung diseases** affect many globally, arising from factors like smoking, infections, and genetics. Lungs deliver oxygen, eliminate carbon dioxide, and are prone to disorders, highlighting the importance of recognizing symptoms for early detection and management.





INTRODUCTION

- The **lungs** consist of bronchioles, alveolar ducts, and sacs that lead to delicate alveoli lined with mucus. The respiratory system is crucial for removing carbon dioxide and delivering necessary oxygen to allow for the functioning of the body's cells.
- **Spirometry** is important for identifying at-risk asymptomatic patients. Our study utilizes plastic bottles to create a sustainable and affordable spirometer, benefiting healthcare practitioners in resource-limited settings.
- Spirometry is a diagnostic test that assesses lung function by measuring airflow, volumes, and capacities. It involves the patient exhaling and inhaling into a spirometer, which records **air volume** and **flow rate**. This test provides valuable information for diagnosing and monitoring respiratory conditions like COPD and asthma, enabling healthcare professionals to evaluate lung function and make informed treatment decisions.

MOTIVATION

- The **rotational speed** of a **turbine** can serve as a useful indicator for determining the **flow rate** of gas. By measuring this speed, we can calculate the volume of gas passing through a pipe by integrating the flow rate over a specific time period. This approach allows us to assess different lung volumes and capacities by conducting the experiment at various time intervals.

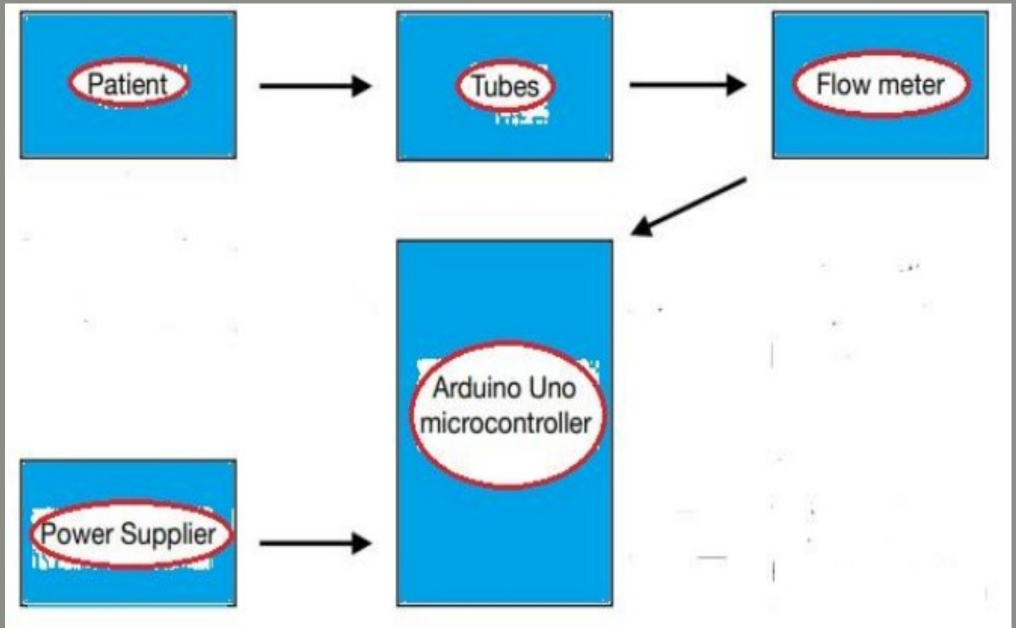
- Using this methodology, we can capture the dynamic changes in airflow during inhalation and exhalation. By monitoring the rotational speed of the turbine, we obtain real-time data that reflects the rate at which gas is moving through the system. **Integrating this flow rate** over a specific time interval allows us to quantify the **volume** of gas that has passed through the pipe.

LITERATURE REVIEW

- A notable study conducted by Cheung et al. [6] investigated the use of three-dimensional electrical impedance tomography to assess spirometric lung impedance. This approach offers a comprehensive evaluation of lung parameters, providing valuable insights.

- Another significant contribution, presented by Sridevi et al. [7], introduced a cost-effective spirometer specifically designed for the detection of COPD. The authors demonstrated that this affordable solution accurately measures lung volumes and capacities, making it accessible in resource-limited settings and enabling early COPD detection.

- Furthermore, Adiono et al. [8] developed a portable device capable of monitoring vital signs, including spirometric parameters. The authors showcased the utility of this device within the context of the Covid-19 pandemic.

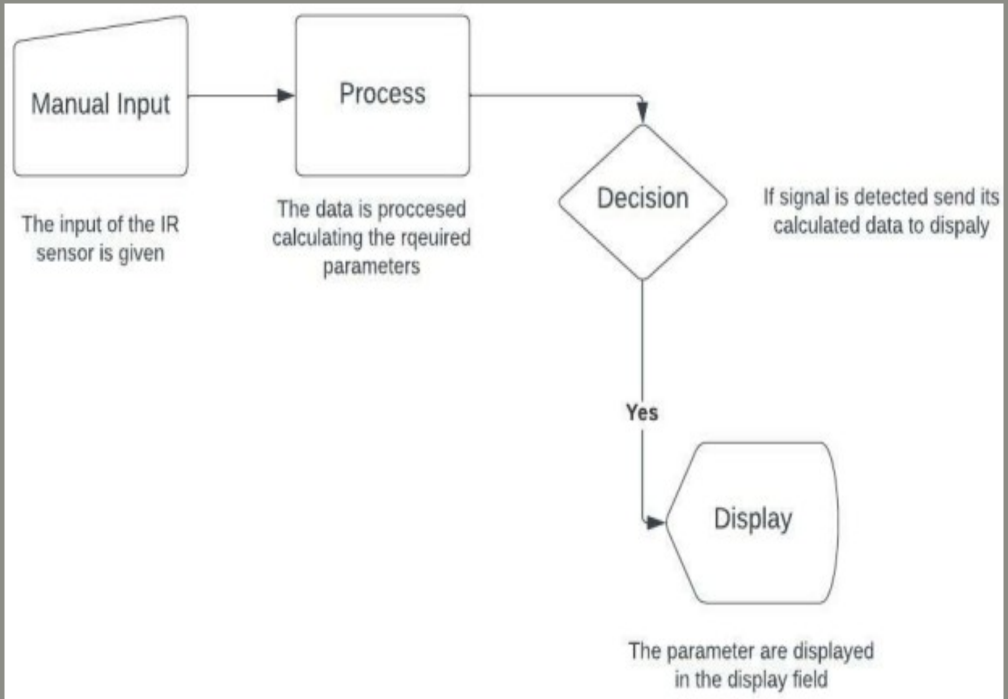


METHODOLOGY

- Our model focuses on the utilization of **IR sensors** in turbine-based spirometers to accurately measure and analyze parameters related to lung volume and capacities. By incorporating **IR sensors** into our spirometer design, we aim to provide a reliable and efficient method for assessing respiratory function.

- In our experimental setup, the spirometer features a vertically positioned **turbine** that serves as the primary mechanism for measuring airflow. As an individual blows air into the spirometer, the airflow creates a **rotational motion** within the turbine. This rotating airflow is a direct result of the exhaled breath, and it allows us to capture and quantify the volume of expelled air.

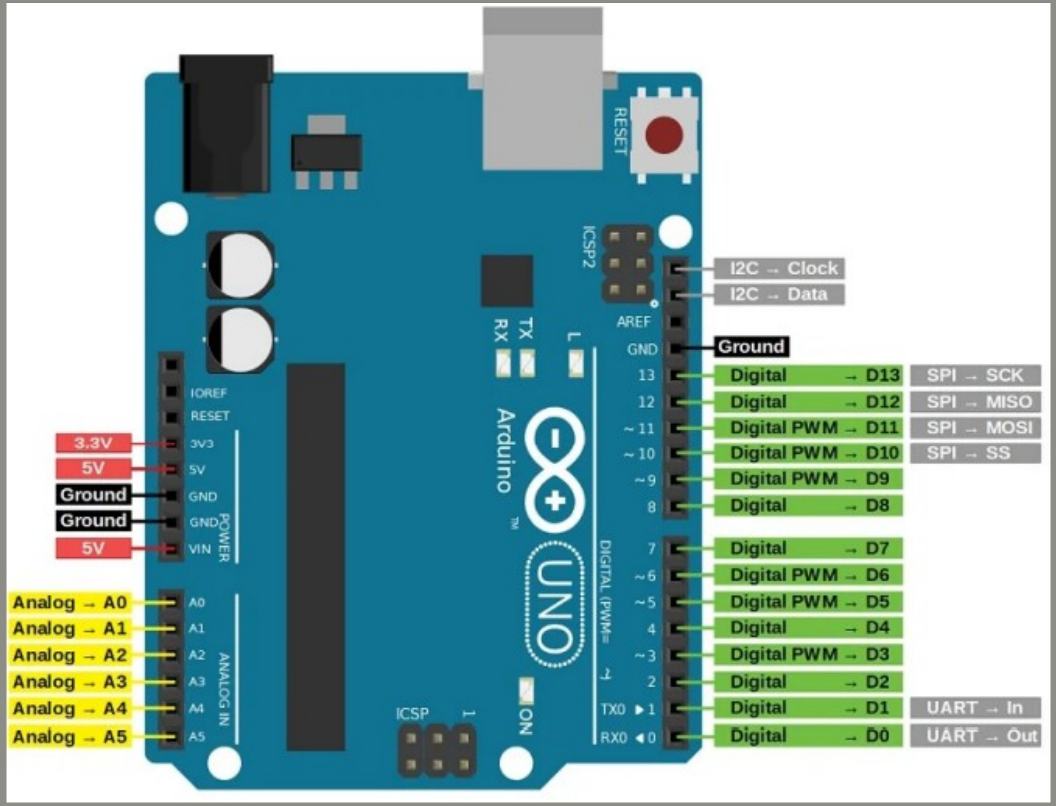
METHODOLOGY



- Once we have collected the data on rotational speed and flow rate, we calculate the **volume** by **integrating** the **flow rate** over a specific time interval, enabling us to accurately determine the volume of gas that passes through the spirometer.

- Component specifications:

- **IR sensor module** for sensing the tip of the fan.
- **Arduino UNO Rev3** Microcontroller for the interface.
- 9V Battery power supply.



Specifications of *Arduino* UNO Rev3 Microcontroller*: Operating voltage: +5V (Recommended),*
Input Voltage:
+7V to +12V, In/Out Voltage (Limit): + 6V to +20V PWM, Digital I/O Pins: 6, Analog Input Pins: 6, Digital I/O pins: 14 [6 pins to provide PWM output] DC Current per I/O pin: 20 mA.

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RESULTS & DISCUSSIONS

- We employed an IR sensor to measure the required parameters in our spirometer. The sensor **detects the blades** of the rotor used in our apparatus. Our design emphasizes simplicity and environmental friendliness, aligning with our goal of creating an affordable and portable spirometer. The rotor blades were crafted from **recycled plastic bottles.**
- The flow rate is calculated based on the velocity of the airflow. Integration of the flow rate yields the subject's volume. Healthy young women typically exhibit flow rates between 150 and 200 L/min, with values decreasing with age for both males and females. Peak Expiratory Flow Rate (PEFR) represents the maximum flow rate achieved during a Forced Vital Capacity (FVC) maneuver, with healthy individuals often surpassing 600 L/min. Males have an average tidal volume of 38.9 mL, while females have an average tidal volume of 46 mL.
- As the subject exhales into the apparatus, the airflow spins the turbine, and the IR sensor measures the time interval between successive blades to determine the airspeed. By integrating the results, we derive the subject's lung volume, providing the necessary parameters for flow rate and volume measurements. These measurements aid in identifying subjects with COPD, allowing for appropriate guidance based on the spirometer's findings.
- Lung volume is obtained by integrating sample flow rate inputs, which are detected by an IR sensor. This information provides insights into individual lung capacities and volumes, facilitating the diagnosis of COPD in subjects.

CONCLUSION & FUTURE SCOPE OF WORK

- The objective of the project was to develop a spirometer that is affordable and user-friendly for measuring lung volumes. Our approach involved incorporating **sustainability** and eco-friendly considerations into the design of the spirometer. By implementing a rotating turbine that is operated by the user, we were able to effectively measure both volume and flow rate, providing valuable information about lung capacities.
- The implementation of our portable turbine spirometer enables accurate assessment of lung parameters, which is particularly beneficial for the early detection of conditions such as COPD. Additionally, the model's **compact size** and **low maintenance** cost makes it **highly portable** and accessible to individuals from various backgrounds, ensuring that it is **affordable** and usable for a wide range of users.
- Spirometry can show airflow restrictions, but it cannot identify the cause. The functionality can be expanded to measure various other parameters. By **integrating oximetry** and **capnometry** functions, the spirometer becomes more versatile, allowing for simultaneous measurement of oxygen, carbon dioxide, and volume parameters, thereby reducing diagnosis time and costs while enhancing diagnostic efficiency.
- Future research can explore **miniaturization** to make the spirometer more portable without compromising functionality. **Wireless connectivity** and **smartphone applications** could enable real-time data monitoring and analysis. Artificial intelligence techniques can also be utilized for advanced data interpretation and personalized respiratory care.

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REFERENCES

[1] Abdulaziz Aladib, Zaid Hayek, Omar Kharsa “Spirometer” Published Online-2018

[2] Seakale Chandrakar, “Design and development Of Low-Cost Spirometer With PC Interface” Published Online - June 2014

[3] Jeremy Glynn, Jeremy Schaefer, Andrew Dias, Andrew Bremer, “Low-Cost Spirometer” Published Online- May 8, 2009

[4] AARC (American Association for Respiratory Care) http://www.aarc.org/headlines/08/11/copd_month/

[5] Spirometry https://byjus.com/biology/spirogram-diagram/

[6] P. T. Cheung, F. Zouari, A. Touboul, V. Sin, E. C. Wong and R. W. Chan, "3D EIT Enables Global and Regional Spirometric Lung Function Assessment," TENCON 2022 - 2022 IEEE Region 10 Conference (TENCON), Hong Kong, Hong Kong, 2022, pp. 1-6, doi: 10.1109/TENCON55691.2022.9978086.

[7] P. Sridevi, P. Kundu, T. Islam, C. Shahnaz and S. A. Fattah, "A Low-cost Venturi Tube Spirometer for the Diagnosis of COPD," TENCON 2018 - 2018 IEEE Region 10 Conference, Jeju, Korea (South), 2018, pp. 0723-0726, doi: 10.1109/TENCON.2018.8650092.

[8] T. Adiono et al., "Respinos: A Portable Device for Remote Vital Signs Monitoring of COVID-19 Patients," in IEEE Transactions on Biomedical Circuits and Systems, vol. 16, no. 5, pp. 947-961, Oct. 2022, doi: 10.1109/TBCAS.2022.3204632.