IOT BASED TELE - SPIROMETER FOR PULMONARY DISEASE DIAGNOSIS

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Abstract

A spirometer is a device that measures how much air you can breathe in and out of the lungs. It is also used to measure the volume and how quickly it occurs. It's used to diagnose and monitor lung conditions. An IOT-based spirometer in rural areas helps to get immediate diagnosis, as it allows the data of the patient to be transmitted to the doctor sitting far away from the patient. This feature of IOT can be integrated with many other medical devices for other diseases. The telemetry systems play a very important role in increasing awareness among people and reducing mortality rates. Other feature that can be added is to make people learn about how to handle this model especially in rural areas, so as to ensure that the model is properly used and better results can be displayed. Output is displayed in mobile through IP link. This information is commonly used to diagnose Asthma, Pulmonary fibrosis, Cystic fibrosis, COPD, and Pneumonia. In India there are more than 10 million COPD cases occur per year. Arduino microcontroller is used to calculate the pressure and breath rate of patient. We created a Tele spirometer at low cost and it can transfer data to the physician in distant location.

Index Terms: Spirometer, IOT (Internet of things), Arduino microcontroller, *COPD (chronic obstructive pulmonary disease).*

1. Introduction

Chronic obstructive pulmonary disease (COPD) is a debilitating condition characterized by irreversible airflow limitation and inflammation, resulting from damage to the airways or other lung tissues. This leads to compromised gas exchange, coughing, and excessive mucus production. COPD is a leading cause of mortality worldwide, accounting for approximately 3.5 million deaths in 2021, representing around 5% of all global fatalities. Notably, a disproportionately high proportion of COPD-related deaths among individuals under 70 years of age occur in low- and middle-income countries (LMIC). The severity of the disease is projected to escalate in the upcoming decades. Techniques based on Artificial Intelligence have proved useful in the healthcare industry. The tremendous amount of heterogeneous data accumulated in the repositories of hospitals, if incorporated wisely, can be used to build up tech-aided systems [13]. Chronic obstructive pulmonary disease (COPD) is a progressive disease that makes breathing hard due to chronically poor airflow. Different factors lead to COPD with smoking in the lead. A COPD patient can suffer from one or more of the common symptoms like dyspnea, chronic cough, sputum production, wheezing and chest tightness [16]. A novel approach to monitoring respiratory health involves the utilization of Internet of Things (IoT)-based spirometers. These devices leverage advanced sensing technologies to measure lung capacity and other vital signs, facilitating remote monitoring and maintenance of patient health following treatment for pulmonary diseases. Analysis of medical records of patients admitted to academic tertiary-care hospitals showed that only 31% of those diagnosed with COPD had spirometry, by contrast with individuals with congestive heart failure, of whom 78% had echocardiography.[7] The use of IoT-based spirometers can also enable early detection of abnormalities in lung volume, thereby enabling timely intervention and improving patient outcomes.Chronic lung disease in the world is both developing and stagerring as aresult of increased air pollution, tobacco use, indoor cooking and workplace issues [4]. In diagnosis of COPD (Chronic Obstructive Pulmonary Diseases), spiromerty is an important "Pulmonary Function Testing" in the medical evaluation of patients. Spirometric measurements FVC & FEV1 are very important to control the treatment, but some difficulties such as incompleteness, inaccuracy and inconsistency are encountered during the test.[1]. Many patients do not feel confident in their understanding of their health status and are uncertain whether their asthma is under control and what their triggers are. Others fail to voice concerns or report troublesome symptoms. In short, patients need tools that help them recognize when they need help, and better methods to convey this information to their doctors [3].

1.1 Spirometer

Spirometry is a quantitative assessment of respiratory function, characterized by the measurement of the volumetric exchange of gas between the lungs and atmosphere. This technique involves the quantification of inspiratory and expiratory flow rates, as well as lung volumes, to determine pulmonary capacity and reserve. Spirometer is a device for measuring breathing parameters such as breathing air volume and velocity along with other parameters resulting from them [14]. The spirometer device employed in this process employs pneumotach graphic principles, utilizing a sensor-embedded tube or hose to detect airflow patterns. Lung collapse is occurred by a decrease in lung volume. It makes patients feel tired, having phlegm, cannot doing a daily life normally, and slow in body recovering process. Lung collapse usually encounters in patients with chest surgery or disability patients with movement problem and older people. Patients can do rehabilitation treatment including breathing exercise, coughing exercise, and using tools to increase lung volume monitoring for future planning based on each patient's conditions [15]. The measurement protocol typically involves patient-mediated breathing through the tube, with the sensor detecting changes in air velocity to calculate flow rates. These data are subsequently processed to estimate lung function parameters, such as forced expiratory volume (FEV1) and forced vital capacity (FVC).

As depicted in Figure 1.1, a basic spirometry setup consists of a pneumotachograph-based spirometer, wherein the patient's respiratory effort is translated into measurable airflow patterns by the integrated sensor. This data-driven approach enables the assessment of various pulmonary diseases, including pulmonary fibrosis, asthma, cystic fibrosis, and COPD (chronic obstructive pulmonary disease), thereby facilitating early diagnosis and intervention."

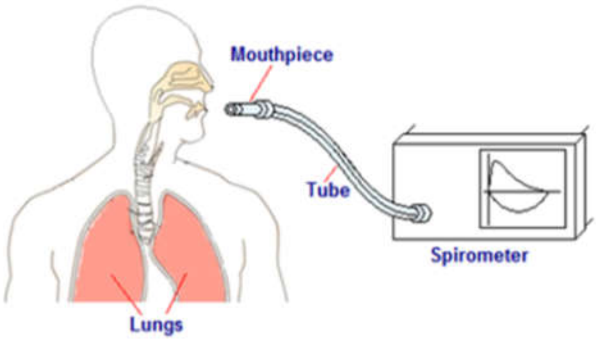

Fig 1.1 Basic Spirometer system

"A spirometer is an instrumental device designed to quantify the volume of air exchanged between the lungs and atmosphere, thereby measuring ventilation patterns. Spirometry can identify two distinct types of abnormal ventilation patterns: obstructive and restrictive, which are indicative of various pulmonary pathologies. The main reason for this increased mortality rate due to Asthma and COPD are the lack of differential diagnosis of these two diseases. Differentiating two diseases is important for their respective drug and therapy treatments [17]. There exist several types of spirometers employing diverse measurement techniques, including pressure transducers, ultrasonic sensors, and water gauges. These devices facilitate the quantification of defects and abnormalities in various lung conditions through a series of medical tests. The results of these assessments enable healthcare professionals to monitor the response of lungs to medical treatment and assess disease severity. Breathing tests, also called pulmonary function tests, are designed to identify and quantify defects and abnormalities in the function of respiratory system (Yeginer et al., 2004). These tests can be broadly classified into two types, depending on the lung characteristics that they measure [2]. Notably, spirometry has been demonstrated to be an effective tool for detecting Chronic Obstructive Pulmonary Disease (COPD) at an early stage (American Thoracic Society, 1995a). In contrast, traditional assessments of cough and wheezing may not accurately reflect the severity of asthma in patients. Spirometric analysis allows for precise monitoring of patient response to treatment, thereby reducing judgment errors and improving treatment efficacy. Several factors associated with COPD development might not be possible to modify, and these include the ageing lung, sex, comorbidities, and repeated respiratory infections in children or adults [6].

The following are potential indications for conducting spirometric tests:

- Diagnosis of specific lung diseases, including asthma, chronic bronchitis, and emphysema
- Identification of underlying causes of shortness of breath
- Assessment of the impact of environmental exposures on lung function
- Preoperative evaluation of lung function to inform surgical decisions"

Regional disparities in healthcare infrastructure in rural India lead to inadequate access to specialized medical facilities, resulting in delayed or unattainable treatment and emergency

care. A comprehensive survey conducted among pulmonologists highlighted several challenges they encounter while managing patients with pulmonary diseases, which persistently affect both urban and rural settings.
The limitations of rural healthcare infrastructure are further compounded by the infeasibility of immediate diagnostic accuracy, largely due to the absence of sophisticated medical equipment, including spirometers. Continuous passive monitoring of subjects using mobile sensors can help detect disease, estimate severity, track progression over time, and predict adverse exacerbation events. One of the most convenient avenues to realize this goal is through analysis of passively recorded natural speech patterns. It has been previously established that diseases such as asthma and chronic obstructive pulmonary disease (COPD) affect pause patterns and prosodic features of speech [12]. The high cost of these devices exacerbates the issue, as access is restricted to remote areas with limited financial resources. Moreover, the remoteness of these locations poses a significant barrier to healthcare delivery. A low-cost spirometer that measures a variety of parameters and graphs data in real-time is necessary for thorough respiratory assessment [5].
To address these challenges, our proposed device aims to provide an innovative solution for rural healthcare settings. By alleviating the need for specialized medical equipment and facilitating remote patient monitoring, we seek to improve early diagnosis and treatment outcomes for patients with pulmonary diseases in areas where access to quality care is severely limited.

1.2 IOT BASED TELESPIROMETER

The Internet of Things (IoT) enables the interconnection of physical devices, infrastructure, and sensory systems, facilitating the collection, analysis, and exchange of data without human intervention. IOT is system of related sensors, computing and digital devices spread across the globe over the internet which can communicate amongst them to share and transfer information using unique id which is assigned to each and every device, as UIDs (Unique Identifiers) [19]. As an Intelligent system, progreses of IoT can be decided with the cooperation of interoperability, awareness, skilled, teamwork, energy, sustainability, privacy, trust [11]. In the context of respiratory diagnostics, IoT-based technologies can streamline data transfer and enable remote healthcare monitoring. Our proposed project focuses on developing an IoT-enabled spirometer for rural areas, with a primary objective of providing timely and accurate diagnostic assessments. For machine learning analysis, each set of labels (the diagnosis and the cough type) were used separately when training the classifier [18]. The Internet of Things (IoT) represents a diverse technology and usage with unprecedented business opportunities and risks. The Internet of Things is changing the dynamics of security industry & reshaping it. It allows data to be transferred seamlessly among physical devices to the Internet [20]. The IoT-based spirometer employs a sensor suite consisting of pressure and airflow sensors to quantify lung function parameters. These sensors detect changes in lung volume and air pressure, facilitating the identification of obstructive and restrictive patterns characteristic of respiratory diseases. IoT architectural design is based on sign acquisition through sensors and, then, highly processed by using a programmable credit card. Database (DB) signs are then noted in a Centre IoT cloud storage space. Hub-IoT is a technology service regarding multiple programming different languages DB access employed in this study. It is used to acquire, save, process, in addition to analyze by implies of a program programming interface (API) [8].

The proposed device consists of the following components:

Detectors: Spirometry detectors utilize advanced algorithms to measure lung volume and tidal flow, while oxyhaemoglobin saturation detectors employ pulse oximetry to estimate blood oxygen levels.

Microcontroller: An At mega 328 microcontroller is employed to calculate vital capacity and other pulmonary function parameters.

Display unit: A LCD display is utilized to present the results of spirometry tests in a clear and concise manner.

Communication module: A Bluetooth module enables wireless connectivity between the spirometer and mobile devices, facilitating data transfer and remote monitoring. The integration of these components enables a comprehensive and portable spirometry system, suitable for rural healthcare settings where access to specialized medical facilities is limited.

2. Previous Work

In spirometry measurements, the quantity of air inhaled and exhaled by the patients together with the speed of the exhalation are needed to describe the conditions of lung. Spirometer is a device for the spirometry test. Spirometer consists of three basic parts: mouthpiece, airflow tube and electronic device [8] . Active or passive smoking and air pollution due to biomass fuel are highly prevalent in deprived areas of middle and low-income countries. These increase the risk factor of pulmonary diseases for those poor people [10]. A low-cost spirometer has been developed in conjunction with a user-friendly software interface for respiratory assessment. The spirometer hardware employs a Flesch-type pneumotachometer design, which measures airflow by detecting pressure drops across a system of internal capillaries. The analog signal output from the pressure sensor is conditioned using a ZMD31014 iLite signal processor, which amplifies and converts the signal to 14-bit digital format.

The processed data is then transmitted via a USB connection to a microcontroller, which relays the information for further processing and analysis. A computer interface enables the conversion of pressure data into flow and volume measurements, allowing for accurate integration of signals and yield of respiratory function parameters. A Java-based graphical user interface provides real-time visualization of flow and volume data, accompanied by an animated incentive display to enhance patient engagement. Additionally, calibration of the device can be performed using a standard 3-L syringe, ensuring accuracy and reliability of measurements.

DRAWBACKS OF EXISTING SPIROMETERS

- Traditional Bluetooth or Wi-Fi-based data transfer protocols are often employed, which may introduce latency or connectivity issues.
- Immediate diagnosis is currently not feasible due to the need for manual analysis and interpretation of data.
- Respiratory readings can be affected by noise and variability in signal quality, limiting accurate online monitoring and feedback capabilities."

3.Methodology

3.1 Proposed System

Our proposed respiratory monitoring system consists of a pressure sensor, flow sensor, Arduino microcontroller, LCD display, and Internet of Things (IoT) module (ESP8266). Upon inhalation, the patient blows air through the mouthpiece, which activates the pressure sensor. The pressure sensor then transmits this data to the Arduino microcontroller. The Arduino chip is programmed to process the analog signal from the pressure sensor and calculate the corresponding volumetric flow rate. This information provides valuable insights into the patient's respiratory function, enabling healthcare professionals to monitor their response to medical treatment in real-time. Furthermore, the IoT module facilitates wireless communication between the Arduino system and a mobile device, allowing for seamless data transfer and remote monitoring capabilities. Immediate diagnosis can be made possible through this system, providing timely interventions and improved patient outcomes.

The system's hardware components operate as follows: a flow sensor and pressure sensor are employed to measure the patient's breath rate and pressure variations, respectively. The Arduino microcontroller then converts the analog signals from these sensors into digital data, which is subsequently transmitted to the IoT module via a 12V power supply. The digital data is then displayed on an LCD display, providing visual representation of the patient's respiratory status.

Key technical specifications:

Pressure sensor: Measures pressure variations during inhalation

Flow sensor: Measures breath rate and volume

Arduino microcontroller: Processes analog signals and calculates volumetric flow rate

IoT module (ESP8266): Enables wireless communication with mobile devices for remote monitoring

LCD display: Visual representation of patient's respiratory status

Power supply: 12V DC power source"

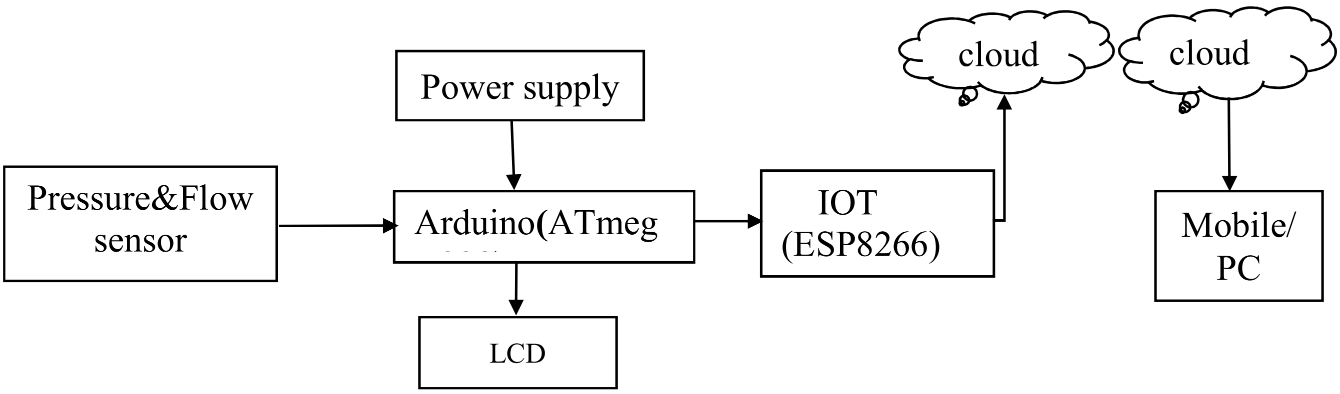

Figure 3.1. Block diagram

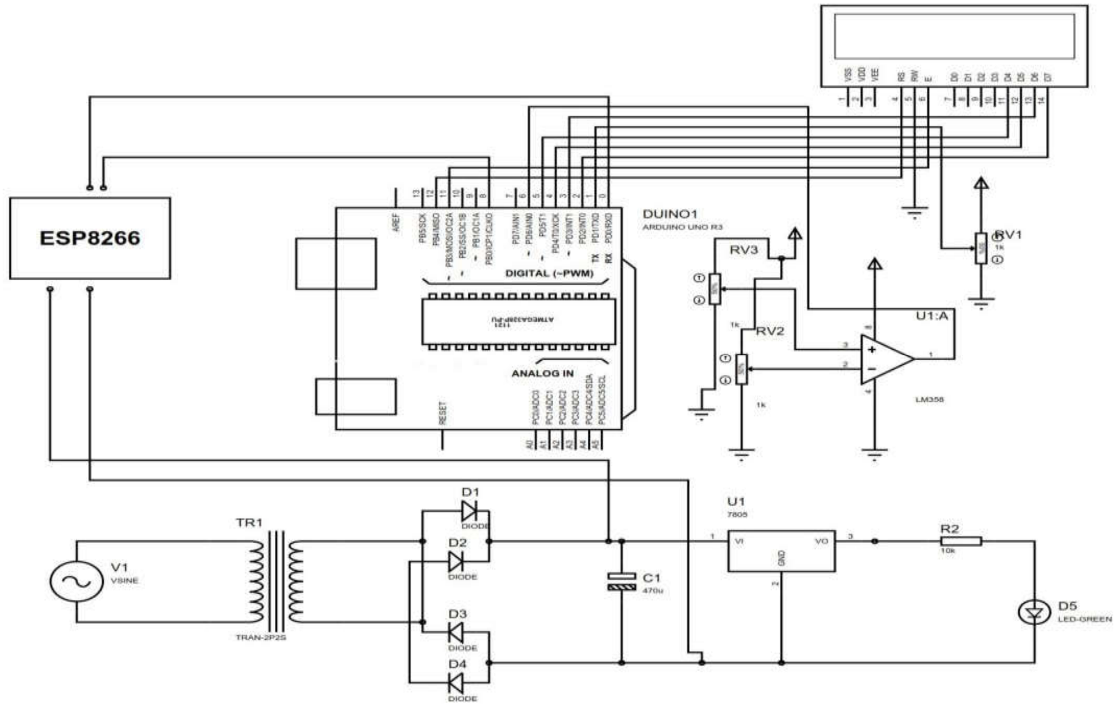

Figure 3.2 Circuit diagram of the power supply

The only circuit component used for this project is a pressure sensor and flow sensor. I used a differential Honeywell ASDX Series Silicon Pressure Sensor. Flow sensor is used to find amount air in the lungs.
Differential pressure sensors are able to convert a difference in two pressures to a voltage. A diaphragm is placed between two compartments of the sensor. Each compartment has a port where a pressure can be applied. When different pressures are applied to the two compartments, the diaphragm moves. The diaphragm is attached to a series of piezo-resistive strain gauges that are connected in a Wheatstone bridge configuration. As the resistances change, the output of the bridge circuit changes and can be used to calculate the pressure difference see figure 3.2

3.2. Air flow sensor

The flow sensor employed in this system converts the airflow through the sensor into an electrical signal. The sensor operates within a temperature range of -25°C to 80°C and requires a supply voltage between 5V-24V. To interface with the sensor, connections are made to a supply voltage (typically 5V) and ground, as well as an output voltage pin where the signal is generated.

The output voltage from the flow sensor varies inversely with the pressure difference across it, with a typical value of half the supply voltage when no pressure differential is applied. In this case, a 5V supply resulted in an output voltage of 2.5V. The data sheet provides an equation that can be used to calculate the pressure based on the output voltage.

3.3. LCD

The LCD display is connected to pins 2-5 as a data pin and updates the reading in real-time, as shown in Figure 3.2. This display is a Liquid Crystal Display (LCD), which consists of two primary types: character-based and graphical displays. Character-based LCDs are widely used due to their simple interface, which can be easily interfaced with microcontrollers.

Character-based LCDs come in various sizes, ranging from 8x1 to 40x2 inches, and are commonly used in everyday products for displaying status information or providing interfaces for user input. Major manufacturers such as Philips, Hitachi, and Panasonic offer custom-designed character-based LCDs for their products. Despite their variations in size and design, all character-based LCDs share common characteristics, including the ability to display alphanumeric characters, numbers, and special characters.

The LCD display's programming is standardized across different models, with 14 pins (0-13) or 16 pins (0-15) providing a consistent interface for microcontroller communication. This standardization enables developers to write software that can be easily ported across different LCD models.

3.4. Power Supply

Power supply circuits are essential components in electronic systems, and their design plays a critical role in ensuring reliable operation. The present chapter describes the operation of power supply circuits, which involve filtering, rectification, and voltage regulation.

The process begins with an AC voltage, typically 120V RMS, being stepped down to a desired DC output using a transformer. The resulting DC voltage is then filtered through a capacitor to remove ripple or AC voltage variations, producing a stable DC voltage.

A diode rectifier converts the AC voltage to a full-wave rectified voltage, which is then further filtered through a capacitor to produce a DC voltage with minimal ripple. A regulator circuit can use this input DC voltage to provide a regulated output voltage that remains consistent despite changes in the input DC voltage or load connected to the output.

The regulation process typically involves using an IC voltage regulator unit, which takes the DC voltage as input and provides a lower DC output voltage that remains stable even if the input DC voltage varies. This approach ensures reliable operation of electronic systems by minimizing ripple or AC voltage variations in the output

3.5. IOT (ESP8266)

In this study, we utilize an ESP-01 module to establish remote control and monitoring capabilities over the internet. The ESP8266 is a low-cost, yet effective platform for wireless communication, making it an ideal choice for IoT applications. Its compatibility with Arduino enables seamless integration into existing microcontroller systems. The system uses National Instrument Single Board Rio 9636 (NI sbRIO) for digital data conversion and data acquisition and breathing hardware from which users will used to flow air into the spirometer[9].

3.6. Arduino Microcontroller

The Arduino Uno board features a 32-bit ATmega328P microcontroller, boasting 14 digital I/O pins (including 6 PWM outputs), 6 analog inputs, and a 16 MHz quartz crystal oscillator. Additional circuitry includes a USB connection, power jack, ICSP header, and reset button. This comprehensive setup enables the Uno board to operate independently, with minimal external dependencies. The Arduino Uno has become an iconic platform for IoT development, serving as the reference model for the Arduino ecosystem. Its widespread adoption is a testament to its versatility and ease of use. With the release of Arduino Software (IDE) 1.0, the Uno board emerged as the standard reference version, paving the way for subsequent iterations. Our project leverages the ESP8266 IoT module to facilitate data transfer between devices over the internet. By integrating this module with the Arduino Uno, we can establish a robust communication infrastructure for remote monitoring and control of electrical devices worldwide.

The ESP8266 IoT module is designed to provide wireless connectivity, enabling real-time communication between devices. Its compatibility with the Arduino platform allows for seamless integration into existing microcontroller systems, making it an ideal choice for our project."

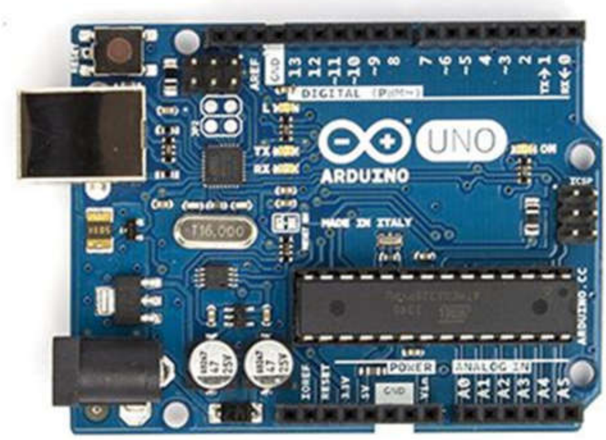

Figure 3.3 Arduino Microcontroller

3.7. Pressure sensors

Pressure sensors are devices designed to accurately detect and quantify external forces, with operating pressures tailored to meet specific system requirements. The International System of Units (SI) defines pressure as force per unit area, measured in Pascals (N/m^2). Other common units include pounds per square inch (PSI), atmospheres (atm), bars, inches of mercury (in Hg), and millimeters of mercury (mm Hg). Pressure sensors can be classified into static or dynamic measurements, depending on the nature of the force being detected. Typically, pressure sensors are designed to measure forces exerted by gases or liquids, with applications including process control, industrial automation, and medical devices.

3.8. Hardware Development

In this study, we employ a rigorous framework for hardware development, grounded in established standards and guidelines. The Hardware Development Standards provide a comprehensive framework for managing and controlling the hardware development process, ensuring consistency and quality across all hardware configurations. We establish a Hardware Development Plan (HDP) to describe the development of each individual hardware configuration item (HWCI), including resource allocation, timeline, milestones, security measures, design methodologies, testing protocols, certification procedures, and risk management strategies.

3.9. Software Development

Our approach to software development focuses on embedded software, specifically designed for control of machines or devices that are not typically considered computers. Embedded software is optimized for the particular hardware platform it runs on, with constraints related to time, memory, and processing resources. Manufacturers often integrate embedded software into various electronic devices, including automotive systems, telecommunications equipment, medical devices, and consumer electronics.

In our project, we utilize a sophisticated software development methodology to design and implement an intelligent control system for remote monitoring and control of electrical devices. The system employs advanced signal processing techniques to detect and respond to changes in pressure, temperature, and other environmental factors. Our approach ensures efficient operation, reliability, and flexibility in the face of changing requirements and conditions."

4. Result and Discussion

"Telemedicine has revolutionized the diagnosis and treatment of pulmonary diseases, particularly in rural or remote areas where access to healthcare facilities is limited. A cloud-based spirometer system, utilizing Internet of Things (IoT) technology, enables remote monitoring and diagnosis of respiratory conditions, facilitating timely interventions and improving patient outcomes. The proposed system employs a wireless transmission protocol to transfer data from the spirometer kit to a distant physician's location via the internet. This allows for real-time examination of patients during emergency situations, regardless of geographical location. IOT based tele spirometer kit is shown in the figure 4.1 The system is designed to be user-friendly, with a simplified interface that enables users to obtain accurate measurements with minimal training. To ensure optimal performance, it is essential to educate users on proper usage and technique, including the importance of maintaining an erect posture and applying a nose clip (if necessary). Our system utilizes a flow sensor to detect airflow rates, which are displayed in real-time through a mobile interface via IP link. The normal breath rate range for humans is between 4.7 liters and 3.5 liters per minute which is shown in the figure 4.2.

Our cloud-based spirometer system offers a scalable and flexible solution for remote pulmonary disease diagnosis, enabling timely interventions and improving patient outcomes.

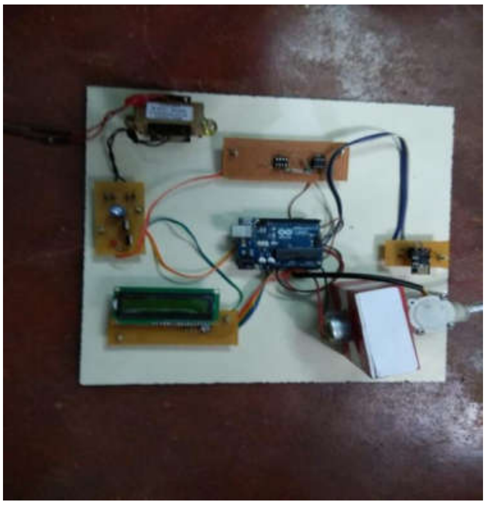

Fig 4.1 IOT Based Telespirometer kit

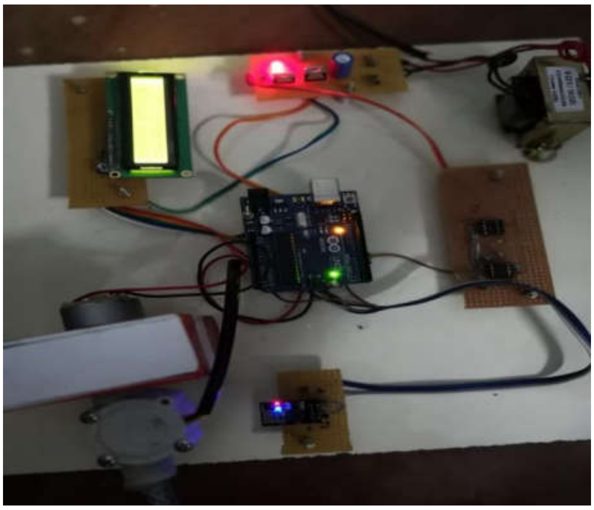

Fig 4.2 Displaying Breadth Rate

Additionally, the pressure sensor measures lung pressures during forced expiration, with output transferred to a microcontroller for display on the mobile device. Normal lung pressure ranges are typically within 75-80% of predicted values (Figure 4.3).

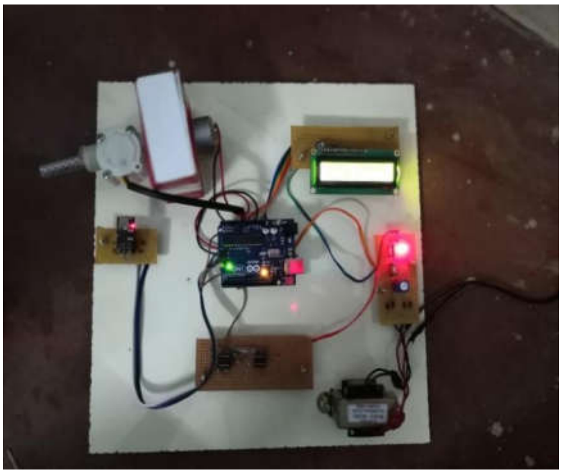

Fig 4.3 Displaying Pressure Rate

By leveraging IoT technology, our system ensures secure and reliable data transfer, with minimal latency and no data loss. We employ multiple IP links to ensure robust connectivity and high-speed data transmission. The speed of data updates is contingent on internet speeds, as demonstrated in Figure 4.4.

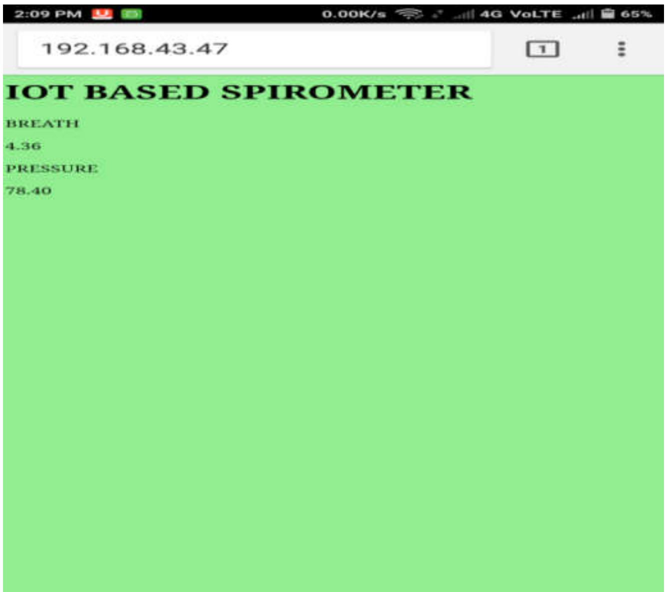

Figure 4.4: Displaying IOT Output

Our cloud-based spirometer system offers a scalable and flexible solution for remote pulmonary disease diagnosis, enabling timely interventions and improving patient outcomes.

5.Conclusion

The proposed project endeavors to improve healthcare accessibility and outcomes for rural populations by leveraging Internet of Things (IoT) technology and microcontroller-based sensor systems. The use of Arduino microcontrollers enables real-time data acquisition and processing of vital signs, including breath rate and blood pressure. A low-cost, portable spirometer system is designed to transmit physiological data via the internet to healthcare professionals in distant locations, facilitating remote monitoring and diagnosis.

This IoT-enabled tele-spirometry platform enables a doctor to examine patients remotely during emergency situations, regardless of geographical location. The system's user-friendly interface and real-time data transfer capabilities facilitate efficient operation and minimize errors.

Key advantages of this proposed system include:

- Simplified usage through an intuitive user interface
- Reduced costs associated with traditional medical equipment and personnel deployment
- Real-time data transmission for immediate healthcare response
- Improved accuracy and reliability due to sensor-based measurements
- By addressing the unique challenges faced by rural populations, this project aims to enhance healthcare accessibility and outcomes, ultimately contributing to improved population health and well-being."

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